A THEORETICAL AND EMPIRICAL STUDY OF ASSET SECURITISATION: RISK MODELLING, SECURITY DESIGN AND MARKET PRICING

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ABSTRACT

Asset securitisation represents an alternative risk management and refinancing method, which allows issues to convert classifiable cash flows from a diversified portfolio of pre-existing assets and receivables *(liquidity transformation* and *asset diversification process)* of varying maturity and quality *(integration* and *differentiation process)* into negotiable capital market paper, so-called "asset-backed securities" (ABS). Over the recent past ambivalence in the definition of capital adequacy for credit risk has particularly facilitated the development of loan securitisation as a refined "regulatory arbitrage tool". However, as impending regulatory change shifts the prime objective of securitisation to the efficient management of economic capital, procedural and substantive aspects of asset securitisation warrant closer inspection. The dissertation presents a comprehensive examination of the risk modelling, asset selection, optimal security design and competitive market pricing of asset-backed securities. We first provide an overview of the main characteristics of asset securitisation and explain its attendant benefits and drawbacks, especially as they pertain to the refinancing of illiquid asset exposures, such as SME-related payment obligations. Subsequently, we explain the gradual evolution of the regulatory treatment of asset securitisation adopted by the *Basle Committee on Banking Supervision* in the wake of a general revision of the 1988 *Basle Accord*, which finally led to the adoption of the so-called *Basle Securitisation Framework* in 2004. We then present a single-factor, loss-based asset pricing model, which estimates the risk-neutral investment return of subordinated debt securities ("tranches") as leveraged contingent claims on a securitised reference portfolio of pooled credit exposures. We challenge common wisdom of robust statistics for the estimation of portfolio credit risk by adopting extreme value analysis, mainly because the leveraged exposure of securitised debt on fundamental asset value changes requires a better parametric specification of extreme quantiles to gauge unexpected loss. Based on the loss sharing between issuers and investors in a common security design, we examine how securitised asset exposure translates into investment risk of asset-backed securities. As a longitudinal extension to this valuation model, we also investigate the price dynamics of securitised debt. A multi-factor GARCH process is applied as an econometric specification of the heteroskedasticity of secondary market spreads of selected types of ABS transactions for valuation and forecasting purposes. In light of the substantial valuation uncertainty in securitisation markets, we conclude with a simple one-shot auction model, in which issuers maximise net payoffs from securitised debt under "winner's curse"-type underpricing as agency cost of adverse selection. In particular, we study how uninformed investment demand at varying degrees of valuation uncertainty affects the utility of endogenous price discovery by informed investors. Overall our synthesis of empirical and theoretical approaches yields instructive findings about important yet unexplored issues concerning the economic rationale of asset securitisation.

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Dedicated to my wife Maria, my parents Renate and Peter, and my brother Florian.

"Mens agitat molem."
[A mind informs the mass.]

(Vergil, Aneis, 6, 127)

Except for commonly understood and accepted ideas, or where specific reference is made, the work in this dissertation is my own and includes nothing which is the outcome of work done in collaboration. The work has not previously been submitted in part or in whole to any university for any degree or other qualification. In accordance with the regulations of University of London the dissertation contains no more than 100,000 words of text.

London, 10th March 2005 Andreas A. Jobst

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I. INTRODUCTION

I.i. Definition of asset securitisation

Asset(-backed) securitisation represents an expedient means of asset funding and risk transfer, which substitutes external capital market-based funding for credit finance. The basic tenet of securitisation rests on the efficient conversion of present or future cash flows from a diversified pool of illiquid balance sheet exposures of varying maturity and quality into tradable debt securities. This is done by re-packaging and diversifying receivables into commoditised structured claims (*liquidity transformation* and *asset diversification*) to: (i) realise certain *accounting objectives and balance sheet patterns*, (ii) *hedge* specific risk from *currency and interest rate exposures*, (iii) *reduce economic cost of capital* and *ease regulatory capital requirements*, and/or (iv) *overcome agency costs of asymmetric information* in external finance (e.g. "underinvestment" and "asset substitution"). As a hybrid of asset risk management ("asset risk component") and fixed income security design ("security component"), the securitisation paradigm has witnessed dramatic changes in the way commercial banks and corporate issuers envisage their funding activity via *asset-backed securities* (ABS). Securitisation was initially used to refinance simple, self-liquidating assets (e.g. credit card balances and student loans in the case of financial institutions and trade receivables with respect to larger corporations). In the meantime, however, mounting competitive pressure over external funds and a notorious squeeze on net interest income has motivated banks in particular to resort to securitisation to offset shrinking client deposits and to proactively manage balance sheet exposures. Securitisation fosters a more efficient use of economic capital by taking fair asset pricing to capital markets, thereby stretching asset funding beyond what would have been possible through conventional on-balance sheet refinancing and depository lending. In the effort to expand external funding sources securitisation also encourages sophisticated internal risk management and improves overall market efficiency by commoditising designated asset exposures into new *marketable* financial claims of *merchantable* quality.[1] Aside from its economic effect of installing capital markets as external sources of funds (rather than credit relationships) asset securitisation leads to fair market pricing of securitised asset risk and broadens the investor base, as the pooling of asset exposures makes the securitisation large enough to be efficient.

Asset securitisation typically involves a complex transaction structure, where issuers create subordinated investor debt claims as stratified positions (or tranches) with different seniority. The

[1] *Merchantable* quality refers to the fact that financial commitments are secured to the investors' satisfaction.

subordinated security design determines the contractual repartitioning of repayments and default losses from the securitised asset portfolio. Such a form of risk-sharing supports a fine-tuned security design, which not only caters to varying risk appetites of investors, but also guards investors against a multiplicity of investment risks. These risks arise for the most part from delayed repayment or outright default risk, adverse movements of market prices *(market risk)* and the inability of issuers to honour contractual repayment due to prepayment risk *(liquidity risk)*. By convention, most if not all of these risks are hedged by internal and/or external credit and liquidity support mechanisms, where the issuer's equity base commonly backs the amount of expected first loss exposure to ensure incentive compatible monitoring and servicing activity.

While corporations originally conceived asset securitisation as a flexible refinancing technology for outstanding trade receivables and leases, the prominence of loan securitisation as it is known today mainly evolved from regulatory inefficiency due to the misspecification of "one-size-fits-all" minimum capital requirements of banks under the 1988 *Basle (Capital) Accord*. Since existing provisions would impose the same capital charge on credit exposures of similar risk, banks could optimise regulatory capital by dispensing with better quality (but low-yielding) assets through securitisation.[2] Given such "regulatory capital arbitrage", national banking supervisors undertook concerted efforts to remedy the shortcomings of the overly simplistic *Basle Accord*. On 11 May 2004 the Basle Committee on Banking Supervision[3] finally reached agreement on a new framework for the *International Convergence of Capital Measurement and Capital Standards*, termed "Basle 2", to come into force in 2006. Basle 2 establishes new capital adequacy rules, which link minimum capital requirements more closely to the actual risk exposure of bank assets to reward both active credit risk management and efficient management of economic capital. The Basle 2 proposal also sets forth a new regulatory treatment of asset securitisation in the so-called *Securitisation Framework*, which was adopted in both the *(Third) Consultative Paper to the New Basle Accord* (April 2003) and *Changes to the Securitisation Framework* (January 2004) in response to the prominence of more complex forms of asset securitisation. Similar to the Basle 2 proposal, the *Securitisation Framework* features more risk-sensitive measures of required bank capital to moderate regulatory arbitrage through (i) the reconciliation of regulatory and economic costs of capital on similarly securitised exposures and (ii) a more consistent regulatory treatment of both securitised and non-securitised credit risk exposures.

[2] This incentive would persist until higher bankruptcy risk associated with the retention of (residual) riskier (high-yielding) on-balance sheet assets would render further securitisation non-profitable.

[3] The *Basle Committee on Banking Supervision* is a steering group of all G10 member countries of the *Bank for International Settlements* (BIS).

Notwithstanding imminent regulatory changes, the popularity of securitisation markets betrays no hint of abating, which suggests that loan securitisation seems to be largely motivated by major economic benefits from credit risk transfer and cost-efficient refinancing rather than by regulatory incentives alone. Admittedly, also its sheer size makes the securitisation market too important to just disappear in the wake of regulatory reform. Once the regulatory capital arbitrage paradigm is repealed, the systemic flexibility of asset securitisation can accommodate regulatory change only if it promises economic viability comparable to what explains the meaning of other investment instruments. From a broader economic perspective, the evolution of securitisation has served to mitigate disparities in the availability and cost of credit in primary lending markets by linking singular credit facilities to the aggregate pricing and valuation discipline of capital markets. Aside from regulatory considerations, loan securitisation entails a more efficient allocation of capital and credit risk as well as a decrease of systemic risk throughout the financial system as a whole. One particular economic dimension in securitisation is the risk-sharing agreement between issuers and investors in the security design of securitised debt. However, the question of how the security design translates and alters asset exposure of the underlying reference portfolio into actual investment risk of securitised asset-backed debt is difficult to answer and not yet fully understood, mainly because securitisation transactions can be structured in a wide variety of ways, resulting in disparate risk profiles for both issuers and capital market investors. Other important economic aspects evolving from perceived investment risk of securitisation include (i) the way valuation uncertainty about securitised assets manifests itself in the design of the issuing process for asset-backed debt securities and (ii) how the non-verifiability of trading motives associated with the agency cost of asymmetric information between issuers and investors affects information processing in secondary market pricing of securitised debt. Given the low liquidity of securitisation markets these question promise instructive insights for management and research, whose interests coincide concerning essential requirements for sustainable securitisation markets.

I.ii. Research objective and structure

This dissertation constitutes a comprehensive theoretical and empirical enquiry into the nature of *asset-backed securitisation* (ABS) to explain risk modelling, asset selection, optimal security design and competitive market pricing of securitised debt. It presents an original contribution to the field of contingent claims analysis in structured finance by way of promoting a deeper understanding of the elaborate procedural and substantive aspects of asset securitisation. The first chapter describes the economic rationale of asset securitisation and its attendant benefits and drawbacks especially as they pertain to the refinancing of illiquid asset exposures, such as SME-related payment obligations. The second chapter surveys the pathology of the regulatory treatment of asset securitisation under the *Basle Securitisation Framework* in response to the growing complexity of securitisation structures since the 1988 *Basle Accord*. The third chapter presents a single-factor, default-based asset pricing model of loan securitisation, which estimates the risk-neutral investment return in subordinated debt securities as leveraged exposures on securitised credit risk. It also demonstrates how the economics of securitisation can be reasoned on the grounds of the relationship between security design and primary market pricing of asset-backed securities. As a longitudinal extension to this pricing model, the fourth chapter investigates how information processing and market liquidity affect the market pricing of securitised debt. A multi-factor GARCH process with time-varying forecast confidence intervals elicits an econometric specification of the heteroskedasticity of secondary market spreads of selected types of ABS transactions. In light of the substantial valuation uncertainty in securitisation due to intricate transaction structures, the absence of sufficient market rigor and insufficient standardisation in measuring and pricing securitised exposures, the dissertation concludes with a simple one-shot auction model, where issuers of securitised debt maximise net issue payoffs under "winner's curse"-type underpricing as agency cost of adverse selection. Given the scarcity of empirical research on asset securitisation, several important economic and regulatory implications, instructive findings and actionable recommendations emerge from this research effort into several important yet unexplored structural and information contingencies impacting the economic rationale of asset securitisation.

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CHAPTER I: "ASSET SECURITISATION AS RISK MANAGEMENT AND FUNDING TOOL"

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1 ABSTRACT

The following chapter critically surveys the attendant benefits and drawbacks of asset securitisation on both financial institutions and firms. It also elicits salient lessons to be learned about the securitisation of SME-related obligations from a cursory review of SME securitisation in Germany as a foray of asset securitisation in a bank-centred financial system paired with a strong presence of SMEs in industrial production.

Keywords: securitisation, ABS, structured finance, SME

JEL Classification: D81, G15, M20

> "Just as the electronics industry was formed when the vacuum tubes were replaced by transistors, and transistors were then replaced by integrated circuits, the financial services industry is being transformed now that securitised credit is beginning to replace traditional lending. Like other technological transformations, this one will take place over the years, not overnight. We estimate it will take 10 to 15 years for structured securitised credit to replace to displace completely the classical lending system – not a long time, considering that the fundamentals of banking have remained essentially unchanged since the Middle Ages."
>
> *Lowell L. Bryan*[1]

[1] Mr. Lowell L Bryan is Director (Global Strategy Practice) McKinsey&Co. (Edwards, 2001).

2 OBJECTIVE

If one was to believe the above statement by Lowell Bryant, the advent of asset securitisation heralds a profound reshaping of conventional financial intermediation. Many financial institutions, large corporates, quasi-government agencies and even local governments and municipalities have issued securitised debt on diverse asset classes ranging from credit card receivables all the way to expected tax revenues. However, asset securitisation lacks cross-sectional reach. The securitisation paradigm has so far been largely confined to liquid asset types, which relegated SME securitisation (i.e. the securitisation of trade receivables and future revenue by SMEs) to sporadic captive finance transactions. In countries whose industrial foundation is made up in large part by SMEs, such as Germany, however, asset securitisation offers an interesting funding alternative to a pernicious bank-based financial system, which leaves many corporate borrowers overleveraged. The following chapter acknowledges the topical nature of asset securitisation and surveys how its attendant benefits and drawbacks impact on the refinancing decision of financial institutions and firms alike. It also elicits salient lessons to be learned about the securitisation of SME-related obligations from a cursory review of SME securitisation in Germany as a foray of asset securitisation in a bank-centred financial system paired with a strong presence of SMEs in industrial production. The utility of this instructive yet succinct exercise is to set the stage for a comprehensive and purposeful debate about use of securitised debt as an alternative refinancing mechanism regardless of issuer size and financial system.

The chapter is structured as follows. After a brief definition of asset-backed securitisation (ABS) we describe the key benefits and investment risks associated with asset securitisation in the third and fourth sections. The fifth section focuses especially on the securitisation of SME-related claims, such as SME loans held by banks or trade receivables owed to SMEs. The sixth section provides a synopsis of the German approach to SME securitisation. Section 7 concludes.

3 DEFINITION OF ASSET SECURITISATION

3.1 The motivation of securitisation

Over the last ten years asset securitisation has established the status of a premier structured finance segment in international capital markets and has redefined the strategic orientation of banking business in a way that qualifies as a critical juncture in the evolution of financial intermediation. Asset securitisation is a refinancing technique that allows for credit to be provided directly to market processes rather than through financial intermediaries. Securitisation specifically refers to the process of refinancing a diversified pool of financial and/or non-financial assets through structured claims, so-called *asset-backed securities* (ABS), issued on the back of these assets, whose cash flows from repayment are used to pay principal and interest on the securities in addition to the transaction expenses.[2] By engaging in securitisation, issuers actively sponsor the commoditisation of asset risk through disintermediated debt refinancing, where capital markets channel funds to efficient uses of economic activity. In principal, securitisation serves as a refinancing mechanism to diversify external sources of asset funding and to transfer specific risk exposures.

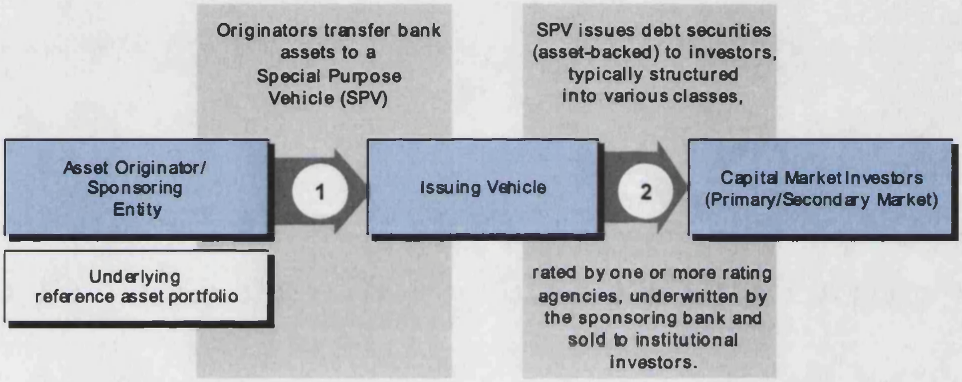

Fig. 1. *The securitisation process.*

Conceptually, asset-backed securitisation (ABS) converts regular and classifiable cash flows from a diversified portfolio of illiquid present or future receivables *(liquidity transformation* and *asset diversification process)* of varying maturity and quality *(integration* and *differentiation process)* into negotiable capital market paper ("tranches") issued by either the originator of the securitised assets/receivables[3] or a non-recourse, single-asset finance company, called a "special-purpose vehicle" (SPV).[4] So these tranches are contingent claims on a designated portfolio of securitsed assets, which can be "divided into different slices of risk to appeal to a range of investors" (Wighton, 2005). They come in two broad classes of securities: debt-like (secured) notes and equity (see Figs. 1 and 2). Whilst the holders of debt-like notes establish structured claims to the underlying reference portfolio in order of seniority, issuers and/or asset originators frequently retain a residual equity-like class as illiquid first

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[2] See Moody's Investor Services (2003) for a brief and Jobst (2003a) for a more exhaustive introduction to asset-backed securitisation (ABS).

[3] The redemption of these securities takes places at maturity out of the cash flow generated by the collected claims of asset exposures. The collection and servicing of securitised payment claims generally remain within the domain of the originator under the general supervision by a trustee.

[4] In the latter case, the securitisation structure involves transfer of assets or the assignment of equitable accessory rights by the sponsor (i.e. the asset originator) to an SPV.

loss position *(credit enhancement)*.[5] Rating agencies require credit enhancement as bad debt provision for expected loss implied by the weighted average rating of issued tranches. The tranching itself allows an efficient placement of securitised claims to capital market investors with distinctive risk-return profiles.

Issued debt securities[6] differ in denomination, size, seniority and risk exposure ("stratified positions"),[7] whose subordination creates leveraged investment on the performance of securitised assets ("reference portfolio"). Both investment return (principal and interest repayment) and losses associated with the underlying reference portfolio are allocated among the various tranches through prioritised contractual repartitioning according to subordination.[8] This risk sharing mechanism sustains a fine-tuned security design of customised debt securities with optimal mean-variance properties. Hence, issuers of asset-backed securities improve overall market efficiency[9] by offering *marketable* financial claims on securitised asset exposures at *merchantable quality*.[10] From a broader economic perspective, the evolution of efficient securitisation markets has served to mitigate disparities in the availability and cost of credit in primary lending markets by linking singular credit facilities to the aggregate pricing and valuation discipline of the capital markets.[11] Hence, the emergence of securitisation as an asset funding tool also remedies deficiencies in financial markets arising from incomplete capital allocation and imperfect information dissemination.[12,13]

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[5] Credit enhancement represents the varying willingness of issuers to securitise only part of the structured claim on the selected loan portfolio and retain a marginal equity claim on some portion to provide capital cover for all expected losses. Issuers buy back the most junior securities, while capital market investors hold the remaining tranches of the securitisation transaction. Alternatively, such credit enhancement could also take the form of a standby letter of credit to the conduit, or by the sponsoring bank. In return for providing such credit enhancement (and the loan origination and servicing functions) the sponsoring bank lays claim to the residual spread between the yields on the underlying loans and the interest as well as non-interest cost of the conduit, net of any losses on pool assets covered by the credit enhancement.

[6] These positions may take the form of fully/partially funded asset-backed securities or unfunded derivatives.

[7] Especially in securitisation transactions of very heterogeneous reference portfolios comprised of assets, which may be domiciled in different countries, constituent tranches also very in terms of currency denomination, interest rate specification (fixed rate notes vs. floating rate notes), maturity and repayment speed.

[8] See also Telpner (2003).

[9] The securitisation process also broadens the investor base, as the pooling of asset exposures makes the securitisation large enough to be efficient – even though securitised assets tend to be fairly illiquid and private in nature.

[10] i.e. financial commitments are secured to the investors' satisfaction (Kendall, 1996).

[11] So one might assert that securitisation represents a structural approach of stretching asset funding beyond what would have been attainable by means of conventional self-funding, on-balance sheet and depository lending against the background of existing inefficiencies in the organisation of financial intermediation and asset pricing.

[12] The Bond Market Association (1998) considers securitisation "an increasingly important and widely-used method of business financing throughout the world, [given that its] continued growth and expansion ... [generates] significant benefits and efficiencies for issuers, investors, securities dealers, sovereign governments and the general public." See also The Bond Market Association (2001).

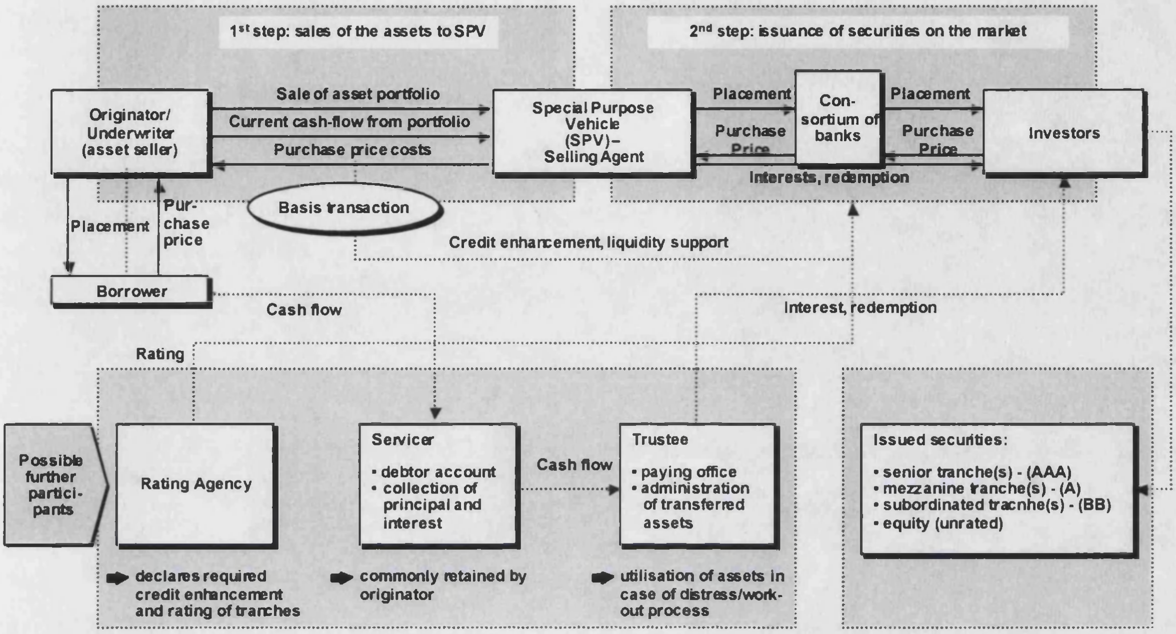

Fig. 2. *Structure of a traditional ABS transaction (Jobst, 2003a).*

Debt securities issued in securitisation transactions generally feature lower levels of investment risk than the original credit risk of underlying securitised exposures,[14] mainly because securitised debt benefits from diversification and a variety of incorporated security mechanisms against credit and liquidity risk. Issuers have a wide range of support mechanisms at their disposal to improve the quality of securitised assets to the extent that they warrant a selling price beyond what would be deemed necessary to offset attendant costs of managing the transaction. For instance, potential timing mismatch between repayment from the securitised (reference assets) and investor payout to issued debt securities requires tight interest and cash flow management. Commonly, liquidity facilities are set aside in the form of back-up lines to cover liquidity shortfalls and to guarantee the full refinancing of an SPV as issuing agent. Even more importantly, the external rating assessment of securitisation transactions strongly hinges on visible signs of credit risk protection. In many cases, issuers resort to (i) over-collateralisation by transferring credit risk at a cash discount, (ii) implicit

[13] See also Jobst (2003a and 2003b) in this regard.

[14] Although asset securitisation represents an increasingly attractive alternative for investors looking for greater diversification as well as investments with lower risk exposure than traditional corporate bonds, investment demand has not translated into a level of market liquidity comparable to traditional fixed income markets. The prevalence of "buy and hold" investment (as many investors hold long-term securities until they mature) does not support a robust estimation of sensitivity of investment interest (i.e. spread) of long-term secured bond obligations in ABS transactions to key rate chances (of the term structure), which is further complicated by the fact that the complex structure of ABS the accurate grading of liquidity (compared to corporate bond market).

guarantees through the cash flow structure ("excess spread")[15] and/or (iii) external third-party guarantees in order to provide *credit enhancement* to investors of issued debt securities.

Of a wide range of creative financing techniques that lost their spark during the 1980s, securitisation remains intact as a cost-efficient and flexible structured finance instrument. Asset securitisation initially started as a way of depository institutions and non-bank finance companies to explore new sources of asset funding in light of competitive pressures in the finance industry, stronger focus on shareholder value and a notorious squeeze on interest spreads from traditional financial intermediation. Originally, securitisation was only used to refer to simple asset-backed securities (ABS), where issuers would reorganise the financing of mortgages as well as consumer and commercial debt by moving asset exposures off their balance sheet or by borrowing against an insulated pool of selected on-balance sheet assets ("liquifying") at a lower cost of capital thanks to the "upgrading effect" of securitisation.[16]

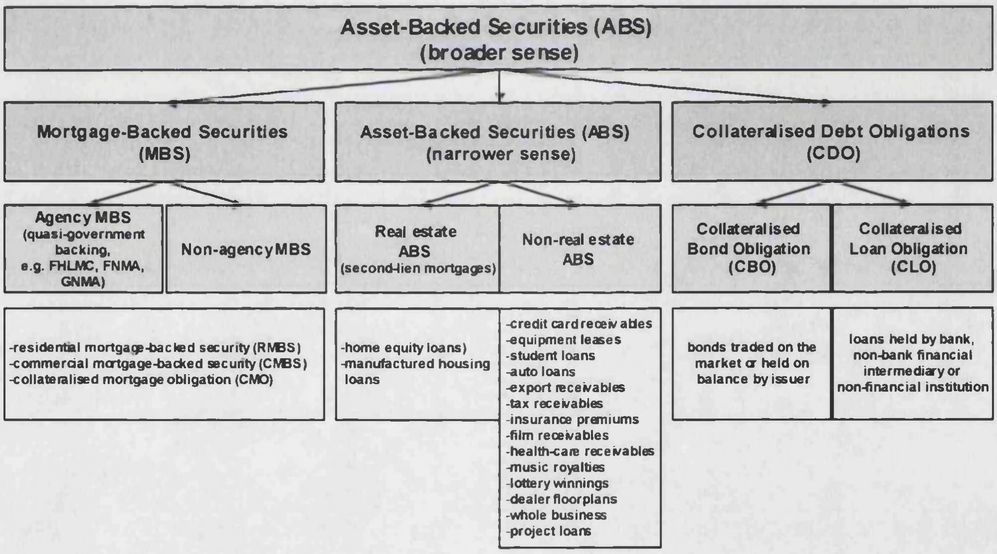

Fig. 3. *Classification of asset-backed securitisation (ABS) (Jobst, 2003a).*

Besides securitising a wide variety of bank loans, including short-term commercial loans, trade and credit card receivables, auto loans, first and second mortgages, commercial mortgages and lease

[15] Excess spread is generated from interest surplus between payment obligations to outstanding debt securities and payment collections from securitised exposures.
[16] The "upgrading effect" refers to the case when highly-rated securitisation of a selection of designated asset exposures provides an issuer with an opportunity to obtain a commensurate refinancing interest rate lower than the cost of capital based on the issuer's actual credit rating (corporate rating) thanks to the de-linkage of securitised assets from the balance sheet. See also Everling (1999).

receivables, banks have also turned to small business loans and middle-market commercial loans as suitable for securitisable reference portfolios (see Fig. 3). Apart from structured leasing and project finance, alternative means of external investment finance vie for the attention of firms, whose credit standing influences their mode of funding, such as small and medium-sized companies (SMEs) (see Fig. 2). The ability of issuers to obtain liquid funds, reduce the cost of capital charge and increase the scope of reinvestment implies benefits not only for financial institutions and their lending activities. Also corporations have mounted efforts to actively seek new sources of external funds through the securitisation of operating cash flows and trade receivables as diversified project finance.[17] So securitisation registers as an alternative source of funds for profitable economic activity at most resourceful factor input and efficient cost of capital if issuers realise one or more of the following key motivations:

(i) to curtail balance sheet growth and realise certain *accounting objectives* and/or *balance sheet patterns*,

(ii) to reduce *economic cost of capital* as a proportion of asset exposure associated with asset funding,

(iii) to ease *regulatory capital requirements* (by lower bad debt provisions) in order to manage risk more efficiently,

(iv) to efficiently access capital markets in lieu of intermediated debt finance at a cost of capital, which would not be possible on account of the issuer's own credit rating, and

(v) to overcome *agency costs of asymmetric information* in external finance (e.g. "underinvestment" and "asset substitution").

While the last two aspects are particularly pertinent to corporate issuers, the first three arguments are more related to the refinancing advantages enjoyed by financial institutions, where asset securitisation serves as a powerful capital management tool. Most commonly, a balanced mix of all these objectives and further operational and strategic considerations determine the type of securitisation in the way issuers intend to shed excessive asset exposures. Depending on the relative importance of these objectives, issuers engage in either *traditional/true sale* or *synthetic* securitisation. In a *true sale transaction* structure, the originator sheds the asset risk associated with a selected pool of on-balance sheet

[17] As a rule, securitised payment claims are average-rated financial assets with a remaining maturity of more than one year. Frequently, they satisfy further conditions, such as specific diversification rules, the transferability of legal ownership or equitable assignment and the availability of historical performance data. The principal asset classes of securitised reference portfolios are loans, high-yield bonds, mortgages, credit card transactions, licence and franchise operations, lease agreements as well as trade deliverables and services, which determine the classification of the securitisation transactions: collateralised loan obligations (CLOs),

exposures by selling them to an SPV ("conduit"),[18] which takes legal title to the assets. Such single-purpose securitisation conduits are completely remote from the asset originator in terms of economic and legal recourse ("bankruptcy-proof").[19] The SPV collateralises the purchased asset portfolio and refinances itself by issuing multiple classes of asset-backed securities (and equity) with different degrees of risk to capital market investors. In compliance with disclosure requirements the originator, however, retains the obligation to ensure the timely collection and administration of repayments from securitised assets ("servicing"), which limits the asset exposure of the SPV only to the risk arising from securitised assets. By unloading credits off their books, loan originators reduce their economic (and regulatory) capital charge and, at the same time, may use liquid funds from the proceeds of the true sale to refinance future lending activity. Special purpose vehicles may also support *synthetic transactions*,[20] in which issuers create generic debt securities, so-called *credit-linked notes* (CLN), out of derivative structured claims on securitised assets to reduce economic cost of capital and raise cash from borrowing against existing assets and receivables.[21,22] Synthetic transactions only transfer unwanted risk exposure of a specifically defined asset pool without placing assets under the control of investors through a transfer of legal title. This mechanism also allows (asset) originators themselves to securitise assets through derivative transactions without an SPV as underwriting agent.[23]

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collateralised bond obligations (CBOs), collateralised mortgage obligations (CMOs), credit card asset-backed securitisation (ABS), student loan ABS or trade receivables asset-backed securitisation ABS.

[18] SPVs are best understood as trust-like entities, which are founded solely for the task of securitising the reference portfolio of assets.

[19] We assume the securitisation vehicle is registered under the statues governing corporations, and, therefore, pays taxes. However, these taxes are offset by tax credits of debt. Since we do not intend to unveil specific tax advantages of loan securitisation (Sullivan, 1998), we consider the tax expense to have the same structure as in the case of the originating company.

[20] Synthetic transactions come in various structural arrangements, which can be specified along three major dimensions: (i) the level of funding (unfunded, (fully) funded or partially funded); (ii) the involvement of an SPV as issuing agent (indirect or direct securitisation); and (iii) the degree of collateralisation of funded elements by means of government bonds, third-party guarantees, letter of credit, certificate of indebtedness, Pfandbriefe and other acceptable type of collateral). The funding level of synthetic structures varies by the proportion of derivative elements in the security design. Unlike true sale transactions, which are commonly fully funded, synthetic transactions are partially funded (or unfunded) if the notional amount of issued debt securities represents only a fraction of underlying exposures (or all exposures are swapped with a third party as protection provider).

[21] Originators only transfer credit risk, which allows them to retain customer relationships and servicing revenues (Böhringer et al., 2001). See also Zweig (2002 and 1989).

[22] The IMF defines true sale transactions as "the creation of securities from a pool of pre-existing assets and receivables that are placed under the legal control of investors through a special intermediary created for this purpose." (IMF, 2004).

[23] In both traditional and synthetic securitisation the issuer is required by law to regularly inform investors about the performance (and composition) of the underlying reference portfolio in so-called "investor reports", which include aggregate information about the portfolio balance, delinquency and termination rates, maturity (weighted average life (WAL)) and seasoning as well as the industrial and geographical classification of securitised claims.

3.2 Strategic purposes of securitisation

Depending on various strategic and operational objectives of risk management and asset funding securitisation is mainly used for either *balance sheet* or *arbitrage* purposes. Although both synthetic and traditional types of structures share similar usefulness for regulatory and economic risk management, they delineate distinctive properties in the treatment of securitised exposures. While the creation of generic securities out of derivative claims in synthetic securitisation affords issuers expedient risk management due to structural flexibility, administrative efficiency and legal practicability, true sale securitisation is particularly useful for the generation of additional sources of liquid funds and/or balance sheet restructuring (see Tab. 1).

	Transaction structure	
Purpose of transaction	***True sale transaction***	***Synthetic transaction***
Risk management & regulatory aspects		
Transfer of asset risk	+	+
Physical asset transfer	+	-
Regulatory optimisation	+	+
Management of cluster risk	+	+
Hedging of interest and currency risk	-	+
Liquidity management	+	-
Funding and cost of capital		
Alternative source of funding	+	-
Balance sheet restructuring	+	-
Optimisation of cost of capital	(+)	(+)*
Reduction of imputed equity capital	(+)	(+)

Degree of compatibility of transaction type and securitisation objective:
+ = yes, - = no, (+) = possibly, (+)* = indirectly possible.

Tab. 1. *Attribution of means and objectives in asset securitisation.*

We distinguish between *balance sheet transactions* and *arbitrage transactions* as two broad categories. In *balance sheet transactions* issuers unload defined asset exposure to third parties in order to change their balance sheet composition or debt maturity structure, whereas in *arbitrage transactions* issuers act as active portfolio managers who acquire assets for arbitrage purposes only. However, this securitisation arrangement only warrants the appellation of an arbitrage transaction if issuers realise leveraged asset return as riskless profit after accounting for structuring cost, investor repayment and default loss. Hence, in a strictly economic sense, the normative distinction between *balance sheet transactions* and *arbitrage transactions* as discrete structural types is to be found wanting. In many cases issuers of balance sheet transactions could potentially enjoy as much "arbitrage profit" from holding the equity tranche as first loss position as would an equity investor in securities sold in the open market or included in managed reference portfolios underlying arbitrage transactions. In the remainder of this chapter we focus on *balance sheet transactions*, which offer an intuitive and straightforward understanding of how firms implement asset securitisation as an efficient *risk management* and *asset funding* technique in debt refinancing (Altrock and Rieso, 1999).[24]

3.3 Securitisation as a hybrid fixed income asset

In contrast to the legal and commercial definition of a "security" as a secured (investment) instrument, the process of asset securitisation involves the creation of a financial claim (with contractual terms and conditions), whose *marketability* and *liquidity* derive from its acceptability as a store of value and whose quality is certified by rating agencies and/or collateralisation through substantial assets. In order to asses the economic value added of securitised debt, we need to translate the complex reality of securitisation into an abstract illustration of viable trading motives between issuers and investors that would support the *marketability* and *liquidity* of securitised debt.

The need for securitisation follows the same rationale as the evolution of organised financial markets in the effort to create multiple financial transactions involving a large number of investors. In their most basic form, financial intermediaries enable two (or more) entities to engage in mutually dependent financial relationships over certain periods of time. Although restricted in scope and efficiency, intermediated finance carries significant benefits as to the erosion of asymmetric information and the durability of effective financial contracting. However, as funding needs grow more diverse, capital market-based financial instruments (external debt finance) replace intermediated finance as a mechanism of large-scale refinancing. Financiers compensate for the loss of informed investment from the borrower-lender relationship by converting financial claims into liquid, homogenous and transparent investment products, which can be easily tailored in quality and denomination to suit investment demand. The conception of asset securitisation – in its generic form – reflects this very interaction between information intensity and financial contracting. Asset securitisation amalgamates two separate areas of finance research – *financial intermediation* (as regards the information economics and risk management of the underlying reference portfolio) and bond pricing (as regards fixed income analysis and security design) by reconciling information-intensive financial relationships of securitised assets ("credit component") and financial contracting in capital

[24] See also Burghardt (2001).

markets ("security component") through the creation of generic securities from structured claims sold to a large pool of investors.

For instance, loan securitisation blends aspects of credit business and fixed income management, where the economic value of commoditised structured claims on defined credit risk exposure determines the degree of *marketability* and *liquidity* of securitised asset risk. Loans are non-standardised, non-commoditised asset claims, whose general illiquidity is mostly due to the opaque nature of the lender-borrower relationship and substantial non-diversifiable idiosyncratic risk. The bonding effect of lending relationships, even at the lowest level of information intensity from client customisation, fuels potential informational advantages of loan originators relative to outside investors. Although loan agreements allow for the renegotiation of credit terms in the event of delinquency or insolvency, their *specificity* ("credit component") compromises essential trading motives underlying the marketability of credit risk[25] in the presence of asymmetric information from lending relationships. Asymmetric information might arise from (see Fig. 4): (i) incentives of biased loan selection at the time the asset composition of the portfolio is determined (*ex ante* moral hazard) and (ii) reduced loan monitoring (*ex post* moral hazard).[26]

Issuers of asset-backed debt securities try to purge most of these loan-specific idiosyncrasies by converting credit risk from a diversified pool of illiquid credit claims into state-contingent (cash flow) claims. In this commoditisation process, issuers and investors share the attendant investment risk according to a transparent security design[27] ("security component"), which defines the allocation of cash flows and default losses to issued debt securities (tranches) of different risk sensitivity. If done successfully, the mitigation of valuation uncertainty facilitates the tradability and fungibility of securitised (credit) exposures, which allows investors to quickly adjust their investment holdings at low transaction cost in response to changes in personal risk sensitivity, market sentiment and/or

[25] Skora (1998) defines credit risk as the risk of loss on a financial or non-financial contract due to the counterparty's failure to perform on that contract. Credit risk encapsulates default risk and recovery risk. Whereas default risk denotes the possibility that the counterparty will fail to meet its obligation, recovery risk is the possibility that the recovery value of the defaulted contract may be less than its promised collateral value. See also Rosenthal and Ocampo (1988).

[26] For one, issuing banks could take advantage of private information gained from longstanding credit relationships by designating predominantly "bad risks" for inclusion in the reference portfolio of a securitisation transaction (ex ante moral hazard). Moreover, the transfer of repayment claims on originated loans (regardless of the so-called servicing function) is likely to decrease incentives on part of banks to continue carrying the high costs of loan monitoring and renegotiation at the same intensity (Gorton and Pennacchi, 1995). See also Elsas and Krahnen (1999). For a detailed description of asymmetric information in asset securitisation, please refer to section 4.2.1.

[27] Additionally, issuers eliminate uncertainty from the specificity of credit risk by including support mechanism (i.e. risk mitigants), which confine the investment risk of securitised debt to a predefined maximum. See also sections 4.2 and 5.4.

consumption preferences. Hence, for loss of fully transparent underlying portfolio quality, issuers seem to entrust both marketability and liquidity of securitised debt mainly to the transaction structure, which matters as it determines the risk sharing between the issuer and investors. Nonetheless, the flexibility of issuers to devise a particular transaction and payment structure bears the risk of misaligned information between issuers and investors about the loss volatility associated with the expected default term structure of securitised debt. In the following section, we expand the critical analysis of information constraints arising from private information by issuers to include other sources of investment risk. Before we do so, let us first survey the economic benefits of asset securitisation in more detail.

issue date

***ex ante* moral hazard (incentive problem)**

Remedy: mandatory credit enhancement required by rating agencies) prevents selection bias (ex ante moral hazard) in the composition of the reference portfolio prior to the date of issue (disciplining device). Credit enhancement makes up for any difference in default probability between the underlying reference portfolio and the desired rating of the transaction. This information problem is confined to costly effort choice by issuers rather than adverse selection of issue quality by investors (disciplining device). Hence, essential credit enhancement is devoid of discriminatory power to separate different issue types.

adverse selection (information problem)

Remedy: any additional credit/liquidity support besides an essential level of credit enhancement serves as costly signal (information measure) to introduce transparency, so that the agency cost of adverse selection in a market with a high degree of asymmetric information is mitigated. Otherwise, rational investor behaviour would anticipate a "lemons market" with merely poor securitisation issues left in the market (screening by issuers).

***ex post* moral hazard (incentive problem)**

Remedy: contractual effort choice (disciplining device), e.g. servicing obligation, etc. bind issuers/originators to maintain due diligence in support of proper investor pay-out.

Fig. 4. *Asymmetric information problems in securitisation.*

4 KEY BENEFITS OF ASSET SECURITISATION

The economic reasoning of securitisation hinges on the ability of issuers as profitable enterprises to maximise shareholder value as the principal goal of economic activity. The market value of outstanding equity as a measure of shareholder value depends on three factors: (i) the amount of future cash flows accruable to shareholders, (ii) the timing of cash flows, and (iii) the risk involved in the generation of these cash flows. Management decisions involve the use of capital market-based models to evaluate the economic impact of competing strategic and operational objectives on shareholder value, i.e. the amount and timing of cash flows (i.e. expected returns) and the associated risk. Financial activities within business entities have to be geared to support the realisation of profitable objectives to what capital markets deem as attainable levels of economic efficiency. The securitisation of balance sheet assets into structured debt securities as contingent claims on pooled asset exposure confers upon issuers mainly financial advantages related to more competitive capital management through efficient asset funding. Further objectives of securitisation might also include active balance sheet restructuring, market-oriented risk management of credit risk and diversified liquidity (Bär, 1997 and 1998).[28] Hence, from a capital market perspective, it is imperative to assess how securitisation affects the (shareholder) value of the issuer and whether the trade-off between attendant benefits and drawbacks yields positive payoffs to both issuers and investors. Obvious benefits from asset securitisation include capital gains from the issuance of securitised debt to capital market investors and the servicing fee that accrues to the originator of the securitised assets. However, only efficient risk management and the reduction of funding costs (in corporate finance) imply economic value added (EVA) from asset securitisation.

4.1 Risk management

Risk Management is a transmission and control mechanism, which encapsulates different approaches to determine risk-return profiles of alternative (investment) strategies to maximise shareholder value. Asset securitisation is one operational means of risk management, which allows issuers to reallocate, commoditise and transfer different types of risk (e.g. credit risk, interest rate risk, liquidity risk or pricing risk) to capital market investors in return for some fair market price.[29]

While banks and other financial institutions view securitisation as an expedient means to evade inconsistent regulatory capital charges for credit exposures of similar risk ("optimisation of regulatory capital"), non-financial entities would employ securitisation primarily for the liquidity management of existing trade receivables. Both objectives benefit largely from active portfolio management through asset securitisation, which mitigates concentration risk (i) by individual exposure to creditors (granularity) and/or (ii) by regional area or industrial classification in optimal portfolio allocation under risk-return efficiency. As issuers rid themselves of clearly identified risk through securitisation transactions, they alter the composition of their asset claim portfolios for purposes of greater diversification. For instance, private economic rents from bank lending explain the prominence of

[28] See also Bigus (2000).

[29] This fair market price would carry a discount for valuation uncertainty, which results in a reservation utility of investors ("discounted offering price").

asset securitisation as a risk management tool. Banks are adept at originating credit exposures due to their long experience of assessing credit risk and strong client relationships.[30] The benefits from relationship lending result from economic rents in revolving loan commitments and improved debtor screening, which leads to higher margins from loan origination (Krahnen and Elsas, 1999).[31] The reduction of economic and/or regulatory cost of capital through securitisation allows issuers to use their capital base more efficiently to pursue lending opportunities without incurring balance sheet growth. Especially, informational rents from SME lending in heavily bank-centred financial systems and the rather unfavourable rating grade distribution of typical SME loan portfolios (see Fig. 5 below) make loan securitisation a perfect candidate for efficient risk management. Hence, loan securitisation not only contributes to the sustainability of client relationships, but also leads to an increased availability of credit finance at lower cost in the primary lending markets (Jobst, 2003a).

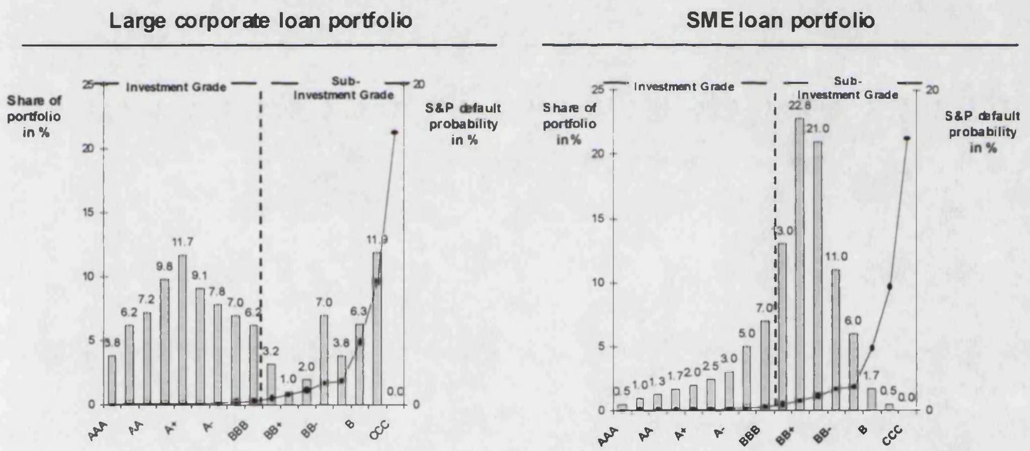

Fig. 5. *Risk characteristics of corporate loan and SME loan portfolios (Jobst, 2003a).*

Furthermore, asset securitisation of fixed interest debt shields originators from adverse interest rate changes. A decrease in loan interest rates reduces the interest rate margin from deposit-based loan refinancing (i.e. high deposit interest rates and low loan rates as the worst case scenario), whereas an increase in loan interest rates leads to actuarial losses and cost-accounting depreciation. By securitising fixed interest loans issuers are able to parcel out a defined proportion of interest rate risk associated with the receipt of future debt repayments. Analogously, liquidity risk from maturity

[30] These relationships might yield informational rents as shown by Elsas and Krahnen (1999) in the context of German banking. See also Elsas and Krahnen (1998) and Mayer (1988).

[31] Unfortunately, the ease of lending coupled with ready and cheap access to liquidity results in a recipe for disaster as banks achieve suboptimal outcomes from holding loans in the long-term.

mismatch, reinvestment risk as well as call (option) risk (e.g. redemption, termination and prepayment) could equally be remedied with the help of securitisation.[32]

4.2 Corporate finance – private information and capital structure

Although there is not a single theory that explains the economic tenet of loan securitisation, the burgeoning securitisation market has sparked a large range of theoretical accounts of what arguably motivates the issuance of secured debt on pooled asset exposures. In general, a major strand of research explores the interdependence and the adverse selection effects of the issuer's asset structure. It proffers several corporate finance-based incentives which stack up to support securitisation as a more efficient means of external finance: (i) private information as a means to mitigate the regulatory capital charge and achieve greater specialisation in areas of comparative advantage, (ii) avoidance of asset substitution and underinvestment, and (iii) reduction of the agency cost from asymmetric information in asset funding.

4.2.1 Private information: mitigation of the regulatory capital charge and greater specialisation in areas of comparative advantages

According to Greenbaum and Thakor (1987) private information held about the quality of originated assets would induce financial institutions to prefer the securitisation of better quality assets to mitigate their regulatory capital requirement for "overcharged" asset exposures, whilst worse quality assets are retained.[33] For this selective bias to be economically sustainable issuers must extract positive payoffs from trading off the benefits from securitising low-risk reference portfolios against increased bankruptcy risk.[34] Private information might also find an outlet in securitisation if issuers aim to achieve greater specialisation in sourcing and monitoring as areas of comparative advantage.[35] Millon and Thakor (1985) assert that banks enjoy certification comparative advantage as opposed to

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[32] However, securitisation is barely used in the bid to reduce excessive exposures from interest rate risk or liquidity risk, because derivative transactions, future and options are more flexible and cost-efficient (Betsch, 2000).

[33] Also it will not be long before a more fine-tuned regulatory treatment of asset securitisation will come into force (Basle Committee, 2004), the current regulatory regime of the 1988 Basle Accord imposes the same risk-based capital charge on differently rated loans. Such a broad treatment of credit risk has led to a problematic outcome. Banks would securitise high quality but low yielding loan claims (for whom opportunity cost of regulatory capital is higher than with higher yielding assets) to reduce minimum capital requirements for credit exposures. Such "regulatory arbitrage" would result in a continuous drain of high-quality loans from loan book, which increases the probability of bank insolvency. The new proposals for the revision of the Basle Accord remedy this shortcoming through the implementation of more risk-sensitive capital requirements.

[34] Greenbaum and Thakor (1987) demonstrate not only how the perceived quality of the asset structure comes to matter, but also assess the extent to which certain credit risk management techniques, such as asset securitisation, could prove to be a suitable for transforming asset structures.

asset funding, where securitisation offers an alternative and diversified source of finance compared to traditional channels of refinancing.

4.2.2 *Agency costs of asymmetric information in the capital structure choice*

The capital structure decision has traditionally been addressed in the context of on-balance sheet funding, where financial intermediaries and corporations are faced with fundamental choice between debt and equity as sources of funds to meet specific investment needs. By definition the different state-contingent payoff functions of equity and debt in the capital structure of firms causes agency costs of asymmetric information. Debt represents a disciplinary device to establish sufficient incentive compatibility of equity and debt holders to prevent non-value maximising managers from implicitly appropriating and transfer wealth from bondholders to equity holders ("asset substitution") if they engage in sub-optimal risky investments at a too low a level of debt (Jensen and Meckling, 1976).[36] However, an excessive debt burden could induce the opportunity cost of abandoning profitable future investment opportunities. The cost of this "underinvestment problem" (Myers, 1977 and 1984) and other agency costs of debt, such as bankruptcy cost, increase in the level of debt in the capital structure.

4.2.3 *Avoidance of underinvestment and asset substitution*

Asset securitisation might redress these conflicts of interest between creditors and shareholders of firms and associated agency cost induced by risky debt, which would otherwise result in suboptimal investment decisions. James (1988), as well as Benveniste and Berger (1987), show that securitisation tranches resemble secured debt, whose agency costs (from monitoring as well as underinvestment and asset substitution) may be lower than for unsecured debt (Stulz and Johnson, 1985).[37] Similar to secured debt, securitisation allows issuers to appropriate partial debtholder wealth by carving out a defined pool of assets (i.e. the "reference portfolio") to satisfy securitised debt claims, which do not capture gains from the firm's future investments. This prioritisation of debtor claims potentially alleviates underinvestment and renders existing debt less inhibitive on the realisation of new

[35] Berger and Udell (1993) proposed a monitoring technology hypothesis in this context.
[36] The role of debt could be conjured as a signal of future profitability (to sustain the payment obligation associated with debt) (Ross, 1977), leading to an alleviation of the agency cost from uncertainty about the true firm value.
[37] See also Berkovitch and Kim (1990), who find that secured debt lower the adverse effect of the underinvestment problem on firm value.

investment opportunities.[38] However, this possible resolution of agency problems in the capital structure choice needs to be qualified as to whether securitised debt actually increases firm value and makes existing bondholders better off.[39] Any positive effect from the appropriation of debtholder wealth ultimately depends on the way the investment policy of entrenched managers guides the riskiness of the use of securitisation proceeds relative to the *ex ante* riskiness of the issuer.

The issuance of securitised debt implies a "nested" capital structure decision, which bears the potential of expropriating claimholder wealth.[40] On the one hand, an absence of bond covenants to restrict the use of proceeds from securitised debt would allow issuers to extract debtholder wealth. Issuers may securitise low risk assets (i) to fund riskier future investment activities or (ii) to pay out securitisation proceeds directly to shareholders and repurchase shares. For instance, banks could similarly be tempted to expand the scope of making fresh loans by using securitisation as a form of "revolving door" refinancing for riskier future lending business. Hence, shareholder wealth increases at the expense of diluted bondholder claims in line with asset substitution. On the other hand, non-value maximising issuers could extract shareholder wealth if asset securitisation allows them to monetise balance sheet assets for negative net present value investment projects without disciplinary effects of poor performance.[41] Alternatively, issuers might also evade capital market discipline by using securitisation proceeds as part of their capital management plan to pay down existing debt at the expense of future equity payouts. Less market monitoring of secured debt compared to unsecured debt could exacerbate this negative effect on shareholder value.[42,43] Consistent with

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38 Additionally, the agency cost of securitised debt might be lower than the cost of bank borrowing and bond debt, mainly because securitised debt does not carry restrictive bond covenants and might be easier to negotiate as it is not subject to asset substitution like in the conventional capital structure choice. Although reference portfolios underlying securitised debt are heavily scrutinised by rating agencies, with debt claims backed by payments from the reference portfolio and not the issuer, debt holders require less information about the issuing firm than unsecured debt holders of corporate bonds. See also Wolfe (2000).

39 Stulz and Johnson (1985) find that existing debtholders can be made better off by the issuance of secured debt if the financing decision is accompanied by a positive change in investment policy.

40 The utility of asset securitisation as a means of skirting the agency cost of underinvestment implicitly involves a rearrangement of risk sharing between constituent debtholders and equity holders. However, the potential claimholder expropriation through reinvestment of proceeds generated from securitised debt in turn effects the variability of issuer cash flows ex post. The agency cost of a given capital structure and associated funding constraints also supports use of securitisation if the volatility of cash flows also depends on the management of foreign exchange rate exposures. Besides the shortening of the maturity of outstanding debt or payout restrictions on dividends generally enhance the level of internal funds, also hedging of foreign exchange risk through asset-backed securities might lower the volatility of cash flow and mitigate the underinvestment problem (Nandy, 2002) if the riskiness of issuer cash flows does not increase. Froot et al. (1993) show that hedging could reduce the volatility of cash flows and leave sufficient funds available to the firm to take advantage of viable investment opportunities, whose riskiness formerly disqualified them from being undertaken for a given level of debtholder claims. If greater availability of internal cash flows from proceeds of securitised debt lessens the adverse impact of cash flow volatility lower underinvestment ensues.

41 See Lang et al. (1995), who argue that asset sales may allow managers to pursue poor projects by creating liquidity for investment. See also Pennacchi (1988).

42 See also Lockwood et al. (1996).

conventional thinking about the capital structure choice, issuers with high agency costs of debt (which implies high financial leverage and/or financial distress) and/or low growth prospects have higher incentives for asset substitution and a higher chance of an underinvestment problem, so they should be more likely to engage in asset securitisation. Any negative effect of shareholder expropriation by suboptimal investment should increase (decrease) the higher (lower) the securitisation proceeds (growth prospects).

4.2.4 Asymmetric information and funding cost

We also need to investigate the impact of asset securitisation on the capital structure decision as a funding choice under asymmetric information, which necessarily involves a closer inspection of both *pecking order theory* and *trade-off theory*. The *trade-off theory* postulates that managers choose a leverage level, where the marginal benefit of debt, such as the interest tax shield, just outweighs the costs of debt, including agency and financial distress cost ("optimal trade-off").[44] In contrast, the *pecking order theory* (Myers and Majluf, 1984) states that firms prefer internal to external finance due to adverse selection arising from information asymmetry in financial relationships between insiders and outsiders.[45] If external funds are needed to undertake a profitable investment project, firms choose the safest claim (which involves the lowest degree of asymmetric information). Without asset securitisation the pecking order theory suggests that firms with high internal refinancing cost and low bankruptcy cost generally prefer debt to equity because of lower information costs from valuation uncertainty.[46] However, this form of external finance increases both the balance sheet volume and

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[43] Note that the use of funds from asset securitisation leads to a reduction in balance sheet volume only in cases of shareholder payout, debt repayment or negative net present value investments.

[44] Barnea et al. (1981) define this consideration as the optimal trade-off between the agency costs of debt and the benefits associated with different financial contracts in terms of their inherent capacity to resolve agency problems and tax exposure.

[45] In Myers and Majluf (1984) managers have superior knowledge about the value of the firm and act to maximize shareholder value. Due to asymmetric information rational potential investors ("outsiders") would discount the value of any security issue.

[46] Hence, rational investor behaviour compels managers to qualify their capital structure choice on the actual firm value. Managers are more likely to prefer debt (equity) if they believe the firm to be undervalued (overvalued). In recognition of these strategic alternatives investors would perceive an equity issue an indication of poor quality, which increases the cost of issuing equity. So the hierarchy of funding alternatives in line with the pecking order theory would suggest that firm issue equity only after the chances of issuing debt or hybrid securities, such as convertible bonds, have been exhausted. In accordance with the modified pecking order theory (MPOT) the following empirically testable hypothesis for managerial capital structure decisions would ensue: (i) avoidance of external equity and risky debt, (ii) dividend policies which can be maintained by internally generated equity, (iii) the maintenance of financial slack, and (iv) the acquisition of additional funds with risky debt rather than new equity, given "sticky" dividend payout and variable investment opportunities. These ideas were later refined by Shyam-Sunder and Myers (1999) into a key testable prediction, which states that the incidence of the pecking order in the capital structure decision of firms should yield a strong correlation between net debt issues and the financing deficit of firms.

the debt-to-equity ratio,[47] which could increase the marginal cost of funding due to higher financial distress cost.[48] By the same token, securitised debt may be considered even safer than unsecured debt, as the value of the insulated reference portfolio entails less information asymmetry than the assessment of the issuer's firm value. Furthermore, the off-balance sheet characteristic of securitisation allows refinancing at a potentially lower cost than equity without attendant balance sheet growth.

Under the *pecking order theory* the issuance of asset-backed securities registers as viable a source of external finance as unsecured debt if issuers face high capital costs of internal funds; yet, issuers with severe information asymmetry problems would be more inclined to issue secured debt, which comes closest to internal funds from an agency cost perspective. Since capital market investors in securitisation transactions receive their payment directly from a diversified pool of asset exposures insulated from the issuer,[49] securitised debt carries lower agency cost.[50] The *trade-off theory* would restrict this assumption only to those cases, where the capital structure of the issuer reflects the optimal balance between the benefits and drawbacks from the agency cost of debt under asymmetric information. Hence, under both the pecking order and trade-off theory, asset securitisation is the structured finance instrument of choice for issuers with stretched internal funds. Their high on-balance sheet funding costs, possibly substandard credit (ratings) and high agency costs of asymmetric information debar them from other forms of external finance.[51]

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[47] Furthermore, the credit rating of the newly issued securities may be capped at the issuer's rating.

[48] As existing creditors would command higher debt returns at a higher leverage ratio, the consolidated credit linkage of the unsecured debt to the originator (unlike in off-balance sheet transactions) raises the cost of funding.

[49] The straightforward calculation of future cash flows from accrued repayment in a diversified asset portfolio replaces the assessment of the overall business risk and the income generating potential of the issuer.

[50] This theoretical observation implies a property of securitised debt, which should be most attractive for small corporate and SME issuers, whose firm value is hard to assess.

[51] Issuers can refinance defined asset exposure at lower cost due to a possibly higher standalone rating of secured debt. If the rating of asset-backed securities might supersede the issuer rating thanks to superior quality, securitisation tranches could be sold at tighter spreads and higher prices. This rating effect ("upgrading"), known as credit risk arbitrage (Bär, 1998; Röchling, 2002), stems from mainly from two sources. For one, after issuers parcel out high quality assets or shed defined risk exposure from their risky core business, the issued debt securities are solely supported by the cash flow from underlying reference portfolio (and any asset protection if available) without interference on part of the asset originator, leaving the rating assessment largely unaffected by counterparty risk. Second, if assets are securitised through a true sale transaction, the legal title is irrevocably transferred to investors (via an SPV). This transaction structure precludes any recourse or economic interest on part of the originator. See also Cantwell (1996).

4.3 Equity return, imputed cost of equity and economic risk transfer

The analysis of the benefits associated with asset securitisation as a funding alternative to traditional on-balance sheet debt finance also needs to consider the role of equity in the capital structure of issuers. The assessment of securitisation on the basis of the cost of debt alone essentially ignores what could be viewed as a conscious capital structure decision of "leverage in disguise." In the following section we examine the leverage effect of securitisation on the return on equity and the *imputed (calculative) cost of equity* ("capital coverage") (Röchling, 2002; Bär, 1998) for a *true sale structure*, which by definition changes the balance sheet composition of the asset originator.[52] We can sketch the effect of asset securitisation on both economic cost of capital, whenever the imputed cost of equity indicates actual cost advantages associated with asset securitisation. First, we specify the total cost of funding as the weighted average cost of capital (WACC)[53]

$$WACC = k_E \times \frac{E}{E+D} + k_D \times \frac{D}{E+D}, \tag{1}$$

where the cost of equity k_E and the cost of debt k_D are weighted by the market value-based proportion of equity and debt in the capital structure (Damodaran, 1996). The imputed cost of equity k_{IE} is defined as the *contribution margin* from the cost of equity over the cost of capital of 100% debt finance (i.e. full leverage), so that

$$k_{IE} = WACC - k_D = \frac{k_E E + k_D D - k_D\left(E+D\right)}{E+D} = \frac{E\left(k_E - k_D\right)}{E+D} = \frac{k_E - k_D}{\frac{E+D}{E}}. \tag{2}$$

A numerical example illustrates the effect of (true sale) securitisation on the imputed (economic) cost of equity. Let us assume that the issuer holds exactly 8% equity (which would match the 8% minimum capital requirement of banks for 100% risk-weighted assets and no risk weight reduction

[52] For simplicity we assume that the issuer re-invests the maximum proceeds from the securitisation (nominal value of the reference portfolio minus expected loss and structuring cost) at the weighted average cost of capital (WACC), so claimholder rights of debt and equity remain unaffected by use of funds from securitised debt. This approach also implies no change in the balance sheet volume if we rule out negative net present value reinvestment of proceeds.

[53] Note here that this WACC-based balance sheet approach is taken from the perspective of the asset originator, whose total assets are assumed to be securitised. In other words, we only analyse the relative balance sheet effect of increased leverage over a defined set of securitised asset exposures of the same asset return and marginal cost of debt.

under Basle Accord (Basle Committee, 2004a and 2004b)[54] and shareholder require at least 15% return on equity, given a cost of debt of 5% at a debt-to-equity ratio of $0.08/0.92 \approx 8.7\%$ (see Tab. 2). Hence, the imputed cost of equity before securitisation amounts to

$$k_{IE_{before}} = \frac{E(k_E - k_D)}{E + D} = \frac{0.08(0.15 - 0.05)}{0.08 + 0.92} = 0.008 \equiv 0.8\%\,. \tag{3}$$

By accepting a first loss position (FLP) of 3%, the issuer now holds 3% instead of 8% equity after completion of the securitisation transaction. The imputed cost of equity has fallen from 0.80% to

$$k_{IE_{before}} = \frac{E(k_E - k_D)}{E + D} = \frac{0.03(0.15 - 0.0525)}{0.03 + 0.97} = 0.002925 \approx 0.29\%\,. \tag{4}$$

On-balance sheet funding		*Off-balance sheet funding*	
Debt capital	92.00%	Debt	97.00%
Equity capital	8.00%	Equity	3.00%
Total capital	***100.00%***	***Total capital***	***100.00%***
Return of available assets	7.00%	Return of securitisable assets	7.00%
Weighted cost of equity (CoE)	**1.20%**	**Weighted cost of equity (CoE)**	**0.45%**
Weighted cost of debt (CoD)	**4.60%**	**Weighted cost of debt (CoD)**	**5.09%**
Risk-free rate	*4.50%*	*Risk-free rate*	*4.50%*
Corporate risk spread	*0.50%*	*Corporate risk spread*	*0.50%*
		ABS structuring cost	*0.25%*
WACC	***5.80%***	***WACC***	***5.55%***
Imputed cost of equity	**0.80%**	**Imputed cost of equity**	**0.29%**
Expected (credit) loss (EL)	1.00%	Expected (credit) loss (EL)	1.00%
		Credit enhancement (CE)	0.25%
Total direct cost (CoD + EL)	5.60%	Total direct cost (CoD + EL + CE)	6.34%
Net return		**Net return**	
before CoE	*1.40%*	*before CoE*	*0.66%*
after CoE	*0.20%*	*after CoE*	*0.21%*
Return on equity (RoE)	**17.50%**	**Return on equity (RoE)**	**21.92%**

Tab. 2. *Simplified calculation of imputed cost of capital and net return from asset securitisation.*

In our calculation the absolute reduction of the imputed cost of equity by 0.51% to 0.29% in off-balance sheet refinancing stems from lower capital coverage, which could eventually reach zero in the

[54] See also Basle Committee (2002a, 2002b and 2001).

extreme case of full leverage. In order to gauge the implications of different levels of imputed (marginal) cost of equity on shareholder return, we consider the net return of securitisation before and after including the cost of equity. We subtract the "total direct cost of debt" (weighted cost of debt, expected loan loss (and the cost of credit enhancement for the case of securitisation)) from the expected "return on securitisable assets" ("return on available assets") for off-balance sheet (on-balance sheet) funding in order to derive the net return before the (weighted) cost of equity. Dividing this result by total equity capital yields the return on equity, which is clearly higher in the case of off-balance debt refinancing (21.92%) compared to conventional on-balance sheet funding (17.50%).

The off-balance sheet conversion of securitised assets through the issuance of securitised debt also involves a change in the riskiness of debt as the return on equity increases.[55] The default distribution of securitised assets shall serve as a straightforward example to illustrate this point. Since issuers commonly retain a first loss position (FLP) as "concentrated risk exposure" to cover expected losses only (see Fig. 6), any loss in excess of FLP is transferred to capital market investors via securitised debt. Although the weighted cost of debt increases in a higher debt-to-equity ratio, the transfer of economic risk implied by the reduction in equity (as FLP) from 8% to 3% alters the issuer's residual risk exposure from credit default[56] and caps the probability density at expected default loss.[57] This risk sharing arrangement creates leveraged investment, where the risk-return profile of issued tranches differs from the risk-return profile of direct investment in the underlying assets.

The leveraged loss exposure of securitised debt relative to the overall notional amount of securitised assets depends on the level of expected loss covered by the issuer through FLP ("enhancement level") to make securitised debt less sensitive to moderate value changes of securitised assets. At the same time, the retention of "concentrated risk exposure" lowers the amount of required economic (equity) capital if *ex ante* total default loss (i.e. expected and unexpected loss) from securitised assets originally exceeded FLP.[58] Note here that the configuration of securitisation itself might imply interest rate and liquidity risk (see section 4.1), depending on the nature of the underlying reference portfolio of securitised assets and the security design of the transaction at hand, which complicate the economic rationale of securitisation beyond this admittedly simplified illustration (see section 5).

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[55] Hence, we do not adjust the corporate risk spread for a higher degree of leverage in the computation of the imputed cost of equity and return on equity, provided that the transfer of economic risk fully compensates for higher bankruptcy cost from increased leverage (see Fig. 4).
[56] In asset securitisation of other asset types, such as whole business ABS or mortgage-backed securities (MBS) a shortfall of expected revenue or debtor prepayment would also constitute instances of liquidity and market risk aside from credit risk as a source of investment risk in asset securitisation.
[57] Issuers shed all unexpected risk and restrict their effective loss distribution to expected loss as upper boundary.

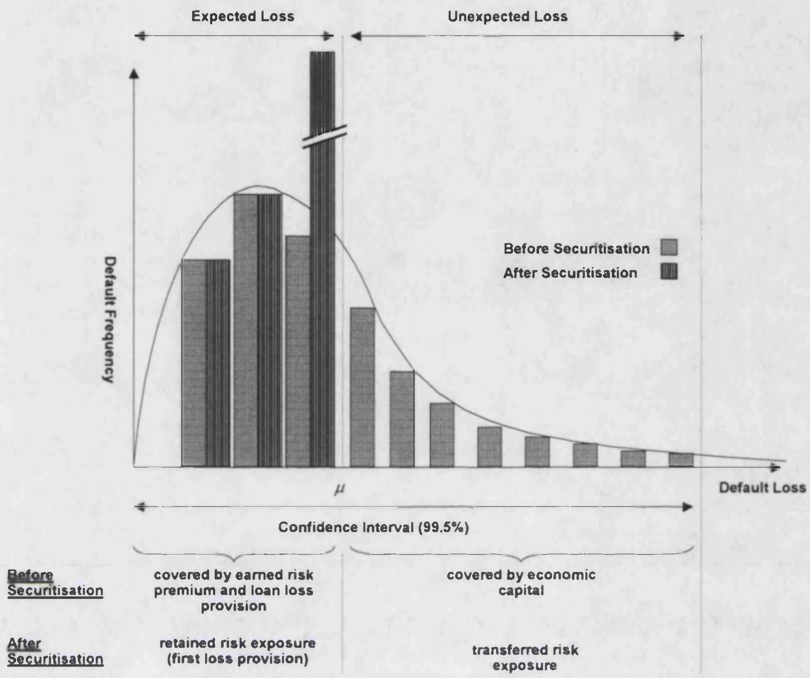

Fig. 6. *Economic risk transfer.*[59]

In the context of loan securitisation by financial institutions, this analysis also illustrates that securitisation does not cast banks free from what is generally considered their traditional function in financial intermediation – namely to measure, assume and manage credit risk. Asset securitisation can potentially carry as much or more credit risk exposure as traditional lending, if banks pursue the mitigation of loan portfolio risk in an unbalanced and single-sided fashion without consideration of concentrated credit risk and systemic risk of asset correlation. For all practical purposes, securitisation qualifies as a remedy for issuers caught in the throes of mounting pressure over diminishing asset returns or excessive regulatory burdens; yet it does not serve to resolve systemic issues of credit risk management or inefficiencies in loan origination and financial intermediation *per se.* Instead, asset securitisation rather *rewards* the general capacity of superior credit risk management and facilitates efficient financial intermediation.

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[58] From a return perspective, the economic risk transfer through asset securitisation decreases the imputed cost of equity, which results in a higher net return after cost of equity.
[59] Adapted from Bluhm (2003). See also Schierenbeck (2001) and Ong (1999).

5 GENERAL INVESTMENT RISKS IN ASSET SECURITISATION

Securitisation is commonly understood as an important risk management tool, mainly because its inherent differentiation and integration process ("risk restructuring") allows issuers to reduce their cost of investment funding by segregating the risk exposure of a designated pool of assets.[60] However, the conversion of balance-sheet risk into marketable securitised debt involves more refined and complicated financial structures in terms of security design and reporting standards than conventional on-balance sheet refinancing. Although securitised assets exhibit the same kinds of risks as loan exposures in bank-based financial intermediation and corporate debt of banking operations, the rarefied and complex nature of asset securitisation intensifies both the importance and scale of how credit (or asset) risk, market risk, liquidity risk and operational risk concur in securitised debt (see Fig. 7). The degree of investment risk in asset securitisation stems from two areas, namely (i) the characteristics and performance of existing and/or future receivables and other financial assets as sources of payments to the securitisation transaction *(collateral level)* as well as (ii) the allocation and distribution of payments from securitised assets to holders of the various tranches of issued debt securities *(security level)* in accordance with specific payment priorities and loss tolerance levels.[61] Moreover, the form of transaction defines the kind of investment risk, which emanates from either (i) uncertainty about payment to investors, who hold (fully funded) contingent claims on the performance of the underlying reference portfolio of asset exposures (in traditional securitisation) or (ii) from the exercise of credit derivatives (mostly in synthetic securitisation),[62] where partially or unfunded investor claims are subject to the risk of a pre-defined credit event.

5.1 Credit risk

First and foremost, investors in securitisation transactions are concerned with the *credit (or asset) risk* of fully and timely repayment of securitised assets in the underlying reference portfolio. Rating agencies commonly distinguish between *downgrade risk* and *claims-paying ability* to describe the debtor's credit posture. For descriptive purposes we follow Canor et al. (2000) to distinguish both concepts. Whereas the claims-paying ability speaks to the probability of a debtor to default on some obligation

[60] See Skarabot (2002), Leland (1998), Frankel (1991) as well as Rosenthal and Ocampo (1988) for an economic analysis of this risk transfer property of securitisation.
[61] The Bond Market Association (2001) refers to the assessment of these two components of securitisation as "transaction reporting", which denotes the periodic (usually monthly) post-issuance calculation and dissemination of performance data about such transactions.
[62] See also Batchvarov et al. (2000).

at one point in time, downgrade risk reflects the probability of a reassessment of the claims-paying ability due to modest changes in the financial condition of the obligor. This forward-looking "benefit of doubt" about credit quality in the definition of downgrade risk primarily focuses on the question of whether available financial resources will withstand some stochastic risk exposure, irrespective of a change in the macroeconomic environment.[63]

Although credit risk transfer by means of structured finance debt obligations lies at the core of risk management through securitisation, there is a host of further credit risk contingencies beyond the collateral level, such as the servicing function of securitised assets, the payment of administrative fees to the SPV, the transfer of payments from debtors to investors and counterparty risk (if the reference portfolio is collateralised by some guarantee or other default protection). Issuers apply structural provisions to mitigate credit risk, such as (internal or external) *credit enhancement* to attain a desired credit risk profile for issued debt securities and *risk-sharing mechanisms* (through the subordination of issued debt securities), which largely shape the security design of securitisation transactions.

Market risk in securitisation mainly stems from adverse effects of interest rate and exchange rate movements on the issuer's cash flow management and the ability to repay securitised debt. In transactions with varying repayment terms and multiple (unhedged) currency denominations of securitised assets the payment agent of the transaction (i.e. the SPV or the issuer, if the transaction is completed without an SPV as conduit) would need to reconcile expected repayment from securitised assets (fixed or floating) with coupon payments (fixed or floating) to securitised debt issued to investors in order to minimise term structure risk, reinvestment risk and/or base risk.[64] Failure to do so would cause fundamental market fluctuations to upset the scheduled amortisation and the timeliness of contractually agreed repayment to investors. The same considerations of balanced cash flow management apply analogously in the case of currency risk exposures on the basis of covered

[63] In loan securitisation, the distressed performance of the high-yield structured finance market since 2001 and persistent downward rating drift of credit claims (with adverse follow-on effects on the performance of securitised loans) has sparked great interest in a diligent surveillance of asset performance. Especially the term structure of loan defaults has drawn attention to the fact that the issuer's ability to cover expected losses through credit enhancement hinges on the capacity to avert unexpected levels of substandard asset performance. As banks have identified loan securitisation as an expedient refinancing vehicle and risk management tool, prudent monitoring of the reference portfolio ("collateral surveillance") commands a more careful contemplation of defaults (i.e. delinquencies and termination rates). Consequently, translating credit risk into investment risk of structured claims in a securitisation transaction becomes essential.

[64] Investment risk arises if both cash inflows and cash outflows are fixed interest payments but differ in maturity ("maturity mismatch"). In contrast, base risk arises from a mismatch of cash inflows and cash outflows as floating interest payments on different interest reference rates. Term structure risk refers to an insufficient immunisation against interest rate movements if cash inflows are fixed (floating) interest payments and cash outflows are floating (fixed) interest payments.

interest rate parity. Both currency and interest rate risks are frequently hedged with standard derivative tools, such as cross-currency swaps and interest rate swaps.

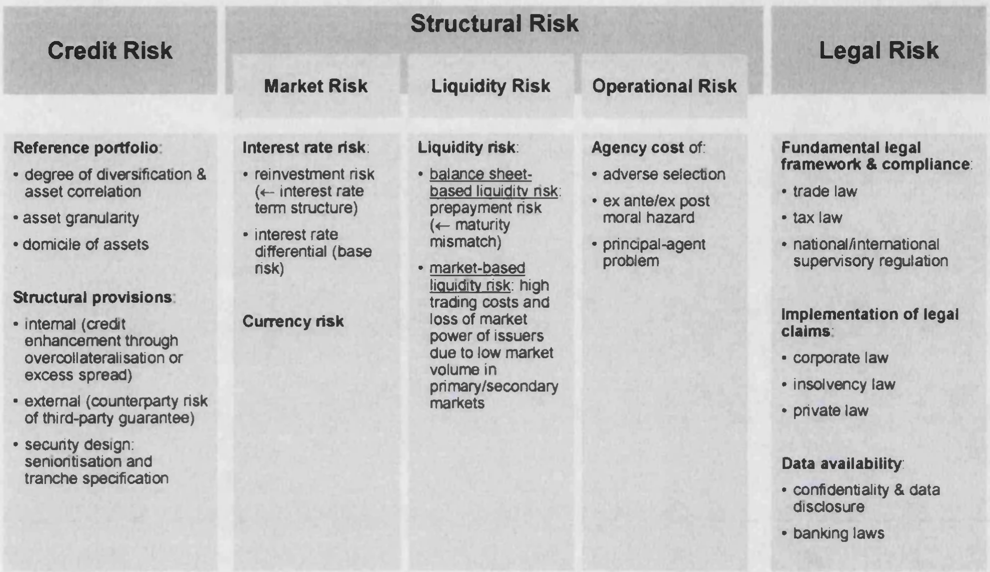

Fig. 7. *Fundamental investment risks in asset securitisation.*

5.2 Market and liquidity risk

A change in the interest rate term structure also changes the propensity of debtors to prepay securitised mortgages and other credit obligations with early termination provisions. If a reduction in short-term interest rates would warrant re-financing, prepayment might significantly change the composition and drain the size of the underlying reference portfolio to generate sufficient repayment to cover expected investor return on securitised debt. Issuers usually attempt to remedy *balance sheet-based liquidity risk* from a possible maturity mismatch of cash inflows and cash outflows through diligent liquidity management. Depending on the transaction structure it is commonplace to allow for asset substitution under certain conditions and/or replenishment of amortising assets in the reference portfolio, with the latter being a routine feature of revolving credit exposures. Moreover, the payment structure[65] of securitisation transactions enables issuers to avoid any liquidity shortfalls

[65] In asset securitisation we distinguish between various payment structures, i.e. the ways of scheduled repayment of principal and interest of the underlying reference portfolio to investors. While some securities return total principal to investors throughout the life of the security (fully amortising) or in equal payments over a set period of time (often one or two years) after a contractually predetermined "revolving period" of defined interest payments (controlled amortisation). So-called "bullet structures" are a viable alternative to controlled amortisation structures for revolving assets (such as credit card receivables, trade receivables, dealer floor-plan loans and some leases). They are designed to return principal to investors in a single payment. Similar to controlled amortisation transactions, "bullet" payment structures feature two separate cash flow

by tailoring future cash flow profiles conditional on changes in actual repayment proceeds. Issuers can combine various options, such as the configuration of cash flow management (pass-through or pay-through), the design of interest and principal repayment (pro-rata or sequential), the definition of early amortisation criteria (economic and/or legal "trigger events") and the use of liquidity facilities to shield investors from *balance sheet-based liquidity risk.*

Additional liquidity risk from low trading activity in asset securitisation markets *(market-based liquidity risk)* cuts both ways for issuers and investors. On the one hand, investors might be faced with *high trading cost* (Duffie and Gârleanu, 2001) associated with a small market volume of outstanding securitised debt issues with comparable characteristics and the prospect of high agency costs from adverse selection of securitised assets due to valuation uncertainty. On the other hand, higher searching cost and the possibility of incomplete issuance due to insufficient investment demand from a limited pool of potential buyers compel originators to offer tranches to the highest bidder at relatively short notice, which implies a clear shift of negotiation power from sellers to buyers.[66] Hence, possible liquidity risk of secondary markets complicates dynamic hedging strategies and entails a misallocation of investment funds if limited discretion in trading asset-backed securities forces investors into a buy-and-hold investment strategy. Issuers alleviate these market frictions by means of liquidity facilities.

5.3 Legal risk

Given the evolving regulatory and legal treatment of asset securitisation in response to perpetual financial innovation in structured finance, legal uncertainty from securitised debt is a major concern of investors and issuers. In this section we consider the constraints imposed by *legal risks* on the governance and due diligence of asset securitisation without reference to specific laws, regulations

management periods. During the "revolving period" principal received from the reference portfolio is retained to buy more receivables, before the principal payments build up in an escrow account during the subsequent "accumulation period" to fund a future bullet payment to investors. As much as in controlled amortisation structures "bullet maturities" suffer from early amortisation risk. We distinguish between "soft bullet maturity" and "hard bullet maturity". The former structure is the most common bullet structure, where only part of the deal is guaranteed on the expected maturity date (unlike the "hard bullet" deal), although past evidence indicates that most such ABS return principal on this date. Nonetheless, a "soft bullet" payment includes the implicit shortfall risk during the accumulation period, so that investors may receive the remaining principal payments over an additional period (usually one to three years) after the maturity date (Fabozzi and Yuen, 1998). In contrast, investors in "hard bullet" structures can expect the principal to be paid off on the scheduled maturity date. This is usually done by providing for a longer accumulation period, a third-party guarantee, or both (The Bond Market Association, 1998).

[66] Market-making investors recognise the risk involved in future resale of any securitised claims on non-transparent reference portfolios and discount their valuation accordingly in addition to adverse selection effects.

and/or statutory provisions. This approach allows us to discuss *de facto* legal concepts in lieu of a non-exhaustive normative discussion of *de jure* provisions in various jurisdictions. We identify the most salient general areas of possible regulatory and legal uncertainty, which would help deduct specific legal risks applicable to varying securitisation structures if transposed to a certain legal framework.

Asset securitisation involves a multitude of legal issues, such as trade law compliance, the implementation of legal claims, information disclosure under divergent national banking laws and income tax liability, which all need to be addressed by both asset originators and issuers for a certain transaction structure of asset securitisation. The completion of traditional securitisation best illustrates the potential for conflicting rules and regulations as regards the "true sale" of securitised assets from the originator's balance sheet to another entity. Most national trade laws recognise a "true sale" only if originators do not retain material economic risk associated with the transferred assets and/or reserve any other form of economic recourse.[67] However, an approved legal separation of assets ("credit de-linkage") might still imply *reclassification risk* if the continued exercise of dominant influence and/or the retention of primary beneficiary status warrant the consolidation of transferred assets under national and/or IAS and U.S. GAAP accounting standards. Hence, in absence of "bankruptcy remoteness", originators would still see their chances of capital reduction through traditional securitisation impeded by the extent to which transferred assets might need to be consolidated in the case of insolvency. Moreover, the regulatory recognition of asset (risk) transfers (Basle Committee, 2004a and 2004b) might differ from provisions under existing trade law, so that the retention of asset exposures by originators as first loss position ("credit enhancement") might infringe on the attribution of a *clean break* on the true sale.

The structural complexity of contractual commitments (with or without an SPV) in asset securitisation also induces significant uncertainty about the tax liability of entities involved and the extent to which the nature of the assets and cash flows transferred are subject to taxation (*tax attribution risk*). Income tax, sales tax and other direct taxes are most pertinent to the business transactions involved in the completion of asset securitisation. Specific areas of uncertainty as regards tax liability include: (i) unexpected cash flow mismatches could upset the fine-tuned regime of eliminating (intertemporal) accrual of taxable income *(accrual risk)* from completing the securitisation transaction (e.g. taxation of interest income by the SPV); and (ii) the identification of all activities

[67] For instance, repurchase agreements or clean-up calls tend to compromise a full transfer if they inflict substantial economic risk on the originator, and any payment received from the SPV in return for the asset transfer might be interpreted as secured credit to the originator.

subject to sales tax requires the delimitation of taxable returns and an a case-by-case assessment of how the basis of taxable return would be calculated *(sales tax risk).*

Furthermore, particularly in traditional securitisation, the insolvency of the asset originator (who commonly retains the servicing function of securitised assets) could jeopardise the orderly implementation of legal claims in asset securitisation. In order to guarantee the full and timely fulfillment of securitised asset claims in the event of originator bankruptcy ("bankruptcy remoteness"), several preventative measures safeguard the role of issuer (which is an SPV in the case of true sale securitisation) vis-à-vis the asset originator and ensure unobstructed payment to securitised debt *(realisation risk).* These measures are: (i) "no petition clauses", which allow only investors to force the SPV into bankruptcy; (ii) "no recourse provisions", which delay any legal challenges related to contractual obligations of the SPV outside the defined scope of the securitisation until after the closing of the transaction; and (iii) credit de-linkage of the securitised assets to preserve the economic and legal insulation of the SPV from credit claims levied on the originator. Unless such "safety features" were put in place, all payments made as regards the legal transfer of asset exposure and any additional collateralisation of issued debt securities[68] would be subject to insolvency proceedings *(risk of rescission)* in the event of originator bankruptcy.[69] The *realisation risk* of incomplete and/or delayed repayment of debt securities due to insolvency procedures also includes *set-off risk* if liquidators terminate in advance or charge against each other mutual payment obligations held by originators and their debtors so as to reduce the net balance of outstanding payment obligations. If this set-off procedure affects securitised payment claims, issuers need to make up for lost interest income from the underlying reference portfolio to meet payment obligations.[70] Although insolvency proceedings apply to almost all agents involved in the management of a securitisation transaction, the task of mitigating legal risk by means of careful due diligence and comprehensive contractual documentation mainly falls upon the issuer. At the same time, servicers, investors and rating agencies are at pains to *seek detailed and exact information* about the

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[68] e.g. if the SPV invests repayments from securitised assets to invest in government debt securities as additional collateralisation of issued debt securities.

[69] This situation might even occur if the assets in question have previously been removed from the originator's balance sheet, provided that one or more of the following causes apply: (i) binding contractual and general principles of contract law could void asset transfer or any assignment of asset risk, e.g. originators and debtors have agreed on prohibiting the sale of assets or the assets have already been transferred to a third party; (ii) if insolvency law and trade law coincide in the treatment of transferred assets, the asset transfer is not recognised by trade law and the purchasing entity (i.e. the SPV) remains to be consolidated; and (iii) the originator did not conduct the asset (risk) transfer through securitisation bona fide but with the purposeful intent to defraud creditors (preference risk).

[70] The run-off of cash flows from payment obligation in the case of originator insolvency is also prone to commingling risk (as a further facet of realisation risk), which arises from the indiscriminate treatment of cash flows received from securitised assets and other income. Commingling risk could compromise the issuer's ability to make full and timely collection of repayment proceeds to be disbursed to investors.

specification of securitised assets and their associated risk exposure of issued debt securities (tranches) in the event of issuer insolvency. However, many times confidentiality provisions of certain banking laws and statutes impede the unrestricted disclosure of asset information.[71,72]

5.4 Operational risk

The variety of credit and legal risks from securitised asset exposures goes hand in hand with *operational risk* from the intricate structural arrangements of securitisation transactions involving multiple agents (see Fig. 4). In the presence of asymmetric information, originators and issuers might be tempted to abuse contractual powers within their area of responsibility to achieve their own economic incentives, which imposes substantial agency cost on efficient asset securitisation.

First and foremost, market imperfection due to information asymmetry from valuation uncertainty could lead to *moral hazard* on part of issuers (asset originators in true sale transactions)[73] if their effort level *before* and *after* the issue date is not incentive compatible with investor interests. Issuers (asset originators) could (i) retain a disproportionately large share of high-quality assets from the designated pool of securitised assets (reference portfolio) and replace them by assets of inferior quality *(ex ante moral hazard)*, or (ii) neglect (or even relinquish altogether) the costly enforcement of contractual restrictions imposed on debtors ("effort choice"), whose payment obligations have been securitised *(ex post moral hazard)*. Given the impending transfer of asset exposures through securitisation asset originators might reduce monitoring of securitised assets or exhibit selective bias in the composition of the securitised reference portfolio due to private information about individual asset exposures *(cherry picking)*.[74] Alternatively, *cherry picking* could arise as *ex post* moral hazard from biased asset sorting, in which maturing assets of the reference portfolio are *replenished* by the sponsoring originator

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[71] Note that originators are apprehensive about seeking permission to divulge client information to investors and rating agencies for consideration of maintaining the integrity of client relationships, even though such action might mitigate some uncertainty from insufficient data availability.

[72] Especially if originators do not act as servicers, information disclosure within the defined servicing arrangement is imperative to satisfy the monitoring requirements of asset securitisation, so that investors and rating agencies are able to continuously update their risk assessment. Any securitisation transaction that fails to address the issue of comprehensive information disclosure about securitised assets would merit subsequent amendments, subject to continual review as to their compliance.

[73] Note that the distinction of issuer and asset originator reflects the fact that asset originator and issuer are the same entity in synthetic structures without SPV. The involvement of an SPV in the transaction structure limits our comments on major incentive problems to the asset originator only.

[74] In so-called cherry picking asset originators would deliberately select a pool of securitisable assets, which does not reflect the general average asset quality of the loan book. Such an ex ante moral hazard problem of asset selection could be explained by the incentive of asset originators to misrepresent the average quality of their loan book quality by including over-priced, low-quality loans in the reference portfolio. Although cherry picking is prohibited by national supervisory bodies, testing the adherence to this requirement is riddled with methodological and administrative difficulties.

(on request by the issuer). If issuers fail to successfully negotiate the structuring process and replace securitised asset claims prior to the maturity date of the securitisation transaction ("portfolio replenishment"), repayment proceeds from the reference portfolio might fall well below the level of *natural* attrition due to prepayment and/or amortisation. Overall, both *ex ante* and *ex post* moral hazard involve the expropriation of investor wealth if issuers (asset originators) engage in selective bias as to the asset composition of the securitised reference portfolio or precipitate reduced effort levels as regards risk monitoring and portfolio administration after issuing securitised debt.[75]

Given the significant agency cost from moral hazard, issuers install support mechanisms, which transpire incentive compatible behaviour towards investors so as to mitigate investment risk from asymmetric information. The detrimental effects of moral hazard are generally resolved through a subordinated security design, whose prioritisation of asset claims implies risk sharing through loss cascading. Issuers would securitise a large proportion of senior tranches as interest-generating asset claims, whose high probability of full repayment inhibits incentives of asset originators to either reduce monitoring effort or include poor asset quality in the reference portfolio. At the same time, originators frequently retain the most junior tranche (or buy junior default protection) to indicate their willingness to bear most (if not all) expected loss from the securitised assets. This loss coverage is termed *first loss position* (FLP) or *credit enhancement*,[76] which allows issuers to attain a desired credit risk profile of securitised debt. The concentration of expected losses in the first loss position reduces both investor default tolerance and leverage of senior tranches, whose relative expected and unexpected losses are smaller than relative portfolio losses.[77,78] Hence, its effect on loss allocation[79] is

[75] See also Leland (1998). See also Leland and Pyle (1977) for a reference on the agency cost of asymmetric information in external finance.

[76] The Basle Committee on Banking Supervision (2002b) defines credit enhancement as a contractual arrangement [,] in which the bank retains or assumes a securitisation exposure and, in substance, provides some degree of added protection to other parties to the transaction. [...]." See also Jobst (2004).

[77] Since contractual measures, such as credit enhancement, guard investors against information constraints arising from lending relationships, investment incentives of loan securitisation appear to depend more on how the transaction structure processes unexpected loss from portfolio risk of securitised assets. Since issued debt securities represent individual interests on aggregated cash flows rather than individual loan claims, structural measures (e.g. credit enhancement or other forms of credit support) help issuers cover aggregate expected asset exposure only. Yet the treatment of unexpected risk is not as straightforward. Prudent investment would warrant a careful assessment of how the transaction structure (security design) effects the risk allocation of unexpected default loss (and its change over time). See also Jobst (2003c).

[78] From regulatory point of view, the credit enhancement is termed a direct credit substitute (CDS), whose value derives from the price movement of the underlying reference portfolio. In a bank-sponsored conduit issue the most junior tranche retained by the asset originator/issuer commonly represents the first loss credit protection for the total notional balance of the transaction. The amount of first loss provision is chosen such that it its notional amount effectively absorbs all estimated default risk of the underlying reference portfolio. From the issuer's perspective, the computation of the required level of credit enhancement is predicated on a detailed credit assessment of securitised assets. Rating agencies ascertain the credit enhancement level for a reference portfolio based on the analysis of the credit quality, expected loss and pool diversity required for senior and mezzanine classes to achieve the desired rating of issued debt securities. The fundamental

instrumental for a viable security design.[80] Essentially, the first loss position/credit enhancement represents an effort choice against *ex ante* moral hazard to restore incentive compatibility between issuers and investors.[81,82] However, it merely compensates for the difference in quality between securitised assets and higher rated securitised debt. Both levels of quality can vary and do not allow for an inference of actual quality upon observation of one or the other.[83] Therefore, the provision of credit enhancement primarily guards against adverse information constraints of credit risk from lending relationships *(credit component)* in loan securitisation. Consequently, for transactions with sufficient credit enhancement we would expect the risk sharing agreement between issuers and investors *(security design component)* to be the most important source of investment risk from valuation uncertainty in asset securitisation.[84]

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parameters entering calculation of the level of first loss position include: (i) average maturity of the reference portfolio, (ii) historical performance, (iii) debtor concentration, (iv) record of payment delinquencies, (v) default rate of portfolio, and (vi) dilution of asset claims/receivables. The amount of credit enhancement signifies the resilience of the reference portfolio to sustain an amount of scheduled losses (determined by the desired structured rating) without compromising the continued servicing of issued debt securities. See also Jobst (2003a).

[79] In the rating process the importance of credit enhancement differs by transaction structure. In case of synthetic transactions rating agencies particularly concentrate on the credit support implied in the amount of the first loss position, since any other asset risk has been isolated and transferred to counterparties by means of credit default swaps or other types of credit derivatives.

[80] Although credit enhancement is commonly derived from internal sources, it can take a wide range of external forms, which includes third-party guarantees, letters of credit from highly-rated banks, reserve funds, first and second loss provisions and cash collateral accounts, which have overtaken letters of credit as the method of choice for major public transactions (Zweig, 2002). If credit enhancement is achieved through subordination, issuers retain the most junior tranche as equity tranche (or "first loss position"; see also section 4.2)), whose amount predicts reasonably well the expected losses on the reference portfolio (Cumming, 1987). Its high illiquidity forces banks to retain it on their balance sheets. Besides the portfolio characteristics, such as the quality and the concentration of debtors, especially the administration (i.e. payment structure and contractual obligations of agents) and configuration (i.e. security design) of securitisation transactions influence the level of credit enhancement. For one, the treatment of accrued interest of defaulted loans can alter the amount of credit enhancement required by rating agencies, depending on whether accrued interest of the distressed reference portfolio is excluded or included, the likely level of interest rates at the time of the credit event and the time horizon of accrued interest. See also Pfister (2002), Gluck and Remeza (2000), Falcone and Gluck (1998), Howard and Merritt (1997) as well as Becker and Speaks (1996).

[81] See also Calvo (1998) for a detailed discussion of the "lemons problem" in the context of financial contagion.

[82] Depending on the perceived average loan quality in the portfolio, the residual cash flow rights of equity holders (i.e. the junior tranche as credit enhancement/FLP) act as limited liability for trust claimholders against costly bankruptcy (Frost, 1997). In absence of control rights the restricted role of equity upholds bankruptcy protection of senior claimholders, as it also serves as an early amortisation trigger for inexpensive prepayment of liquidation value of a deteriorating reference portfolio.

[83] However, as opposed to DeMarzo and Duffie (1997), who interpret the retention of the most junior claim in a transaction as a costly signal in the spirit of Leyland and Pyle (1977), credit enhancement does not constitute a signalling device, as it fails to increase transparency. Only in combination with remedial measures against ex ante moral hazard (such as optimal tranching) can issuers ward off the risk of possible adverse selection à la Akerlof (1970).

[84] The security design of securitisation, in turn, is determined by the envisaged economic effects of information asymmetries and valuation uncertainty of securitised assets. However, also the market implications of private information as well as trading costs affect the way the potential agency costs associated with illiquidity affect the feasibility of securitisation. For instance, the efficiency-improving effect of securitisation could be subject to

Adverse selection is the second effect of market imperfection due to asymmetric information between agents in the securitisation process. The valuation uncertainty of securitised assets (due to the complex security design and/or opaque nature of securitised assets) suggests superior information of issuers about the true valuation of securitised debt, which enables them to appropriate claimholder value from (uninformed) investors. Hence, rational investors would form negative beliefs about the actual quality of securitised assets and expect the adverse selection of securitised debt with poor reference portfolios similar to the *lemons market problem* à la Akerlof (1970).[85] The estimated value of private information about the actual value of the securitised assets imposes a *lemons premium* on the issuer. Since investors assume all (or most) transactions to be of poor quality, they request a reservation utility in the form of a lower selling price and/or higher return ("underpricing") as compensation for the anticipated investment risk of a disproportionately large share of poor transactions in the securitisation market.[86,87] Securitisation transactions cannot exhaustively guard investors against the agency cost from adverse selection arising from the private nature of many types of "securitisable" asset classes, such as bank loans. Although issuers seek to counteract adverse selection by bundling assets and then further tranching these bundles before they are sold in capital markets as debt securities, some residual degree of private information remains sanctioned by investors. In cognisance of the asymmetric information, issuers could suppress the pecuniary charge associated with the *lemons premium* only by soliciting increased transparency about the true value of securitised assets through signalling and screening mechanisms. Issuers usually commit additional

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the "capitalisation" of a particular financial system and the importance of market transparency of borrower fundamentals in external finance (e.g. relationship lending (Petersen and Rajan, 1994)). Hence, we would expect capital-market oriented financial systems to offer a higher capacity to absorb investment risks in a commensurate configuration of the security component of securitisation compared to bank-based systems.

[85] See also Calvo (1998) for a detailed discussion of the "lemons problem" in the context of financial contagion.

[86] Hence, they will be prepared to pay only some average market price below the fair market price of high-quality reference portfolios.

[87] Adverse selection from private information is also intimately linked with ex ante moral hazard. The agency cost of negative investor beliefs is frequently compounded by the attendant degree of unilateral information advantage by asset originators if they also act as issuers. Since private information associated with securitised assets also induce ex ante moral hazard in the asset selection process, rational investors being outsmarted by issuers, who are in a better position to judge the true credit quality of the reference portfolio. Note that we need to carefully distinguish between remedial structural measures as regards the kind of information problem at hand. Both adverse selection and moral hazard impose agency cost of asymmetric information. Whereas the former requires issuers to increase investor information about the actual quality of the transaction (in order to achieve market separation), the latter case typically calls for some disciplining mechanism that ensures incentive compatible behaviour of issuers. Hence, the rating process of transactions and disclosure requirements of asset information increase market transparency, whilst essential credit enhancement required by rating agencies to at least cover expected loss of the reference portfolio clearly serves as a commitment device by issuers to mitigate moral hazard. In the securitisation process the sources of agency cost are highly inter-related, e.g. ex ante moral hazard of biased asset selection – paired with some information advantage by issuers – could give rise to rational investor beliefs about adverse selection.

internal and external resources to a securitisation transaction, such as reserve funds, variable proceeds from excess spread as well as second loss positions and liquidity facilities, as a costly signal of asset quality. Securitisation transactions typically include further credit and liquidity support mechanisms beyond subordination and credit enhancement. We distinguish the following types of internal and external support mechanisms of securitisation transactions, which protect investors from a deterioration of the securitised reference portfolio (see also section 10 (Appendix)):

(i) *internal* credit support: reserve fund, yield spread (excess servicing), "turboing", and "commingling".

(ii) *external* credit support; third-party and parental guarantee, bond insurance, letters of credit (LOC), bank facility, cash collateral account (CCA), collateral invested amount (CIA).

The implicit risk sharing mechanism of these support mechanisms especially bears critical importance as to how issuers signal their ability to absorb default risk through the tranching and loss allocation of the transaction, without affecting the promised repayment to investors.[88] .

In arbitrage structures of securitisation transactions the principal-agent problem[89] between managers of securitised assets and investors constitutes a further source of uncertainty surrounding the proper administration of securitisation due to asymmetric information. So-called *front running* as a principal-agent problem occurs if the benefit from trading activities exceeds the gains to be generated from securitising assets based on these trading activities. For instance, traders in securitised market value portfolios might prefer to trade on their own account rather than allocating the traded assets to a securitised reference portfolio. However, if issuers choose to securitise less liquid assets to encourage incentive-compatible trading behaviour, an increase in transaction cost entails allocational inefficiencies and may result in a lower valuation.

Issuers of asset-backed securities have to carefully balance this array of potential investment risks (credit risk, structural risk and legal risk) against the economic benefits of securitisation by evaluating the significance of pros and cons vis-à-vis the strategic and operational demands they impose on

[88] This insight has important implications for the provision of credit enhancement, mainly because the essential level of first loss provision required by rating agencies as credit enhancement varies by the quality of the underlying reference portfolio. Note that credit enhancement is not a costly signal as it fails to separate good from bad issuers of debt securities with the same rating – assuming that relationship between the quality of securitised assets and the degree of credit enhancement is linear.

[89] For an explanation of the principal-agent problem in context of corporate finance see Weiss (1999). Jobst (2003a) provides a succinct overview of transactions structures in asset-backed securitisation.

securitisation. Certainly, an informed securitisation decision will need to consider the suitability of the type of assets to be securitised. In the following section we analyse possible ways more illiquid assets, such as SME-related claims, are securitised by financial institutions and corporations.

6 ASSET SECURITISATION OF SME-RELATED CLAIMS

While bank-sponsored structured finance has mostly been in the limelight of finance professionals, growing internationalisation of business relationships and capital market-based business models have also encouraged non-financial enterprises to consider asset securitisation as a more cost-efficient form of corporate finance. Corporate issuers mainly employ securitisation in order to both diversify funding sources at more competitive capital costs[90] and pro-actively manage balance sheet growth.[91] Large corporations in particular have begun to replace traditional on-balance sheet debt and equity finance by securitised debt as an alternative external source of corporate finance to convert illiquid payment claims from services and deliverables (trade receivables) into marketable, commoditised debt.[92] This proposition of corporate securitisation, however, does not apply to small- and medium sized companies (SMEs), which largely remain dependent on bank lending and private equity, mainly because low turnover, weak public disclosure of accounts and high monitoring effort inhibit direct access to capital markets.[93] At the same time, shrinking margins from interest-based deposit business and new, more risk-sensitive regulatory capital standards (Basle Committee, 2004) keep banks hard pressed to adopt a more stringent long-term lending policy, which leaves risky borrowers most affected. Against this background, SMEs find themselves squeezed in the middle between rising borrowing cost in traditional channels of bank finance and restricted capital market access.

Although corporate securitisation has become a favourite structured finance instruments for an expedient reorganisation of financial relationships, technical barriers to entry (e.g. critical amounts securitisable asset exposure and prohibitive start-up costs) have dissuaded smaller companies from directly accessing asset securitisation markets without the support of financial institutions. Aside

[90] Lower refinancing costs are mainly owed to the "upgrading effect" associated with the insulation of securitised asset exposures from legal recourse and economic influence by the originator. Since most tranches of securitised asset pools enjoy high investment-grade ratings, originators with lower credit ratings can refinance at a lower interest rate if the rating assessment of securitised exposures concurs with the higher rating classification. Especially unrated SMEs benefit from this effect.
[91] More recently the focus has also shifted to risk transfer as a motivation of synthetic securitisation structures.
[92] The efficiency-improving effect of securitisation, however, depends on whether the security design of securitisation can largely absorb adverse implications arising from both private information, i.e. adverse selection and moral hazard, and trading costs as potential sources of illiquidity.
[93] The "capitalisation" of the financial system at hand arguably signals the importance of market transparency in external finance.

from bank-sponsored loan securitisation through *collateralised loan obligations* (CLOs), *asset-backed commercial paper* (ABCP) programmes have evolved as an alternative form of asset securitisation, whose flexibility (in terms of security design and underlying asset type) and disclosure requirements about securitised assets remedy existing market challenges of refinancing SME-related exposures. ABCP programmes are typically administered by bankruptcy-remote SPVs to finance the acquisition of consumer and commercial receivable pools or securities of varying maturity with the proceeds of short-term commercial notes issued to capital market investors.[94] The most common types of exposures sold by asset originators to these conduits are trade receivables, consumer loans, mortgages, as well as lesser known asset classes, such as auto rentals and revenues from whole business and project finance. While some financial institutions use ABCPs for the sole purpose of refinancing their own lending activity on the back of existing or revolving asset pools, many banking organisations (called "arrangers") have successfully sponsored *multi-seller* ABCP securitisation programmes to fund corporate clients by securitising their asset exposures from trade receivables via SPVs. This refinancing mechanism allows banks to extend loans to corporate customers in return for their contribution of payment claims to a standing asset portfolio.[95,96] Corporate banking clients, especially SMEs, benefit from the cost efficient funding through ABCP conduits.[97] In *SME conduits* of multi-seller ABCPs small companies especially can seek indirect funding from capital markets in return for selling their payment claims from trade receivables to the SPV ("liquidity generation").[98,99] Multi-seller ABCPs in the dealer-placed commercial paper market offer intermediated access to securitisation markets for small-scale originators, whose collateralisation of commercial receivables works up the spectrum of refinancing alternatives. ABCP programmes frequently decrease overall refinancing costs (after consideration of transaction costs) lower than what would have been obtainable in conventional on-balance sheet external finance (such as bank debt) and standalone off-

[94] In many cases the participation in ABCP conduits allows asset originators to remove assets from their balance sheets and free up economic and regulatory capital.

[95] ABCP conduits exploit arbitrage opportunities by purchasing longer term securities from asset originators and funding these acquisitions with shorter term capital market debt securities (commercial notes).

[96] The sponsoring bank typically provides liquidity and credit enhancements to the ABCP programme, which aid the program in obtaining high quality credit ratings (Office of Thrift Supervision, 2003).

[97] The attractive risk-return trade-off associated with ABCP issues draws growing investor interest, spurred by a general shift from savings accounts to higher yielding money market investments, especially highly rated, short-term commercial paper.

[98] The flexible security design of asset-backed securitisation as regards the maturity and redemption criteria has critical consequences for the liquidity of issued debt securities. Many investors are inclined to hold long-term securities until they mature, which makes short-term commercial papers the most liquid deals in the securitisation market. The combination of "buy-and-hold" investment and the attendant lack of market liquidity of ABS transactions with long maturities impede corporate bond-style analysis, adding to the limitations imposed by the complexity of ABS structures in general.

[99] SME conduits traditionally accept only large SME receivables of at least €50 million (U.S.$60 million) into ABCP programmes. However, over the last three years some arrangers of ABCP have begun to specialise in small-sized deals, which involve more than 10 creditors and a minimum value of individual asset claims of at least €5 million (U.S.$6 million).

balance sheet funding (project finance ABS and whole business ABS).[100,101] Such a reduction in the financing cost mainly derives from the diversification effect of pooling individual asset claims into the securitised reference portfolio and the higher rating classification of ABCP programmes thanks to credit de-linkage and bankruptcy remoteness of issued debt securities from the originator. ABCP has become a popular source of external finance particularly, in those countries where more restrictive bank lending has dried up conventional channels of credit supply amid a deteriorating equity base. In summary, asset-backed securitisation (ABS) techniques that involve the issuance of structured claims on the performance of SME-related payment claims, such as trade receivables by SMEs, future operating revenues from SMEs and SME loans originated by financial institutions, are specified as follows:

(i) Channels of securitised asset refinancing by corporations ("corporate securitisation"):

   a. indirect[102]: Multi-seller *asset-backed commercial paper* (ABCP) programmes[103] are methods of securitisation sponsored by financial institutions to facilitate the funding of selected asset exposures on a short-term basis. If these assets are trade receivables of SMEs, the ABCP programme is referred to as a *SME conduit.*

   b. direct: Companies themselves engage in asset-backed securitisation (ABS) by securitising own payment claims, such as long-term revenues from entire operations, a particular line of business *(whole business ABS)* or defined project cash flows *(project ABS).*[104]

(ii) Channels of securitised asset refinancing by banks: banks securitise medium-term and long-term SME credit exposures in large scale asset-backed transactions, so-called *SME collateralised loan obligations* (CLOs).[105,106]

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100 Nonetheless, securitisation is only profitable if it increases the average value of the reference portfolio to a selling price beyond what would be deemed necessary to at least offset the management cost associated with a securitisation.

101 Moreover, ABCP programmes do not necessarily reveal what types of assets have been sold by which asset originator, leaving the underlying lending relationship unaffected by issues of confidentiality.

102 In this context, the distinction of indirect and direct securitisation refers to the involvement of an intermediary in the securitisation process. We have pointed out earlier that the professional use of "indirect securitisation" indicates the presence of an SPV as issuing agent (see section 4.3).

103 Note that ABCP programmes of consumer and corporate loans are the short-term equivalent to CLO and other ABS loan transactions. However, they warrant conceptual distinction for they allow corporate clients to pledge trade receivables against short-term funding in lieu of seeking funds from an outright asset securitisation.

104 In this case financial institutions merely act as underwriters. Note here many large corporations have established own securitisation platforms (e.g. General Electric, Siemens). Whole business and project loan ABS transactions of SMEs are hardly observed but in the U.K.

105 See also Bund (2000a and 2000b), Herrmann and Tierney (1999), Eck (1998), Kohler (1998), Stopp (1997), Ohl (1994).

106 Sometimes the transaction structure is arranged by a government-sponsored agency (such as Kreditanstalt für Wiederaufbau (KfW) in Germany, see section 7.2).

In the next section we use the example of Germany to sketch important lessons from the development of SME securitisation in a historically bank-dominated financial system with a strong SME sector.

7 THE GERMAN APPROACH TO SME SECURITISATION

7.1 Asset securitisation in Germany

In the German bank-centred financial system is renowned as a hallmark of a close-knit network of long-term lending relationships between commercial borrowers and their *Hausbanken* ("house banks"), with capital markets playing only a minor role in external finance. More than three million German *Mittelstand* (SME) companies represent the backbone of the German economy[107] and are traditionally financed by banks, which partly refinance their exposures by "on-lending"[108] through government-sponsored credit programmes[109] as secured credit finance. Notwithstanding the inherent benefits of long-term, trust-based lending, such a system of corporate finance has now become a pernicious inheritance of Germany's post-war organisation of financial relationships, which has discouraged risk taking, biased companies into excessive leverage and misallocated capital, "while producing a fragmented banking system overburdened with underpriced loans" (Pearlstein, 2004) and huge loan loss provisions.[110] This make-up of the financial system has made corporate lending vulnerable to mounting competitive pressure on already beleaguered banks.[111] Tighter risk controls

[107] According to the Institut for Mittelstandsforschung (IfM) in Bonn, more than 3.3 million SMEs represent 99.5% of all registered enterprises in Germany. German SMEs employ more than 70% of the total workforce and generate almost 60% of GDP (DSGV, 2004). See also Albach (1983) for a general description of the German Mittelstand and its pivotal economic role.

[108] "On-lending" of residential mortgages by government agencies could be compared to mortgage funding by Fannie Mae, Freddie Mac and Ginnie Mae or collateralised bank advances for mortgages by the Federal Home Loan Bank in the U.S. In the case of Germany government agencies, such as the Kreditanstalt für Wiederaufbau (KfW), would provide funding to SMEs via commercial banks as underwriters, who retain full liability for the repayment of principal and interest.

[109] The Kreditanstalt für Wiederaufbau (KfW), jointly owned by the Federal Republic of Germany and the German states, is one of the development agencies, commissioned by the German government to ease the financing costs for SMEs and private homeowners as well as to promote export and project finance in Germany and developing countries abroad. See also Deutsche Bundesbank (1997) for an early assessment of the asset securitisation market in Germany. For a historical account of the role of large banks in the German financial system see Riesser (1910).

[110] According to the association of German savings banks (DSGV, 2004) the own-funds rate (capital ratio) of German SMEs was merely 7% in 2000 and averaged 5.5% between 1993 and 1999. In contrast, large corporations (with an annual turnover of more than €50 million (U.S.$ 60 million)) boast an equity rate of 23%. 37% of all German enterprise have no equity or are overleveraged (i.e. negative capital ratio). See also Edwards and Fischer (1994).

[111] The abolishment of state guarantees to the savings bank system, which originates most of SME loans in Germany, and the slow-paced implementation of sophisticated credit risk management technologies with this

of revised bank capital standards and higher investor demands on equity returns poised German banks to recast riskier and less standardised financing of SME-related obligations and residential mortgages). In corporate lending, this development especially pitted those companies against a shortage of funds, which had previously amassed quite substantial leverage during times of lower-than-average interest burden from bank-based debt finance.

More recently, however, German banks, once considered trapped in the fixation towards credit-based financial intermediation, seem to have awakened to the new reality of a more risk-return oriented approach. After the U.K. mortgage lending companies were the first financial institutions to debut modern securitisation in Europe, German commercial banks emulated high street U.K. banks, who began to see the benefits of loan securitisation in earnest around 1997. Large banks, such as Deutsche Bank and Dresdner Bank fully embraced asset-backed securitisation through CLOs and ABCPs as one possibility to marry the benefits of credit business with fixed income management in moving to lower the economic cost of capital, improve risk management and remedy funding shortfalls (Rajan, 1996).[112] Surprisingly, such bank-sponsored securitisation of payment claims also included SME-related obligations early on.[113] This development is remarkable to the extent that it reflects the potential of a bank-based financial system to seize on an inherently capital market-based structured finance technique to refinance highly illiquid asset exposures.

In 1998 the first German SME portfolio was securitised by Deutsche Bank in CORE 1998-1, which was followed by successive transactions on the CORE and CAST securitisation platforms.[114] After Deutsche Bank had launched this first large-scale loan securitisation transaction in Germany to unload excess risk capital and proactively manage its balance sheet by means of a true sale structure,[115] other large commercial banks quickly followed suit and enlisted securitisation as a

segment of the banking sector. Note that 75% of all German SMEs bank with at least one of the 17,700 (2002) regional branches of the German savings bank system. Savings banks and state banks (which act as clearing houses of the savings bank system) have originated 42.3% of all corporate loans in Germany (DSGV, 2004).

112 Although many large banks have begun shifting main business interests to investment banking and asset management, they did so without necessarily abandoning less profitable lending and deposit business.

113 While corporate loans, mortgages as well as different types of consumer loans (student loans, credit card debt) have been securitised for more than 20 years in U.S., it was only until the mid-1990s that European fixed income markets have seen significant issue volumes of asset-backed securitisation (ABS). SME loans have proven to be a highly attractive asset class, partly because their inherent valuation uncertainty and illiquidity put a premium on sophisticated security design and risk management capabilities. Overall, given the sizeable contribution of SMEs to the economic factor output in many of the largest economies across the globe, the market for securitised SME loans and trade receivables by SMEs has already grown to more than €1.3 billion (U.S.$1.6 billion) of outstanding obligations world-wide in 2002.

114 These securitisation platforms differ insofar as CORE transactions feature a conventional true sale structure, while CAST transactions rely on partially funded synthetic structures.

115 The CORE 1998-1 transaction securitised the cash flow proceeds from DM-denominated loans to over 5,000 German SMEs (and a small selection U.S.$-denominated bonds) at a total notional value of DM4.26

refinancing technology to unload highly illiquid SME credit exposures. Subsequently, one prominent government-sponsored credit programme administered by the *Kreditanstalt für Wiederaufbau* (KfW) for the promotion of SME loans and residential mortgages[116] was extended to include an asset-backed securitisation scheme as a more cost-efficient source of funds for bank creditors wishing to refinance the origination of such asset exposures. In this way KfW envisaged to discharge its public service obligation of alleviating competitive pressures of commercial banks to adopt more stringent lending conditions for SME and private mortgage loans. As a result of this political effort and the emphasis on shareholder value and equity return, German commercial banks have quite successfully pursued the securitisation of SME loans over the last six years – either as standalone transactions or sponsored by securitisation platforms of quasi-government agencies. KfW's PROMISE (Promotional Mittelstand Loan Securitisation) synthetic CLO programme, for example, has issued 12 transactions so far at total market value of more than €17.4 billion (U.S.$20.9 billion) in collaboration with large private banks such as HVB (HypoVereinsbank) Group, Commerzbank and Dresdner Bank since its inception at the end of 2000.[117,118] Although many German SMEs have become aware of the benefits associated with direct ABS transactions in view of more stringent bank lending conditions, they have not made the securitisation of trade receivables an integral part of their refinancing decisions.[119]

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billion (€2.17 billion, U.S.$2.6 billion). This ground-breaking deal did not only win critical acclaim for kick-starting the European CLO/CBO market, which has developed into the fastest growing sector of European asset-backed securities. It was also the first securitisation of German SME loans and the most highly diverse CLO portfolio to come to global capital markets. At that time, Deutsche Bank AG estimated its overall share in total lending to German SMEs to amount to 5.3% of a total market volume of €58 billion (U.S.$70 billion) in the first half of 1999 (Deutsche Bank, 1999). Securitised loans were included in the CORE 1998-1 transaction on the basis of the following selection criteria (Deutsche Bank, 1998): (i) loans must have been originated by Deutsche Bank AG; (ii) all obligors must have their primary office/residence registered in Germany and all loans must be denominated in Euro or a national currency, which is part of EMU; (iii) no credit obligation must exceed 1.9% of the nominal original balance of the reference portfolio; (iv) all loans must be serviced in according to contractual conditions, without any repayments being delinquent or credit recovery subject to court action; (v) the date of final loan repayment coincides with scheduled termination of issued debt obligations on the reference portfolio; and (vi) no debtor has been rated lower than "C" (approx. a "Caa1" Moody's rating) according to the credit risk classification (internal rating system) of Deutsche Bank.

116 The complete range of statutory tasks of KfW include the promotion of SMEs, home finance or housing modernisation, the protection of the environment and the climate, export and project finance and the promotion of the developing and transition countries.

117 Besides the PROMISE programme, the KfW has also established a separate securitisation scheme for residential mortgages at the end of 2001, called PROVIDE.

118 Although both agency-sponsored SME and RMBS securitisation platforms have already established an impressive four-year track record, the "German share" in European securitisation of 3.4% of €207 billion (U.S.$248 billion) in 2003 (Source: Thomson Financial) is still found wanting; yet, the German on-balance sheet equivalent to off-balance sheet ABS structures, the Pfandbrief, claimed a respectable 81.5% of €219 billion (U.S.$263 billion) outstanding volume in 2003 (Source: Dealogic Bondware).

119 The exact definition of SMEs as a mostly privately owned, niche market operators varies by country. For instance, according to the Institut for Mittelstandsforschung (IfM) in Germany SMEs are classified by annual turnover (≤€1 million [small size enterprise] and ≤€50 million [medium size enterprise]) or by the number of employees (≤9 employees [small size enterprise] and ≤499 [medium size enterprise]). A revised classification by the European Union in May 2003 (which will take effect from 1 January 2005) raises the threshold values of annual turnover and introduces balance sheet volume as a third measure: (i) annual turnover (≤€2 million

Hence, amidst sporadic corporate securitisation (such as *Tenovis Finance Ltd.* (2001) and *Volkswagen Car Lease No.1-3* (1999-2002) to name two well-known examples), *bank-sponsored* securitisation – be it through SME CLOs (with and without the involvement of KfW as arranger) or SME conduits – constitutes the main driver of incipient SME securitisation in Germany.

7.2 The KfW PROMISE platform and the *True Sale Initiative* (TSI)

7.2.1 The KfW PROMISE platform

In anticipation of potential structural changes and associated adverse effects on lending conditions due to tighter risk controls in the German banking sector, the PROMISE platform is meant to assist German financial institutions to achieve regulatory capital relief (see section 3) for securitised SME lending.[120] The idea behind this concept is that lower levels of equity (i.e. minimum capital requirements) required by banks to support existing SME loan exposures create more scope for future loan origination to SMEs. Aside from capital reduction on on-balance sheet loan exposures, further reasons for the prominence of KfW's securitisation programme include the limitation of the economist cost of capital and the generation of additional liquidity from an alternative source of external finance. The organisational requirements of securitisation also create economic incentives of consistent internal risk management and internal rating systems. Additionally, the KfW programme adds both economies of scale from a standardised securitisation structure and lower heterogeneity of asset pools, which help originators keep securitisation costs low, while contributing to a further maturation of the SME securitisation market.

The standardised securitisation structure of PROMISE CLOs is based on a partially funded, synthetic transaction, where the originating bank enters into a credit default swap (CDS) with KfW as protection provider, taking over the entire default risk of a selected pool of SME loan exposures (i.e. the notional value of the reference portfolio of assets) (see Fig. 8). The transferred credit risk is subsequently structured in a subordinated set of tranches with different seniority, so that the largest share of the risk exposure (80-90%) carries hardly any default risk. This co-called "super-senior"

[micro size enterprise], ≤€10 million [small size enterprise] and ≤€50 million [medium size enterprise]), (ii) balance sheet volume (≤€2 million [micro size enterprise], ≤€10m [small size enterprise] and ≤€43 million [medium size enterprise]), and (iii) number of employees (<10 employees [micro size enterprise], <50 employees [small size enterprise] and <250 employees [medium size enterprise]). Note that in smaller economies these criteria might be lower. Besides the quantitative criteria, the following qualitative criteria typically apply to SMEs: (i) strong interdependence between ownership and management, which manifests itself in the direct influence of executive management on all strategically important processes, (ii) personal accountability of management for all significant business decisions and (iii) trust-based relationship between employees and management.

tranche is passed onto another bank (preferably an OECD bank for a low risk-weighting of the risk transfer) via a senior CDS. The first loss position (FLP), the most junior tranche, which carries almost all of the expected default loss (based on historic default rates), is retained by the originating bank or covered by a junior CDS. KfW sells the remaining mezzanine tranches as subordinated bonds (credit-linked notes (CLNs)) to capital markets via an SPV, which operates under the PROMISE platform and assumes credit-linked certificates of indebtedness to link the issued CLNs to the reference portfolio. The SPV might seek collateralisation by a third party up to the notional amount of the issued CLNs.

In are more advanced security design, KfW accommodates several loan portfolios of different banks in a slightly modified structure. In 2002 KfW made inroads with the diversification demands raised by the stratified German mortgage loan market by arranging a *multi-seller securitisation* transaction (see section 6) with the cooperative mortgage bank DG Hyp *(Deutsche Genossenschafts-Hypothekenbank AG)* as originator. The credit risk of several portfolios of credit cooperatives were pooled with DG Hyp and placed in the capital market via the KfW's PROMISE platform (PROMISE 2002-C). This arrangement would also allow smaller financial institutions to resort to securitisation conduits as an alternative refinancing mechanism. In this way, KfW extends the reach of securitisation in the effort to maintain the viability of SME lending under the KfW's promotional credit programme.

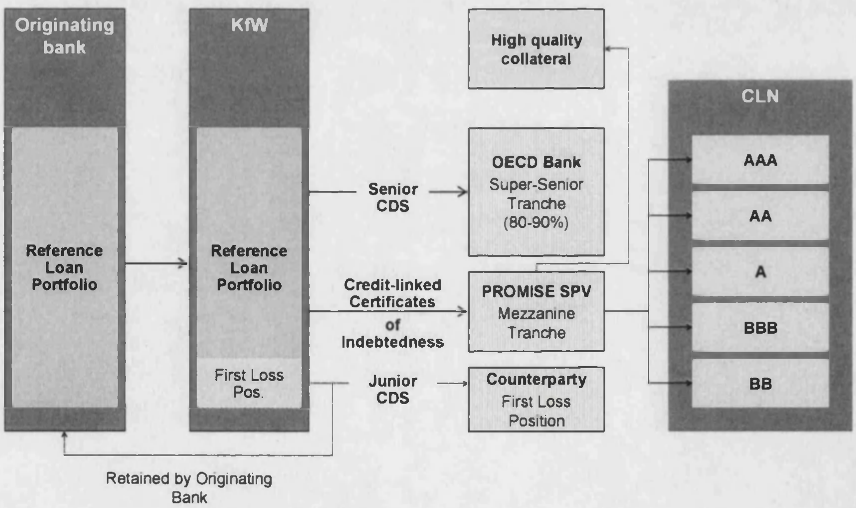

Fig. 8. *The KfW PROMISE securitisation platform structure.*

[120] Note that only loans originated under the KfW credit promotion programme for SME loans.

7.2.2 The True Sale Initiative (TSI)

True sale securitisation has remained scarce in Germany due to regulatory and taxation constraints as well as unresolved legal issues regarding redemption criteria and insolvency proceedings in cross-border disputes. It took until 1997 (BaFin, 1997a and 1997b; Bartelt, 1999) for the national regulatory body for banking supervision, the German Federal Financial Supervisory Authority *(Bundesaufsichtsamt für Kreditwesen (BaFin))*, to first permit the use of ABS,[121,122] at a time when the U.S. and most all (Western) European countries had already put in place a legal framework for true sale securitisation. Moreover, in 2003 the German trade tax *(Gewerbesteuer)* law, a major obstacle to true sale securitisations in the past, was amended by the Act to the Support of Small Businesses *(Gesetz zur Förderung von Kleinunternehmen und zur Verbesserung der Unternehmensfinanzierung)*, which exempts SPVs purchasing certain receivables originated by banks in (true sale) securitisation transactions from trade tax.[123] Further efforts are underway to actively promote true sale transaction structures in the bid to (i) improve the external financing of SMEs by creating an alternative source of funds, and (ii) facilitate the risk management of asset originators by way of securitising SME loans.

In keeping with its public service task of safeguarding adequate private and SME sector financing the KfW has recently sponsored the so-called "True Sale Initiative" (TSI) as a concerted effort of German banks to facilitate traditional off-balance sheet (true sale) asset securitisation in Germany, targeting a capital-market segment whose national development has been retarded by unfavourable legal, tax and accounting provisions. After consultation with market participants, supervisory authorities and rating agencies the TSI puts forth a uniform securitisation platform, which promises to lower refinancing cost and capital charges for credit exposures securitised by participating banks.

According to a joint statement released on 12 December 2003 by representatives of the 13 participating banks – the most important commercial banks, cooperative banks and the savings bank group[124] – the proposed TSI foundation structure (see Fig. 9) establishes a multi-seller securitisation

[121] See also Eichholz (2000).

[122] After the Circular 4/97 by the German Federal Financial Supervisory Authority (BaFin, 1997a and 1997b), the October 2002 Guideline by the German Institute of Accountants (IDW) laid the groundwork for the legal and accounting treatment of asset securitisation in Germany, the continued trade tax liability ("withholding tax") of bankruptcy-remote special-purpose vehicles has practically rendered true sale securitisation meaningless.

[123] See also Bernard et al. (2003).

[124] On 9 July 2003, Bayerische Landesbank, Citigroup, Commerzbank, DekaBank, Deutsche Bank, Dresdner Bank, DZ Bank, Eurohypo, HSH Nordbank, HVB Group, KfW Group, Landesbank Hessen-Thüringen and WestLB AG signed a Letter of Intent to define the business model for a securitisation platform to facilitate traditional (true sale) transaction structures in Germany (KfW Group, 2003).

platform as a standing arrangement for the formation of SPVs as insolvency-remote ABS issuers in compliance with national competition law and regulatory requirements as well as international standards of true sale constructions. The economic case for TSI derives from the development of a cost-efficient, ready-made securitisation infrastructure, which allows participating banks to securitise reference loan portfolios through newly established SPVs within a foundation structure. The structural model of TSI is comprised of a limited liability service company ("TSI Service GmbH")[125] as servicing agent and three non-profit foundations (charitable trusts),[126] which jointly create separate SPVs as limited liability companies under German law ("GmbH") to refinance each loan portfolio bought from a participating bank. The SPV converts the payment received from a reference portfolio of securitised assets into tradable debt securities. Although any bank is permitted to use the securitisation platform without mandatory participation in TSI, all servicing privileges to securitised assets are to be surrendered to the TSI Service GmbH as servicing agent. The TSI Service GmbH is also charged with the tasks of (i) developing uniform minimum standards for (true sale) securitisation in terms of both reporting and administration and (ii) providing a forum of exchange for originating banks.[127]

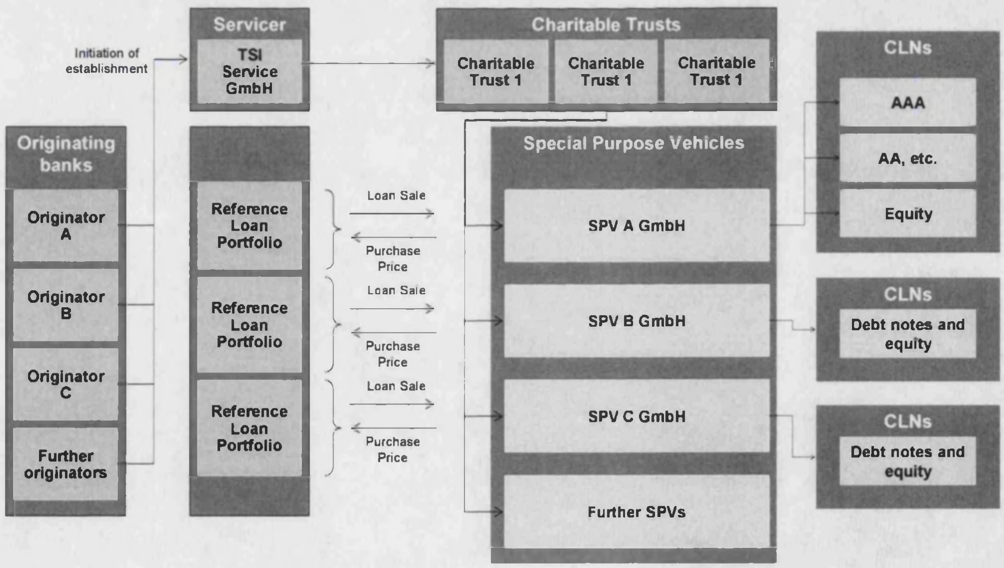

Fig. 9. *The TSI securitisation platform structure.*

[125] Since its first successful launch of an ABS transaction using a TSI-certified German SPV, Driver One GmbH, with ABN AMRO bank as arranger and lead manager of the transaction, the servicing entity of TSI has adopted the business name "True Sale International GmbH" (see also http://www.true-sale-international.de/index.php?id=118).

[126] The charitable trusts establish the foundation element of the TSI structure, whose principal statutory requirement is the promotion of research topics related to Germany as "financial centre".

[127] These functions are envisaged to promote (i) the standardisation and branding of the TSI securitisation platform structure as well as (ii) further development of true sale securitisation in Germany.

Overall, the structure of TSI conspicuously emulates the economic logic of large-scale (indirect) synthetic securitisation facilitated by the KfW-sponsored PROMISE and PROVIDE securitisation programmes (see section 7.2.1), which aim to dissuade German banks from restrained SME and private mortgage lending as they adjust their risk exposure in the face of rising competitive pressures on traditional funding. Given an apparent lack of gross-roots conviction by German corporations to make asset securitisation an important source of external finance any time soon, the multi-seller design of TSI provides brokered access to securitisation markets as an alternative form of refinancing to small and regional banks in a financial system whose dominance of bank-based external finance has so far thwarted any serious attempt at establishing large-scale corporate securitisation.

7.3 Lessons learned from SME securitisation in Germany

Although the case of quasi-government sponsored asset securitisation in Germany is limited in scale and scope, the successful introduction of synthetic securitisation platforms by KfW bears witness to the capacity of a heavily bank-dominated financial system to absorb a capital market-based refinancing tool. It also reveals the appreciable influence of efficient and transparent securitisation on the willingness of banks to securitise SME loan exposures to realise strategic and operational objectives. Although securitisation markets generally have been equivocal about a preferred transaction type (true sale vs. synthetic securitisation), in Germany, the volume of partially or unfunded, synthetic ABS transaction structures has outstripped fully-funded traditional (true sale) ABS structures at a ratio of roughly 25 to 1 in 2002, while only €1.31 billion (U.S.$1.57 billion) of the €32.8 billion (U.S.$39.3 billion) total involved true sale transactions (Althaus et al., 2003). The synthetic nature of the German ABS term market due to the predominance of large scale KfW-arranged transactions (PROMISE and PROVIDE) and several ABS/ABCP securitisation schemes developed by large German commercial banks (e.g. CORE, CAST, GLOBE and HAUS by Deutsche Bank, GELDILUX by HVB Group and SILVERTOWER by Dresdner Bank to name a few) indicates that mainly systemic obstacles (e.g. the trade taxation of SPVs of true sale transactions in Germany) have fuelled the growth of synthetic securitisation, which caters to the optimisation of regulatory capital and risk management rather than efficient refinancing (which typically applies to true sale structures).[128] At the same time, standardised securitisation structures have contributed to informed investment and lower issuing cost. Hence, the case of asset securitisation in Germany is instructive as to how institutional constraints shape the nature of securitisation, whose structural

[128] See also Meissmer (2001).

versatility offers economic benefits irrespective of the configuration of the financial system. It also suggests that a bank-based financial system like that in Germany would be more likely to encourage the development of mature securitisation markets to be determined by financial sector initiatives, whose reach and intensity might be enhanced by top-down initiatives of quasi-government agencies like KfW.

8 CONCLUSION

In the previous sections we attempted to equally privilege the benefits and drawbacks associated with asset securitisation by financial institutions and corporations. We also explained the various forms of ABS structures as they pertain to the securitisation of SME-related claims. Finally, we reviewed the evolution of the German securitisation market as a foray of SME securitisation in a financial system, where bank-based external finance coincides with a strong presence of SMEs in industrial production. Overall, SME securitisation as an alternative source of liquid funds seems promising amid increased political attempts to foster what could be regarded a level playing field in the regulation, taxation and legal treatment of asset securitisation across countries. The elimination of significant national disparities in these areas, especially as regards true sale transactions, would certainly be highly desirable to expand the spectrum of "securitisable assets" to include more illiquid and heterogeneous asset classes, such as SME-related payment claims. So far SME securitisation remains largely limited to indirect securitisation transactions, where banks mainly issue securitised debt on the back of SME-related claims to fund future lending activities. At the same time, smaller corporations in capital-market based financial systems (e.g. the U.K. and the U.S.) would enlist the help of banks as arrangers of securitisation transactions due to costly direct capital market access.[129] However, as banking competition dries up traditional channels of funding riskier SME borrowers, the search for alternative sources of capital might encourage SMEs to consider asset securitisation to meet funding needs by pledging asset receivables to multi-seller ABCPs. Also lower agency cost of asymmetric information vis-à-vis external investors in securitisation transactions (which are valued on the specific performance of a designated asset portfolio) might give securitised debt an edge over other forms of external finance. Banks would be more inclined to make use of uniform securitisation platforms (such as KfW's PROMISE deal structure) to lower the refinancing cost of SME loans they are inevitably bound to originate due to traditionally higher risk-adjusted margins from SME loans and/or high macroeconomic importance of SMEs as commercial borrowers (like in Germany).

[129] In our analysis will deliberately ignored operational and fundamental constraints to the securitisation of SME-related claims, such as reporting standards of SMEs, the idiosyncratic nature of SME loan contracts and

Although substantial legal uncertainty and incompatible financing strategies may render securitisation less pressing for SMEs than for the banking industry, it is safe to say that it might not be too long until asset securitisation will join ranks with traditional (intermediated) debt finance.

credit scoring of SMEs and/or the cash flow analysis of trade receivables held by SMEs, which certainly render SME securitisation more costly than bank-sponsored ABCPs or corporate securitisation for that matter.

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10 APPENDIX: ALTERNATIVE FORMS OF STRUCTURAL SUPPORT IN ASSET SECURITISATION

The use of a *reserve fund* is a popular alternative to a bank facility in senior/subordinated structures in order to finance timely payments on outstanding debt of the securitisation transaction. A reserve fund, is separately created by the issuer to reimburse the issuer for losses up to the amount of the reserve amount. It is often used in combination with other types of enhancement. This form of credit support draws its prime benefit from the permanent coverage of asset losses, as it is required to be sufficiently liquid (held on the issuer's bank account) to ensure its availability whenever necessary. Moreover, issuers forgo the cost of maintaining a bank facility and incurring interest on any drafts made. Nonetheless, notwithstanding these inherent benefits, the cost associated with its funding, such as bond proceeds or a loan whose accrued interest must be repaid with surplus funds held by the issuer, have to taken into account in benchmarking the reserve fund mechanism with a bank facility. Since the issuer cannot release the surplus unless the reserve fund is sustained at its contractually required size, the risk of a rating downgrade of an issue is mitigated.

Excess spread[130] represents the net amount of interest payments generated from the underlying assets after repayment of issued debt securities, which can also be employed as credit coverage and liquidity support.[131] Excess spread is used to cover current-period losses and may be paid into a reserve fund to boost credit enhancement (Giddy, 2002). In the case of so-called *turboing*, excess servicing is applied to outstanding tranches as principal. Any excess spread must cover financial shortfall arising from the combination of credit loss, in the worst-case scenario of both prepayments and termination rates on asset claims, and maximum payments to debtholders. Additionally, taxation of any excess spread further reduces the amount available to the issuer. Nonetheless, in some cases a portion of the excess spread might be *trapped*, i.e. it is stricter from being released by the issuer, as it stands to be available for future needs.

In cases where collections of interest and principal on assets are pooled in a general account by the servicer and commingled with its other funds (especially in cases of mortgage-backed securities)[132] before these payments are passed on to the issuer, insolvency risk (see section 5.3) might inhibit

[130] The Basle Committee (2002a) defines excess spread as "gross finance charge collections and other fee income received by the trust or special purpose entity (SPE) minus certificate interest, servicing fees, charge-offs, and other senior trust or SPE expenses. Finance charges may include market interchange fees."

[131] A specialised form of excess spread is the so-called yield spread, which comprises the difference between the coupon on the underlying assets and the security coupon. As a first defence against losses, excess servicing complements the yield spread, which may be applied to outstanding classes as principal (Giddy, 2002).

[132] See also Fabozzi (2000 and 1998) as well as Fabozzi and Yuen (1998).

appropriate credit coverage. Based on the legal opinion from the issuer's counsel as to whether the loss of funds would be temporary (liquidity stress) or permanent (credit loss), the availability of sufficient funds to cover credit losses has to be guaranteed. In the move to evade negative implications of commingling as regards credit coverage, any payments received from assets should be redirected to the issuer, such as the SPV. Hence, the amount of funds likely to be drawn into any bankruptcy or insolvency resolution process could be minimised.

In addition to internal credit and liquidity supports, external credit enhancement from a third party also represents an alternative means of shielding investors from expected credit loss. Under a *third-party* or *parental guarantee*, an external party (such as an insurance company or the parent company of the servicer/issuer of the transaction) enters into a contractual commitment to reimburse the issuer for losses up to a predetermined notional amount. Such a guarantee agreement could also be extended to include the obligations of advancing principal and interest to investors in a trustee-like fashion and/or buy back defaulted loans.[133] *Bond insurance* (through surety bonds) can serve as a vehicle of specialised third-party credit/liquidity support. It is provided by a rated *monoline insurance companies* (generated triple-A rated), which guarantees full payment of principal and interest to noteholders of the transaction, as it reimburses the issuer of the transaction for any losses incurred. Even though issuers are able to achieve an "AAA" rating for "insured" tranches, bond insurance is a credit enhancement much less prevalent as a means of credit support in securitisation transactions than subordination due to higher cost. The higher expense associated with this form of credit coverage stems not only from the cost of insurance but also from the requirement of the underlying reference portfolio to be drawn on a loan pool of a sufficient *investment-grade rating* level. In most cases the insurer provides guarantees only to investment-grade securities. Hence, the insurance-based credit/liquidity support disciplines issuers to carefully balance both the level of credit enhancement needed for a desired structured rating of a designated reference portfolio and their financial capacity to provide such additional enhancement if they so desire. *Letters of credit (LOCs)* are the surety bond-equivalent in regards to non-insurance financial institutions are guarantors, where typically banks promise to cover any amount of losses up to the level of credit enhancement needed for a given portfolio quality of the underlying reference pool of assets. Third-party guarantees, bond insurance and letters of credit expose the security level rating of securitisation transactions to the claims paying ability of the institutions providing enhancement as we need to think of these provisions as pledges of cash in keeping with some guarantor obligations, devoid of actual cash transfer or other payments. Hence, the character of such external credit enhancements does not betray any hint of downgrade risk independent of the actual time-varying loan performance of the underlying reference portfolio.

A *bank facility* represents another possibility of external liquidity support for a securitisation transaction, as the issuer can draw and redraw on the facility as and when needed, with repayment of drawn amounts being made when sufficient funds are held by the issuer of the transaction. The continuity of a *standing bank facility* is only guaranteed if the rights of the facility provider to termination are limited to cases of issuer's bankruptcy, whereby the lender is prohibited from petitioning the issuer into bankruptcy given that any utilisation of the facility does not constitute an act of insolvency. However, under the provisions of a bank facility, the issuer ought to be entitled to terminate the facility agreement if the lender's rating is downgraded or, if specially agreed, has been downgraded such that future drawing rights can no longer be guaranteed. This impediment to third-party risk is obviated by a *cash collateral account* (CCA). Here, the issuer borrows the required amount of first loss provision (credit enhancement) from a commercial bank only to purchase a corresponding amount of highest-rated short-term commercial paper. Unlike in the case of third-party guarantees, CCA represents an actual deposit of cash rather than a pledge of cash only, and, thus, the downgrade risk of the securitisation transaction remains unaffected by a rating change of CCA providers. The *collateral investment amount* (CIA) is the final forms of credit support. The CIA, akin to a subordinated tranche of a transaction, is either purchased on a negotiated basis by a single third-party credit enhancer or securitised as a private placement and sold to several investors.

[133] See also The Bond Market Association (1998).

CHAPTER II: "THE REGULATORY TREATMENT OF ASSET SECURITISATION"

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1 ABSTRACT

This chapter provides a comprehensive overview of the gradual evolution of the supervisory policy adopted by the Basle Committee for the regulatory treatment of asset securitisation. We carefully highlight the pathology of the new "securitisation framework" to facilitate a general understanding of what constitutes the current state of computing adequate capital requirements for securitised credit exposures. Although we incorporate a simplified sensitivity analysis of the varying levels of capital charges depending on the security design of asset securitisation transactions, we do not engage in a profound analysis of the benefits and drawbacks implicated in the new securitisation framework.

JEL Classification: E58, G21, G24, K23, L51

Keywords: banking regulation, banking supervision, asset securitisation, Basle Committee, Basle 2

2 INTRODUCTION

2.1 Loan securitisation and regulatory arbitrage

The broadbrush determination of capital requirements for credit risk exposures in the one-size-fits-all regulatory straightjacket of the 1988 *Basle Capital Accord* has rendered the cost-effective origination of loans (especially investment-grade credits) increasingly difficult and prompted banks to consider large-scale loan securitisation as one way to lower their regulatory cost of capital. Securitisation generally refers to the process of refinancing a diversified pool of illiquid present or future financial and/or non-financial receivables through the issue of structured claims into negotiable capital market paper issued to capital market investors *(liquidity transformation* and *asset diversification process).*[1] The fairly indiscriminate risk-weighting and a flat regulatory capital charge for on-balance sheet credit risk exposures under the existing regulatory framework of the 1988 *Basle Capital Accord* and later amendments made it less efficient for banks to retain highly rated loans (with low yields relative to

[1] See Moody's Investor Services (2003) for a brief introduction to asset-backed securitisation (ABS).

required regulatory capital) vis-à-vis risky loans with high net interest income. The main channel through which banks arbitraged these inflexible regulatory provisions was by offering securitised debt on their better quality assets, whilst retaining their riskier assets on their own books. Consequently, the market for securitised assets grew dramatically from the early 1990s onwards and attracted a large following with all major investment banks (Jobst, 2003).

2.2 The consultative process of the Basle Committee

Following protracted efforts over recent years to enhance financial market stability, the Basle Committee on Banking Supervision[2] on 11 May 2004 finally reached agreement on new international rules for the capital adequacy of internationally active banks in *International Convergence of Capital Measurement and Capital Standards: a Revised Framework* (June 2004), termed "Basle 2". It provides binding guidance as to establishment of international convergence on revisions to supervisory regulations governing bank capital. The new regulatory provisions link minimum capital requirements closer with the actual riskiness of bank assets in order to redress shortcomings in the old system of the overly simplistic 1988 Basle Accord. The new regulations represent the final outcome of a series of consultations, each of which followed the three proposals for revising the capital adequacy framework in June 1999, January 2001 and April 2003, with associated quantitative impact studies.[3]

Given the rapid growth of securitisation markets around the world, the Basle Committee acknowledged the importance of asset securitisation as an emergent structured finance funding tool for financial intermediaries and adopted a comprehensive regulatory policy for asset securitisation, which was deemed critical to a viable implementation of a revised Basle Accord.[4] As an integral part of the new proposal of the Basle Accord (Basle Committee, 2004b), the Basle Committee was poised to establish the so-called *Securitisation Framework* based on earlier provisions in the *(Third) Consultative Paper to the New Basle Accord* (April 2003) and subsequent *Changes to the Securitisation Framework* (January 2004) in response to new developments in bank-based structured finance and growing sophistication in synthetic forms of asset securitisation. Prior to the *Securitisation Framework*, which will finally come into force in 2006, the Basle Committee had made several proposals and revisions for a consistent

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[2] The *Basle Committee on Banking Supervision* is a steering group of all G10 member countries of the *Bank for International Settlements* (BIS).

[3] For a general discourse on the rationale of banking regulation we refer readers to Benston and Kaufman (1996) as well as Besanko and Kanatas (1996).

[4] Failure to do so would have certainly missed the objective of financial stability set out by the Basle Committee.

regulatory treatment of securitised exposures based on feedback received from banks and supervisory agencies.

The *First Consultative Paper* (see Fig. 1), released by the *Securitisation Group of the Basle Committee* in June 1999, introduced a general securitisation proposal, which was later expanded upon in the *Second Consultative Paper* on securitisation in January 2001. At this stage, the drafting of common regulatory policy focused primarily on the *standardised* treatment of traditional securitisation transactions, where banks were required to assign risk-weights to securitisation exposures based on few observable characteristics, such as an issue rating. However, it also presented an initial distinction of sponsoring and investing banks, revolving asset securitisation, cash advancement and liquidity facilities as well as risk transfer requirements for traditional securitisation.

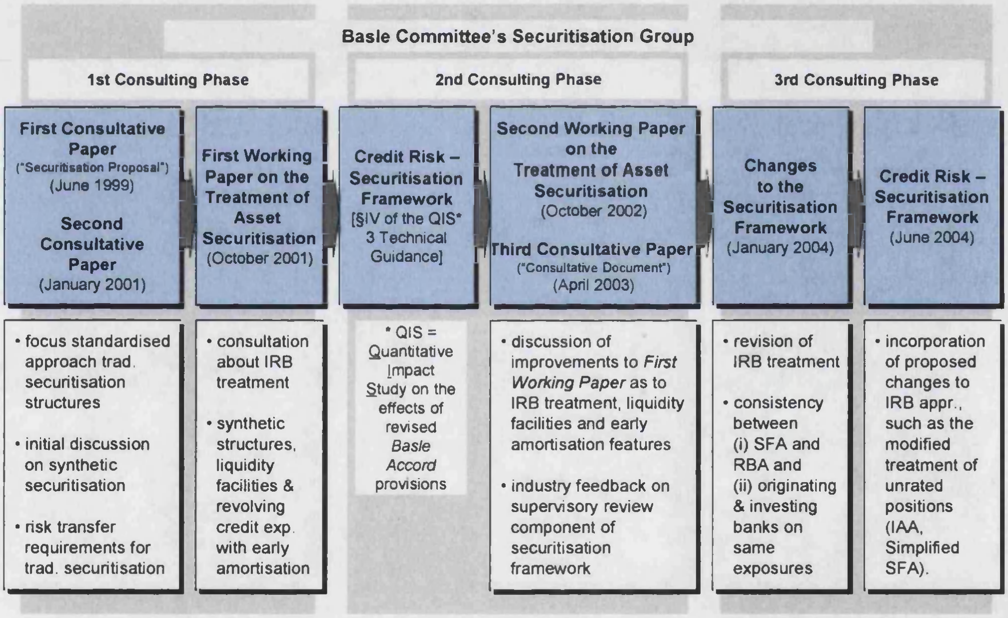

Fig. 1. *The evolution of securitisation framework by the Basle Committee.*

After consultation with the industry and further analyses, the Basle Committee issued the *First Working Paper on the Treatment of Asset Securitisation* in October 2001 (see Fig. 1), which comprised an in-depth *internal-ratings based* (IRB) treatment of securitisation exposures in addition to the *standardised*, "one size fits all" approach. It also sought to initiate further consultation on a concrete treatment of synthetic securitisation, liquidity facilities and early amortisation features, which culminated in the *Securitisation Framework* (Credit Risk – Securitisation Framework, §IV of the QIS 3 Technical Guidance) before yet another round of consultation talks then commenced to fine-tune the quantitative criteria of higher risk-sensitivity in the determination of minimum capital requirements for issuers and investors of securitisation transactions. The products of this latest regulatory effort were the *Second Working Paper on the Treatment of Asset Securitisation* of October 2002 and the *(Third) Consultative Paper to the New Basle Accord* of April 2003, which – among many new qualitative aspects of securitisation regulation, such as supervisory review (Pillar 2) and market discipline (Pillar 3) – also proposed a more *ratings-based approach* (RBA) for securitisation transactions in line with the distinction of the *standardised approach* and the *internal ratings-based* (IRB) approach to the computation of general minimum capital requirements.

As a decisive step on the way towards a securitisation framework, the Committee issued the *Second Working Paper on the Treatment of Asset Securitisation* on 28 October 2002, a result of a series of consultations to sound out the viability of new, more risk-sensitive elements of a securitisation framework it had already set forth in the *First Working Paper on the Treatment of Asset Securitisation*. The existing regulatory framework according to the 1988 *Basle Accord* then fell short of providing guidance on the comprehensive treatment of synthetic securitisation structures, liquidity facilities, asset-backed commercial paper (ABCP) programmes and securitisation transactions of revolving credit exposures containing early amortisation features. Besides improvements to the *standardised* and the *internal-ratings based* (IRB) treatment as well as the *supervisory formula approach* (SFA) in context of capital adequacy in securitisation, the *Second Working Paper on the Treatment of Asset Securitisation* was mainly put forward in the effort to request input from banking organisations on the need of future modifications to the existing proposal or adjustments to the regulatory treatment of asset securitisation. Notwithstanding its tentative nature as a way to solicit feedback from financial institutions concerning the supervisory review component ("Pillar 2", see Basle Committee, 2002a and 2002b),[5] the *Second Working Paper on the Treatment of Asset Securitisation* represented a purposeful attempt to address critical gaps in the securitisation framework.

Before the conclusion of the third consultative phase on the regulatory treatment of asset securitisation, the Basle Committee issued its *Changes to the Securitisation Framework* (January 2004) to establish greater consistency of capital charges for (i) securitised exposures and conventional credit risk of the same rating grade and (ii) similar exposures across different regulatory approaches in the bid to reduce the complexity of the *(Third) Consultative Paper to the New Basle Accord* (April 2003). Eventually, after incorporating most of the proposed modifications in *Changes to the Securitisation Framework*, the Basle Committee released the final version of the securitisation framework as part of the new *Basle Accord* of *International Convergence of Capital Measurement and Capital Standards*.

2.3 Objective and structure

The following sections provide a comprehensive overview of the gradual evolution of the *Securitisation Framework* for the treatment of asset securitisation, a culmination of a series of consultative processes completed by the Basle Committee in response to the continued use of loan securitisation for purposes of regulatory arbitrage. We carefully probe the founding components of this new regulatory framework so as to provide accessible understanding of what constitutes a consistent yet still contested regulatory approach to the computation of adequate capital requirements for securitised credit exposures. Although we incorporate a simplified sensitivity analysis of the varying levels of capital charges depending on the configuration of asset securitisation transactions, we do not engage in a profound analytical discourse about the benefits and drawbacks that the new securitisation framework entails.

In the following section, we first explain the contents of the *First Consultative Paper* and the *Second Consultative Paper* of 2001, before moving on to specify the *supervisory formula approach* (SFA) and the *ratings-based approach* (RBA) in their original tenors as stated in the *Second Working Paper on the Treatment of Securitisation* (Basle Committee, 2002a and 2002b), which had been the first account of a consistent regulatory policy for asset securitisation until the adoption of the *(Third) Consultative Paper to the New Basle Accord* (Basle Committee, 2003). Finally, a final exposition of substantial modifications to the regulatory treatment of securitisation under the IRB approach in the new *Basle Accord* of *International Convergence of Capital Measurement and Capital Standards* (Basle Committee, 2004b) outlines the *Changes to the Securitisation Framework* (Basle Committee, 2004a).

3 THE PATHOLOGY OF THE REGULATORY TREATMENT OF ASSET SECURITISATION – THE SECURITISATION FRAMEWORK

3.1 The new Basle Accord and the regulatory treatment of asset securitisation

The revised version of the Basle Accord rests fundamentally on three regulatory pillars. In principle, the first pillar (Pillar 1, "Minimum Capital Requirements") is set for a similar tenor as the 1988 Basle Accord, which requires banks to meet minimum capital requirements for exposures to credit risk, market risk and operational risk. Banks are permitted to use any one of the following approaches to

[5] See also Basle Committee (2003).

the computation of regulatory capital: the *standard approach*, the *foundation internal ratings-based* (IRB) approach or the *advanced internal ratings-based* (IRB) approach. Although most attention has been devoted to capital adequacy set out in Pillar 1, the two remaining pillars are believed to be of even greater importance (The Economist, 2004). The second pillar (Pillar 2, "Supervisory Review") grants discretion to national supervisory authorities to tweak regulatory capital levels, e.g. they may impose additional capital charges for risk exposures they deem insufficiently covered in Pillar 1. Pillar 2 also includes the requirement for banks to develop internal processes to assess their overall capital adequacy commensurate to their risk profile in compliance with supervisory standards, and to maintain appropriate capital levels. The third pillar (Pillar 3, "Market Discipline") compels banks to disclose more information to financial markets under the objective of strengthening their market discipline and transparent risk management practices (Basle Committee, 2003).

Similar to the on-balance sheet treatment of straightforward credit exposures, the revised Basle Accord also requires banks to hold a certain amount of capital against any securitisation exposure under the *Securitisation Framework for Credit Risk*. It applies to securitisation transactions (synthetic or traditional) involving one or more underlying credit exposures from which stratified positions (or tranches) are created that reflect different degrees of risk. Besides distinguishing between different transaction structures, the securitisation framework not only accounts for the characteristics of securitised assets in terms of both available rating and portfolio characteristics but also for the different roles played by banks in the securitisation process (e.g. originating bank, investing bank and servicing agent/sponsoring bank). Originating banks are of particular interest in this exposition of capital adequacy, mainly because they must satisfy a set of operational criteria depending on the type of transaction structure. Interestingly, these operational criteria for the capital treatment of traditional and synthetic structures are based on the economic substance of the credit risk transfer rather than its legal form. While initial proposals almost exclusively focused on traditional (true sale) securitisation transactions, subsequent amendments also included credit risk transfer exposures arising from synthetic transactions, investments in ABS securities and retentions of subordinated tranches, as well as liquidity facilities and credit enhancements. The securitisation framework distinguishes only between the so-called *standardised approach* and the *internal ratings-based approach* (IRB) in the way investing and originating banks compute the regulatory capital charge for securitised positions as so-called "risk-weighted assets" by multiplying the notional amount of securitised tranches by a specific risk-weight applied to the standard capital ratio of 8%.

3.2 The *Consultative Package*: the *First Consultative Paper*, the *Second Consultative Paper* and the *First Working Paper on the Treatment of Asset Securitisation*

After the first serious attempts at formulating a regulatory position on the regulatory governance of asset securitisation in the *First Consultative Paper* in June 1999 the Basle Committee issued the *Second Consultative Paper* for the capital requirements of asset securitisation transactions on 16 January 2001, which eventually led to the publication of the *First Working Paper on the Treatment of Asset Securitisation* in October 2001. This revised proposal for an adjustment of regulatory capital and supervision by financial regulators was published as a separate 32-page chapter of a new proposal for the Basle Accord on the *International Convergence of Capital Measurement and Capital Standards* as a comprehensive effort to codify a regulatory framework. Although the First Consultative Paper had already set out definitions of key aspects of securitisation and established minimum operational criteria related to traditional (true sale) structures of credit risk transfer (i.e. where the originator transfers assets usually to an SPV), it remained completely silent on synthetic transactions as a coming structural innovation in asset securitisation. It was not until the *First Working Paper on the Treatment of Asset Securitisation* was published that initial regulatory provisions were revised to include a separate section on synthetic securitisation and operational criteria for the status of banks in securitisation transactions.[6] The subsequent exposition outlines the most prominent aspects raised in the *First Working Paper on the Treatment of Asset Securitisation.*[7]

3.2.1 Definition of true sale transactions by originating banks

The outright transfer of assets off the balance sheet in standard (true sale) transactions represents the most fundamental case of regulatory relief sought by an originating bank. The originating bank is permitted to remove assets from the calculation of risk-based capital ratios only if a "clean break" (or "credit de-linkage") of transferred assets meets regulatory approval. According to the *First Working Paper on the Treatment of Asset Securitisation*, regulatory capital relief through true sale transactions applies only if the following operational criteria are satisfied: (i) in compliance with legal provisions governing asset sales, the transferred assets have been legally isolated from the transferor; that is, the assets are put beyond the reach of the transferor and its creditors, even in bankruptcy or receivership;

[6] Besides the critical issue of information disclosure requirements, the revised proposal also draws an important distinction between implicit/residual risks and explicit risks in securitisation. In this context implicit risk refers to residual risk that is thought of not being legally assumed by an originating or sponsoring bank; however, due to an obligatory commitment to safeguard investors' interests it might still be tacitly recognised to that extent that actions in defiance of an understanding might prejudicially affect the reputation of the originating or sponsoring bank participating in a securitisation transaction.
[7] See Basle Committee (2001), 87ff.

(ii) the transferee is a qualifying special-purpose vehicle (SPV) and the holders of the beneficial interests in that entity have the right to pledge or exchange those interests, and (iii) the transferor does not maintain effective or indirect control over the transferred assets.[8] Unless these conditions hold, the Basle Committee proposes to retain the respective assets on the books of the originating bank for regulatory accounting purposes (RAP), even if the assets have been removed from the books under GAAP standards. These operational criteria were refined later on in the Second Working Paper on the Treatment of Asset Securitisation and the new Securitisation Framework of the agreement on *International Convergence of Capital Measurement and Capital Standards* by the Basle Committee (see section 3.4).

3.2.2 Regulatory capital requirements of originating and investing banks

The regulatory provisions in the *Second Consultative Paper* and the *First Working Paper on the Treatment of Asset Securitisation* also specify minimum capital requirements of securitised exposures held by investing banks (and originating banks, if they retain a fraction of the original transaction volume or a standing commitment/residual claim). For loss of detailed information about the underlying exposures of securitised reference portfolios, investing banks are required to hold regulatory capital for positions of securitisation transactions. In a nod to previous regulatory advances the *Second Consultative Paper* proffers the adoption of ratings-based risk weightings ("ratings-based approach" (RBA)) for rated tranches (see Tab. 1 below) as a regulatory default risk equivalent to their external rating grade.

Rating range		Risk weighting
AAA	AA-	20%
A+	A-	50%
BBB+	BBB-	100%
BB+	BB-	150%
B+	D	capital deduction*
unrated		capital deduction*

** regarded as credit enhancement*

Tab. 1. *Risk-weights according to the revised "Consultative Package" (2001).*

In the case of low-risk, *unrated* tranches (e.g. in private placements) or guarantees, the Basle Committee introduced the so-called *look-through approach* for the calculation of the capital charge.

[8] These conditions are essentially the same as in IAS 39/FASB 140/FASB 125, and therefore, there is no new

Subject to supervisory review this approach requires that the unrated, most senior position of a transaction will receive the average risk-weight that would otherwise be assigned to all securitised credit exposures in underlying portfolio on aggregate, whilst all subsequent, less senior tranches (mezzanine classes but also second loss facilities and other similar structural enhancements) will be accorded a 100% risk-weighting. An originating bank (but also a sponsoring or even an investing bank) might provide a first or second loss position as credit support (credit enhancement).[9,10] For instance, the originating bank commonly retains the most junior, unrated tranche as a first loss piece. Any first loss position would be fully deducted from capital, whilst a second loss facility is considered to be a credit substitute with a 100% risk-weighting after it has been valued at an arm's length basis in line with normal credit approval and review processes. The restrictive use of the *look-through approach* for the most senior positions implies that investing banks (which hold the more senior "investor" positions) are effectively exposed to the aggregate default risk arising from securitised exposures. According paragraph 527 of the *First Consultative Paper* the following conditions would need to be satisfied for the *look through approach* to be applicable:

(i) rights on the underlying assets are held either directly by investors, by an independent trustee[11] on their behalf, or by a mandated representative;

(ii) in the case of a direct claim, the holder of the securities has an undivided *pro rata* ownership interest in the underlying assets, i.e. the underlying assets are subject to proportional rights of investors, whilst the SPV must not have any liabilities unrelated to the transaction;

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restriction or qualifying condition being put up by the regulators.

[9] Under the *First Working Paper on the Treatment of Asset Securitisation* the originating bank would need to deduct the notional amount of the first loss position directly from its capital stock. Thus, if a sponsoring bank, for instance, accepts a credit enhancement for first losses in the amount of €5m out for a €100m transaction, a full capital deduction (which implies a risk-weighting of 1250%) reflects the capital loss in case of default. However, any additional loss protection is viewed as a *direct credit substitute* with a 100% risk weighting, provided that a sufficient and significant level of first loss protection is being provided. Hence, a second loss provision of €10m on top of a first loss protection of €5m would incur a further capital charge of €0.8m.

[10] The Basle Committee (2002b) defines credit enhancement as a contractual arrangement [,] in which the bank retains or assumes a securitisation exposure and, in substance, provides some degree of added protection to other parties to the transaction. [...]." According the current regulatory framework, the *optimal structure* of securitisation transactions would avoid a first loss piece altogether, so there would be no specific credit enhancement for the most junior tranche. Consequently, the degree of the credit enhancement needed also proxies for the discrepancy of standardised minimum capital requirements and the issuer's own assessment of adequate risk provision for a certain quality of the reference portfolio to be securitised. However, if the provision of a so-called "first loss piece" cannot be avoided, the issuers follow the objective of setting credit enhancement levels *as low as possible*. Although credit enhancement is commonly derived from *internal* sources, i.e. they may be generated from the assets themselves, it can take a wide range of *external* forms, which includes third-party guarantees, letters of credit from highly-rated banks, reserve funds, first and second loss provisions and cash collateral accounts, which have overtaken letters of credit as the method of choice for major public transactions.

[11] e.g. by having priority perfected security interest in the underlying assets.

(iii) in the case of an indirect claim,

a. all liabilities of the trust or special purpose vehicle (or conduit) that issues the securities are related to the issued securities;
b. the underlying assets must be fully performing when securities are issued;
c. the securities are structured such that the cash flow from the underlying assets fully meets the cash flow requirements of the securities without undue reliance on any reinvestment income, i.e. the securitisation transaction perfectly matches the cash flow stream generated from the underlying portfolio; and
d. funds earmarked as pay-out to investors but not yet disbursed do not carry a material reinvestment risk.

Furthermore, the look-through approach requires a risk-weighting of unrated tranches equal to the highest risk-weight assigned to an asset of the reference portfolio. When the *First Consultative Paper* was published, however, the method proposed by the Basle Committee still lacked sufficient clarification of how the capital charge would be determined in this case. At the time, two basic approaches would have lent themselves as suitable means of resolution either: (i) some inferred external rating of an unrated securitisation tranches or (ii) the quantification of both the residual risk held by the originating bank following the securitisation of assets and the amount of credit risk that was actually transferred in the stratified positions of securitised exposures. Soon it became clear that the incentive of originating banks to engage in regulatory arbitrage by shifting high quality assets from their balance sheet would require regulatory action to prevent banks from assuming a higher risk profile at the same regulatory charge. Hence, the Basle Committee gave more credence to a model-based method of deriving risk-weights for unrated tranches.

3.2.3 Regulatory distinction between credit support and liquidity support in securitisation programmes and asset-backed commercial paper (ABCP) conduits

The notion of sponsoring or managing banks includes the administration of securitisation programmes or *asset-backed commercial paper* (ABCP) conduits, where credit exposures from different banks and/or small business creditors are pooled in a securitised reference portfolio. These conduits typically feature an integrated liquidity support mechanism by sponsoring banks (either programme-wide or pool-specific). Such a contractually fixed commitment to lend on the part of the sponsoring or managing bank attracts risk-weightings depending on its maturity. While a short-term agreement to lend is converted with a 0% risk-weighting, any long-term agreement is treated as a direct credit substitute, and, thus, attracts a 100% risk-weighting. Moreover, as one of several special provisions concerning such off-balance sheet exposures, the *First Working Paper on the Treatment of Asset*

Securitisation addresses mounting concern over the regulatory treatment of liquidity facilities to ABCP as credit enhancement without any clear-cut practical distinction of credit support and liquidity support being put in place. Consequently, the Basle Committee has established a set of essential criteria to conceptually distinguish liquidity support from credit support:

(i) a facility, fixed in time and duration, must provided to the SPV, not to investors, which is subject to usual banking procedures,

(ii) the SPV must have the option at its disposal to seek credit support from elsewhere,

(iii) the terms of the facility must be established on grounds of a clear identification in what circumstances it might be drawn, ruling out the utilisation of the facility either as a provider of credit support, source of permanent revolving funding or as cover for sustained asset losses,

(iv) the facility should include a contractual provision (on the basis of a reasonable asset quality test) either to prevent a drawing from being used to cover deteriorated or defaulted assets or reduce or terminate the facility for a specified decline in asset quality, and

(v) the payment of the fee for the facility should not be further subordinated or subject to a waiver or deferral, while the drawings under the facility should not be subordinated to the interests of the note holders.

If the above-mentioned criteria hold, liquidity support as a contingent commitment for future lending draws a 20% conversion factor. Otherwise, the liquidity facility will qualify as a credit enhancement, which would be treated no different than an investment in a securitisation transaction with a risk-weighting based on either internal or external ratings. So a back-of-the-envelope calculation of a liquidity facility for a partly-supported ABCP conduit of €100m (of which €50m have already been drawn) would require a capital charge of €50m+(€100m-€50m)*20%=€60m.

Moreover, the *First Working Paper on the Treatment of Asset Securitisation* considers the reimbursement of cash advances by the servicing bank in the context of liquidity or credit support granted to an SPV. Nonetheless, it recognises contractual provision for temporary advances to ensure uninterrupted payments to investors only as long as "the payment to any investors from the cash flows stemming from the underlying asset pool and the credit enhancement [are] subordinated to the reimbursement of the cash advance." This qualification ensures seniority of cash advances and requires the servicer of the transaction to withhold a commensurate fraction of the subsequent cash collections to recoup previous cash advances.

3.2.4 Revolving asset securitisation

In most revolving asset securitisation transactions, the SPV advances funds to the originating bank in the form of revolving credit in return for the receipt of periodic repayments from a pool of outstanding loans that this refinancing arrangement allows the originator continue to generate.[12] At the same time, the SPV refinances itself by issuing commoditised structured claims as debt securities to capital market investors. These revolving securitisation structures are frequently supplemented by early amortisation triggers, which force an early wind-down of repayment of principal and interest to investors in the event of a significant deterioration of securitised portfolio value due to higher than expected levels of debtor delinquency and/or loan termination. However, in the case of a sudden drop in the cash flow position of the underlying reference portfolio, the originator could be denied a timely withdrawal of revolving credit from the SPV. Early amortisation compels the SPV to use cash flows from securitised loans to pay down investors instead of revolving the amount back to the originator because the originator's claim in appropriating collections in replenishing the collateral portfolio is subordinated to the payment claims of investors.

Although early amortisation functions like credit support to the benefit of investors, the Basle Committee considers such a mechanism potentially hazardous to proper cash flow allocation if early amortisation is triggered in the context of revolving asset securitisation transactions. Hence, if a transaction includes an "amortisation trigger", the *First Working Paper on the Treatment of Asset Securitisation* set forth that the notional amount of the securitised asset pool is to be regarded a credit equivalent and charged with a minimum 10% conversion factor for the off-balance sheet piece of the reference portfolio, which may be increased by national regulatory authorities depending on their assessment of various operational requirements.

3.3 The *Second Working Paper on the Treatment of Asset Securitisation* and the *(Third) Consultative Paper (CP3)*

The *Second Working Paper on the Treatment of Asset Securitisation* (Basle Committee, 2002a and 2002b) refines the preceding consultative process on the treatment of synthetic transactions by providing a more detailed specification of distinctive operational criteria applicable to different types of transaction structures, depending on their economic substance rather than their legal form. An originating bank is exempted from including securitised exposures in the calculation of their minimum regulatory capital requirement for credit risk if the following conditions below hold:

(i) traditional securitisation:

a. the credit risk of associated exposures has been transferred to third parties;

b. no legal and/or economic recourse: the transferor has no direct or indirect control over the transferred assets, i.e. assets are legally isolated from the transferor and beyond the reach of the transferor and its creditors, even in the event of insolvency or receivership (which must be supported by a legal opinion);[13]

c. the transferee is a qualifying special-purpose vehicle (SPV) and the holders of the beneficial interests in that entity have the right to pledge or exchange those interests without restrictions;

d. investors purchasing debt securities issued by the SPV as a means of refinancing the purchasing price of the securitised assets have a claim on the underlying assets but not on the transferor;

e. clean-up calls are permissible if they are (i) not mandatory, (ii) exercised at the discretion of the originating bank and (iii) not designed as credit support;[14] and

f. transaction must not contain clauses that would require the originator to systematically alter (i) the asset quality of the reference portfolio, (ii) the level of credit enhancement and (iii) the nominal investor return after inception of the securitisation transaction.

(ii) synthetic securitisation:

a. originating banks must have sought appropriate legal opinion, which verifies that the contractual obligations arising from the documented credit risk transfer are legally enforceable and binding to all parties involved;

b. significant transfer of credit risk of securitised exposures to third party and protection provider as eligible guarantor;

c. the credit quality of the [credit default swap] counterparty (i.e. the protection provider) and the value of the securitised reference portfolio must not have a material positive correlation;

d. clearly defined redemption criteria: procedures for timely liquidation of collateral in a credit event/default of the counterparty;

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[12] See also Grill and Perczynski (1993) for a more detailed description.

[13] Direct control is defined as any provision that gives rise to economic recourse, such as the possibility to repurchase transferred exposures or the obligation to retain some residual risk in the performance of transferred assets.

[14] The exercise of a clean-up call should be limited to cases when the notional value of assets <10% and the cost of servicing outweighs the benefits from continued repayment.

e. the types of collateral that qualify for synthetic transactions are: cash, certificates of deposit, gold, rated debt securities, certain unrated debt securities, equities[15] and funds; and

f. transaction must not contain clauses that would (i) limit credit protection, (ii) alter the nature of the credit risk transfer or (iii) alter the securitised exposures in a way that would deteriorate the quality of the reference portfolio.

Once a traditional (true sale) or synthetic securitisation meets these requirements, the securitised exposures are subject to a regulatory treatment pursuant to the securitisation framework.[16] Under the securitisation framework, both originating and investing banks are required to provide a regulatory capital charge for the risk-weighted assets of securitised exposures held.[17]

Moreover, in combination with the *(Third) Consultative Paper to the New Basle Accord* (Basle Committee, 2003) *the Second Working Paper on the Treatment of Asset Securitisation* represents the first attempt to expand the *Securitisation Framework* (see Fig. 1) in a revised definition of risk-weightings (RWs) of securitised assets. In particular, the proposition aims to discriminate between rated and unrated securitisation exposures held by originating and investing banks. The regulatory policy put forward by the *(Third) Consultative Paper to the New Basle Accord* distinguishes between two methodologies for the treatment of securitisation transactions in keeping with the general regulatory treatment of credit risk: the *standardised approach* and the *internal ratings-based approach* (IRB), where the latter approach breaks down into the *supervisory formula approach* (SFA) and the *ratings-based approach* (RBA) in an advanced treatment of positions in securitisation transactions.

3.3.1 Standardised approach for securitisation exposures

§526 *(Third) Consultative Paper to the New Basle Accord* (Basle Committee, 2003) explicitly mentions that issuing banks have to choose the same method for the regulatory treatment of securitisation transactions as the one used to determine the capital requirements for the type of underlying credit

[15] Only equities listed in main indices are eligible for the simple approach of operational criteria that qualify for eligible collateral in synthetic securitisation. The comprehensive approach allows for all equities to be considered.

[16] Note that the securitisation framework does not cover implicit support mechanisms, such as moral recourse.

[17] Generally, in §§521-524 the *(Third) Consultative Paper to the New Basle Accord* stipulates that banks are required to hold regulatory capital against all of their securitisation exposures arising from (i) the provision of *credit risk mitigants* to securitisation transactions, such as investments in asset-backed securities, (ii) the retention of subordinated tranches, and (iii) the extension of liquidity facilities or credit enhancements. In case of capital deduction for securitisation exposures, banks are required to provide appropriate regulatory capital by taking

exposures. Hence, for loss of insufficient information about the designated reference portfolio and/or inadequate in-house credit risk management capabilities (in order to calculate the IRB risk-weightings and the regulatory capital requirement K_{IRB}),[18] the use of the *standardised approach* for the credit risk of the underlying exposures of securitised exposures automatically entails the use the standardised approach within the securitisation framework.

		Rating Grades						
		AAA to AA-	A+ to A-	BBB+ to BBB-	BB+ to BB-	B+ to B-	below B-	Unrated
Claims on								
Sovereigns		0%	20%	50%	100%	100%	150%	100%
Banks	*Option 1*	20%	50%	100%	100%	100%	150%	100%
	Option 2	20%	50%	50%	100%	100%	150%	50%
Corporates		20%	50%	100%	100%	150%	150%	100%
Securitisation products *(long-term rating)*		20%	50%	100%	350%	Capital deduction	Capital deduction	Capital deduction

Tab. 2. *Risk-weighting (standardised approach).*

The *standardised approach* does not distinguish between originators and investors in securitisation, while third-party (non bank) investors are treated differently. Analogous to the standardised approach of ordinary credit exposures, the basic procedure for the risk-weighting of individual claims (in the context of securitisation, read *securitised claims* or *tranches*) is determined by the external rating (see Tab. 2). The risk-weights for securitised claims are based on the *long-term rating of the securitisation products* and decrease in a higher rating grade (similar to "regular" claims, categorised by the type of debtor, e.g. sovereigns, banks[19] and corporates). These risk-weights are further distinguished by the type of underlying exposure, i.e. retail portfolios *(individual and SME claims)*, residential property *(residential mortgages)* and commercial real estate *(commercial mortgages)*. Whereas unrated securitisation exposures with an internal rating equivalent to a non-investment grade classification (i.e. below "BBB-") are deducted from capital by issuers (§§529 and 530 *(Third) Consultative Paper to the New Basle*

50% from Tier 1 capital and 50% from Tier 2 capital – except for regulatory provisions of any expected future margin income, which would need to be deducted from Tier 1 capital (Basle Committee, 2003).

[18] K_{IRB} is the ratio of (a) the IRB capital requirement for the underlying exposures in the securitised pool to (b) the notional or loan equivalent amount of exposures in the pool (e.g. the sum of drawn amounts plus undrawn commitments).

[19] The risk-weights for banks break down into two options: (i) risk-weighting on the country the bank is incorporated *(Option 1)* or (ii) risk-weighting based on the assessment of the individual bank *(Option 2)*. Moreover, claims on banks with an original maturity of three months or less would receive a risk-weighting that is one category more favourable.

Accord),[20] the *unrated* most senior tranche of a securitisation transaction would be subject to a so-called *look-through treatment*, i.e. the risk-weight is determined by the average risk-weighting of the underlying credits. However, as illustrated in Tab. 2, the capital charges of securitised claims (esp. for non-investment grade tranches) are substantially higher than the charges imposed on corporate and bank credits with the same rating.[21]

3.3.2 Internal ratings-based approach (IRB) for securitisation exposures

The IRB approach extends the *standardised approach* along two dimensions. First, it (i) modifies the *external ratings-based* assignment of *risk-weightings* (RWs) of the *standardised approach* by controlling for tranche size, maturity and granularity of securitisation tranches (*ratings-based approach* (RBA); see Tab. 2)[22] and (ii) introduces the *supervisory formula approach* (SFA) as an *internal-ratings based* (IRB) measure to allow for more regulatory flexibility of issuers (and investors) with sophisticated credit risk management capabilities, which would otherwise not be accounted for in the standardised approach.

Second, according to §567 *(Third) Consultative Paper to the New Basle Accord* (Basle Committee, 2003) the IRB approach departs from an undifferentiated treatment of originators and investors in securitisation markets under the *standardised approach*. A distinction of originating and investing banks requires that (i) investors generally use the *ratings-based approach* (RBA) (except for those approved by national supervisors to use *supervisory formula approach* (SFA) for certain exposures), and (ii) originators use either the *supervisory formula approach* (SFA) or the *ratings-based approach* (RBA), depending on the availability of an external or inferred rating and sufficient information about the securitised exposures (see Tab. 4).

[20] Similarly, securitisation exposures in *second loss positions* do not have to be deducted if the first loss position (most junior tranche) provides enough protection (§§529 and 532 *(Third) Consultative Paper to the New Basle Accord*). Third-party (non-bank) investors may recognise external ratings up to "BB+" to "BB-" for risk-weighting purposes of securitisation exposures, i.e. capital deduction for securitised claims applies only for rating grades of "B+" and lower.

[21] The *(Third) Consultative Paper to the New Basle Accord* also proposes specific risk-weightings according to the type of underlying exposure: (i) claims included in *regulatory retail portfolios* (75% risk-weighting), i.e. exposures to individuals (e.g. credit card debt, auto loans, personal finance) or SMEs with low *granularity* (e.g. single obligor concentration must not be higher than 0.2% of overall regulatory retail portfolio) and low *individual exposure* (i.e. maximum counterparty exposure not higher than €1 million); (ii) *claims secured by residential property* (35% risk-weighting); and (iii) *claims secured by commercial real estate* (100% risk-weighting).

[22] Hence, both the *standardised approach* and the *internal ratings-based approach* (IRB) allow for qualifying external ratings and various operational criteria (see §525 *(Third) Consultative Paper to the New Basle Accord* (2003)) to be used in the *ratings-based approach* (RBA).

Originating banks are required to calculate K_{IRB} in all cases and hold capital against held positions (i.e. securitisation claims/tranches) as follows:

(i) *unrated* tranches:

a. insufficient information to calculate the IRB capital charge from K_{IRB}: full capital deduction;
b. sufficient information to calculate the IRB capital charge from K_{IRB}: capital deduction of tranche sizes ("thickness levels") up to K_{IRB}, then application of the *supervisory formula approach* (SFA).
c. The maximum capital requirement is capped at K_{IRB} regardless of the notional amount of unrated tranches.

(ii) *rated* tranches:

a. *inferred* rating: risk-weighting according to the *ratings-based approach* (RBA) based on the rating of the externally rated subordinate tranche, provided that it is longer in maturity;
b. *external* rating[23]: capital deduction of tranche sizes ("thickness levels") up to K_{IRB}, then risk-weighting according to the *ratings-based approach* (RBA).[24]
c. The maximum capital requirement is capped at K_{IRB} regardless of the notional amount of unrated tranches.

Investing banks would need to use the *ratings-based approach* (RBA) if an *external* rating were available or could be *inferred*, irrespective of whether a position held falls below or above the K_{IRB} boundary. Unrated positions must be deducted unless the investing bank receives supervisory approval to calculate the K_{IRB} through SFA like originating banks if the position in question is above the K_{IRB} threshold.

The *supervisory formula approach* (SFA) determines the regulatory requirement for each issued tranche $k \in m$ as "risk-weighted asset", where the (regulatory) *IRB capital charge* for a certain tranche amount (i.e. its exposure at inception) is multiplied by factor 12.5 (which would imply a full capital deduction of the tranche size if the IRB capital charge amounts to a 100% risk-weighting at an 8% capital ratio). The SFA-based regulatory capital requirement is computed on the basis of five essential bank-supplied input variables, reflecting the structured risk of the transaction set forth in *Section III Credit Risk – the Internal Ratings-based Approach* (Basle Committee, 2002a): K_{IRB}, the internal ratings-based

[23] i.e. public ratings only.
[24] see §§575-577 *(Third) Consultative Paper to the New Basle Accord.*

(IRB) capital charge that would be applied had the underlying exposures not been securitised (but held directly on the sponsor's balance sheet);[25] the "credit enhancement level" of each tranche (position) L_k; the "thickness" of each tranche T_k; the effective total number N of loans in the securitised loan pool; and the exposure-weighted average loss-given-default (LGD) of the given reference portfolio.[26] The *IRB capital charge* for each tranche *k*[27] is defined as the amount of securitised exposures C_k multiplied by $\max\left[0.0056\times T_k, S\left(L_k+T_k\right)-S\left(L_k\right)\right]$, where the *supervisory formula* (SF) is defined by the function $S()$, and the *credit enhancement level* L_k gives rise to an intensity-based approximation of the tranche-specific capital charge.[28] This securitisation framework of the *Second Working Paper on the Treatment of Asset Securitisation* was subsequently followed by a period of intense negotiations between national regulatory authorities and banks about the risk sensitivity of proposed measures during the so-called third consultative phase, which resulted in the *(Third) Consultative Paper* in April 2003. For further amendments in response to continued concern by the banking industry eventually established a new securitisation framework within the revised *Basle Accord* on *International Convergence of Capital Measurement and Capital Standards* in 2004.

3.4 Amendments to the *Third Consultative Paper: Changes to the Securitisation Framework* and *International Convergence of Capital Measurement and Capital Standards: Credit Risk – Securitisation Framework*

In October 2003 the Basle Committee announced plans to revise the internal ratings-based (IRB) approach within the securitisation framework in response to criticism received by the banking industry, which mainly concentrated on what was considered an unbalanced treatment of senior securitised asset exposures and conventional credit risk of the same rating grade. After the Basle Committee issued a working paper on proposed *Changes to the Securitisation Framework* (Basle Committee, 2004) in the bid to reduce the complexity and the burden of implementing the provisions of the *Second Working Paper on Asset Securitisation* and the *(Third) Consultative Paper* (CP3) on

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[25] The Basle Committee defines K_{IRB} as the ratio of (i) the IRB-based capital requirements including the EL portion for the underlying reference portfolio of securitised assets to (ii) the exposure amount of the "exposure amount of the pool (e.g. the sum of drawn amounts related to securitised exposures plus the EAD [exposure-at-default] associated with undrawn commitments related to securitised exposures (Basle Committee, 2002a)." The IRB-based capital requirements have to be calculated in accordance with the IRB approach for credit risk as if the securitised exposures were continued to be held by the originating bank, mainly because it reflects the beneficial effect of any credit risk mitigant applied to the underlying reference portfolio on all of the securitised exposures.

[26] See Appendix 1, section 7.1 for the definition of the effective total number of exposures N and the average loss-given-default (LGD).

[27] Note that whenever a bank holds proportional interest in a tranche, the capital charge for this position equals a commensurate proportion of the capital charge of the entire tranche.

[28] See Appendix 2, section 7.2 for the specification of the *supervisory formula* (SF) and the *credit enhancement level* L.

30 January 2004, it finally published new guidelines on the treatment of asset securitisation as part of the *International Convergence of Capital Measurement and Capital Standards: Credit Risk – Securitisation Framework* in June 2004. Based on the *Changes to the Securitisation Framework* the Committee affirms efforts to (i) install greater internal consistency of risk-weightings applied to similar securitisation exposures, irrespective of the approach used (SFA vs. RBA) and (ii) eliminate differences in the treatment of securitisation exposures held by originators and investors (see Tab. 3).

<table>
<tr><th colspan="2" rowspan="2">Securitisation exposure</th><th colspan="2">Standard Approach</th><th colspan="2">IRB Approach</th></tr>
<tr><th>Originating Bank</th><th>Investing Bank</th><th>Originating Bank[1]</th><th>Investing Bank</th></tr>
<tr><td rowspan="4">Rated[3]</td><td rowspan="2">Investment Grade Rating</td><td colspan="2" rowspan="2">Risk-weight (RW) of long-term ratings: AAA to AA- (20%), A+ to A- (50%), BBB+ to BBB- (100%)
Risk-weight (RW) of short-term ratings: A1/P1 (20%), A2/P2 (50%), A3/P3 (100%)</td><td colspan="2">RBA</td></tr>
<tr><td>Max. capital requirement: K_{IRB}</td><td>Max. capital requirement: None</td></tr>
<tr><td rowspan="2">Non-Investment Grade Rating</td><td rowspan="2">All positions: Deduction</td><td rowspan="2">Risk-weight (RW) of long-term ratings: BB+ to BB- (350%); all positions rated B+ and lower: Deduction</td><td colspan="2">RBA</td></tr>
<tr><td>Max. capital requirement: K_{IRB}</td><td>Max. capital requirement: None</td></tr>
<tr><td colspan="2" rowspan="2">Unrated[4]</td><td colspan="2" rowspan="2">All positions: Deduction</td><td>SFA/ Simplified SFA[2]</td><td>All positions: Deduction</td></tr>
<tr><td>Max. capital requirement: K_{IRB}</td><td>Max. capital requirement: None</td></tr>
</table>

1: Investing banks need to seek supervisory approval for inclusion in this category of regulatory capital treatment, whereas originating banks automatically fall into this category. 2: The application of the *Simplified SFA* in lieu of the *SFA* is also subject to supervisory approval. 3: Under the IRB approach the term "rated" refers to positions with an external rating or an inferred rating. 4: The IAA permits originating banks to used RBA for exposures to ABCP conduits, where the internal rating equivalent represents an investment grade/rating.

Tab. 3. *The new securitisation framework (Basle Committee, 2004a and 2004b).*

The major structural change proposed in the revision of the *(Third) Consultative Paper* concerns a refined methodological treatment of unrated and rated positions of investing and originating banks in securitisation transactions for regulatory purposes. For one, the new securitisation framework adopts the proposed *Changes to the Securitisation Framework* (January 2004) concerning the IRB approach by extending the *Ratings-Based Approach* (RBA) to include all rated positions (either rated explicitly or with an inferred rating), regardless of whether the bank is an originator or an investor. This provision also renders irrelevant both the availability of sufficient information for the computation of K_{IRB}[29]

[29] i.e. the capital charge that would have been applied to the underlying exposures had they not been securitised.

and the question of whether positions fall above or below the K_{IRB} threshold as put forth by the *(Third) Consultative Paper* for the application of RBA to rated positions held by originating banks. Moreover, the RBA would also be used in the *Internal Assessment Approach* (IAA) for unrated low-risk positions,[30] e.g. liquidity facilities and credit enhancements banks extend to ABCP conduits. The IAA maps internal risk assessments of such exposures to rating agency criteria for the asset type purchased by the conduit so as to more closely reflect leading banks' current risk management practices.

	New RBA Risk Weights (CP3 RBA Risk Weights)		
Long-term Rating Grade [Short-term Rating Grade] *(illustrative)*	**Senior tranches**[1] (fomerly: thick tranches, backed by highly granular pools (N>99))	**Base Case**	**Tranches backed by non-granular pools (N<6)**
Aaa/AAA [A-1/P-1]	7	12	20
Aa/AA	8	15	25
A1/A+	10 (20)	18 (20)	35
A2/A [A-2/P-2]	12 (20)	20 (20)	
A3/A-	20 (20)	35 (20)	
Baa1/BBB+	35 (50)	50	
Baa2/BBB [A-3/P-3]	60 (75)	75	
Baa3/BBB-	100		
Ba1/BB+	250		
Ba2/BB	425		
Ba3/BB-	650		
Below Ba3/BB- [all other ratings/unrated]	Deduction		

The "old" RBA risk weights according to the *Second Working Paper on the Treatment of Asset Securitsation* (2002) have been added in parenthesis. Note the change of the qualification criteria for the most preferential risk weights from "highly granular tranches" to "senior tranches". 1: The most preferential risk weights are also assigned to unrated low-risk positions subject to IAA unless a liquidity facility or credit enhancement constituted a mezzanine position in economic substance, which would render applicable the "base case" applicable in this situation.

Tab. 4. *The new long-term and short-term RBA risk-weights (Basle Committee, 2004a and 2004b).*[31]

Changes during the third consultative phase towards a revised securitisation framework also include a closer alignment of the RBA-based risk-weights to the actual riskiness of securitised positions with a high external or inferred rating (as well as low-risk exposures to ABCP, where the IAA applies). The

[30] The IAA only applies to exposures with an internal rating equivalent of investment-grade at inception.

[31] The "mark-up" of risk-weights on securitisation tranches can be illustrated by comparing the IRB risk-weights *per se* for an underlying asset class, e.g. residential mortgages and corporate loans, with the risk-weights imposed on securitisation claims. The difference is the greatest especially for low investment grade ratings (e.g. "A", "Baa1" and "Baa2").

proposed measure moves the focus of assigning the lowest set of risk-weights for investment grade ratings away from the "thickness" (as in the *(Third) Consultative Paper*) to the level of seniority of exposures with little or no loss of risk sensitivity, at the cost of disqualifying some granular tranches from the use of the most preferential risk-weights (see Tab. 4).[32] Separate risk-weights are assigned to (i) senior, granular tranches, (ii) non-senior, granular tranches ("base case") and (iii) tranches backed by non-granular pools. The change of eligibility for the preferential risk-weights is also accompanied by a more fine-tuned differentiation of risk-weights for different levels of investment grade-rated positions, so as to simplify the RBA framework.

Generally, the regulatory risk-weightings for unrated positions (including liquidity facilities and credit enhancements extended to ABCP conduits, which are not captured by the IAA) in securitisation transactions continue to be based on a modified *Supervisory Formula Approach* (SFA), which, in its initial version, was considered unnecessarily complex (see Appendix 2, section 7.2). However, the new securitisation framework according to the *International Convergence of Capital Measurement and Capital Standards* partially redresses the complexity of the original SFA formula.[33] The *Changes to the Securitisation Framework* before the agreement on the definition of SFA within the framework of the *International Convergence of Capital Measurement and Capital Standards* also set forth the so-called *Simplified Supervisory Formula* ("Simplified SF") as an alternative calculation to the existing *Supervisory Formula* (SF) of the *(Third) Consultative Paper*, easing some the computational burden involved in the old SF.[34] However, the *Simplified SF* did not find entry in the final agreement on a new securitisation framework as subsection to the agreement on *International Convergence of Capital Measurement and Capital Standards* in June 2004.

Additionally, the Basle Committee decided to develop less restrictive operational criteria for the "top-down" IRB approach under the *(Third) Consultative Paper* to calculating K_{IRB}, especially for purchased receivables as securitised exposures. This revision reflects the inability of many banks during the consultative process to decompose expected loss estimates into reliable estimates of default

[32] Generally, the working paper on *Changes to the Securitisation Framework* defines the term "senior tranche" in context of RBA as a position that is "effectively backed or secured by a first claim on the entire amount of the assets in the underlying securitised pool." Although this definition may only apply to the most senior position within a securitisation transaction, "in some instances there may be some other claim that, in a technical sense, may be more senior in the waterfall (e.g. a swap claim) but will be disregarded for the purpose of determining which positions are subject to the 'senior tranches' column (Basle Committee, 2004a)."
[33] Note that the final Basle agreement on the *International Convergence of Capital Measurement and Capital Standards* (2004) suggests the elimination of the non-linear solution to the computation of a minimum risk weighting (i.e the "Floor") for a given tranche thickness (see Appendix 3, section 7.3).
[34] See Appendix 4, section 7.4 for the definition of the *Simplified SF*.

probabilities (PD) and loss-given default (LGD). A flexible regime of deriving the capital charge for these assets (consistent with the IAA) would allow banks to rely on their own LGD estimates.

Overall, the revision of the securitisation framework enhances internal consistency across the standardised and IRB approaches as regards the treatment of both unrated and rated positions. This effort addresses concerns by the banking industry about the need for greater consistency within the securitisation framework in the way capital charges are computed on similar securitisation exposures irrespective of the approach (SFA or RBA) being used. The *Simplified SF* and the IAA represent viable alternatives to the modification of the original SF of the *(Third) Consultative Paper* in order to (i) simplify the complex IRB approach for unrated positions and (ii) reconcile the difference between the two-factor model used to verify the RBA risk-weights and the single risk factor model applied in the context of SFA. Moreover, the implementation of the so-called "external rating override" grants originating banks (like investing banks) the privilege to calculate RBA-based risk-weights even if a rated position falls below the K_{IRB} boundary. This expanded use of RBA, irrespective of whether the tranche size meets the K_{IRB} threshold, rewards the use of the IRB approach of securitisation especially for non-investment grade rated tranches, whereas the more fine-tuned treatment of senior tranches (and the associated benefit of preferential risk-weights) helps align capital requirements closer to the actual risk included in low-risk investment grade tranches. This measure attests to the growing importance of external ratings as market signals of the inherent risk of securitisation exposures, which should carry the same regulatory capital charges irrespective of the holders of such positions.[35] Finally, the Basle Committee upholds the original prerequisite of significant credit risk transfer in a securitisation transaction to ensure integrity of the securitisation framework between securitised and non-securitised exposures within the overall revision of the capital requirements of the new Basle Accord.

[35] At the same time, the Basle Committee rejects further decomposition of risk-weights into portions of unexpected loss (UL) and expected loss (EL) in the bid to increase risk sensitivity of the securitisation framework due to the current definition of K_{IRB} as the sum of UL and EL portions of on-balance sheet credit risk exposures. Since the EL tends to be relatively small compared to UL for senior securitisation positions the existing capital requirements are treated as fully representing capital against UL for investment grade-rated positions and unrated positions above K_{IRB}. Conversely, in the case of unrated positions that fall below K_{IRB} or are rated non-investment grade, full deduction of the notional tranche amount appears sufficiently adequate to account for the changing proportions of EL and UL in declining seniority of securitised exposures.

4 CASE STUDY: THE OPTIMISATION OF REGULATORY CAPITAL

The new Basle Accord on the *International Convergence of Capital Measurement and Capital Standards* ("Basle 2") presents a consistent securitisation framework, which all but eliminates possibilities of regulatory arbitrage through securitisation due to both (i) a more risk-sensitive computation of the capital charge for on-balance sheet credit exposures and (ii) a close alignment of capital requirements of securitised exposures and non-securitised credit exposures. While the mitigation of regulatory capital requirements cannot be deemed the single most important motivation for securitisation, regulatory optimisation has influenced and continues to influence the way issuers devise and advance securitisation techniques to transfer asset exposures to capital markets until the new Basle Accord comes into effect in 2006. If we were to limit our analysis to the regulatory capital charge of *originating banks only*, benefits from securitisation still remain if the issuer incurs different capital charges for non-securitised and securitised exposures of similar credit risk and both operational and processing costs remain low. Let us assume that under the existing Basle Accord a portfolio of on-balance sheet credit exposures would translate into 100% risk-weighted assets (RWA), which draw a standard capital charge of 8% ("capital ratio") on their notional amount. Hence, any arrangement that yields minimum capital requirement for securitised exposures of less than 8% under simplifying assumptions would attest to regulatory optimisation through asset securitisation.[36] The different degrees of reduced regulatory capital requirements of securitised credit risk exposure can be best illustrated on the basis of the disparate configurations of transaction structures commonly used in loan securitisation. In Tab. 4 we traverse the spectrum of different structures of securitisation transactions – from *conventional* (true sale) to *synthetic* securitisation – to show the capital requirements of an originating bank.

Under the most straightforward transaction type of *conventional* true sale securitisation, the asset originator completes an outright asset sale to an SPV, which issues senior and mezzanine debt securities (notes) to capital market investors, where the originator retains a first loss position (FLP) as commitment device to mitigate default risk. In the first transaction type (traditional/true sale structure), we assume investor notes to amount to 96% of the transaction volume (with 92% senior notes and 4% mezzanine notes) and an FLP of 4% relative notional value. After completion of off-

[36] This assumption implies that the revised framework for the risk-sensitive treatment of credit risk exposures under the new agreement of *International Convergence of Capital Measurement and Capital Standards* is ignored and any collateral eligible for a risk weight reduction as well as transaction costs of securitisation are disregarded for the purposes of this analysis.

balance sheet refinancing through a true sale securitisation, a bank originator would have cut its regulatory capital requirement by half, as it is now required to hold equity of only 4% of the securitised reference portfolio (according to 100% risk weighting of outstanding liabilities from the retention of FLP).

Transaction type	FLP	Reg. capital calculation	Regulatory capital	Reg. capital with interest sub-part.
Without transaction	-	100% risk weight, 8% capital ratio, no collateral.	**8%**	**N/A**
True sale transaction (92% senior notes, 4% mezzanine notes, 4% FLP)	4%	FLP is fully deductible (100%), which equates to 1250% risk weight at 8% capital ratio	**4%** (0.04x12.5x0.08)	**N/A**
Fully funded indirect synthetic trans. with 98% CDS with OECD bank (FLP 2% see text)	2%	FLP is fully deductible; OECD bank CDS draws 20% risk weighting	**3.568%** (0.02 + 0.98x0.2x0.08)	**1.728%** (1x<u>0.0016</u> + 0.98x0.2 x0.08)
Same as before with SPV and 0% risk-based capital collateral	2%	FLP is fully deductible; collateralised CDS draws 0% risk weighting	**2%** (1x0.02 + 0.98x0x0.08)	**0.16%** (1x<u>0.0016</u> + 0.98x0x0.08)
Partially funded indirect synthetic trans. with 98% CDSs with OECD bank (90% super senior swap, 10% junior swap)	2%	FLP is fully deductible; both CDSs with 20% risk weight	**3.568%** (1x0.02 + 0.98x (0.9x0.2+0.1x0.2)x0.08	**1.570%** (1x<u>0.0016</u> + 0.98x (0.9x0.2+0.1x0.2)x0.08
Same as before but 10% junior swap is collateralised by 0% risk-weighted assets.	2%	FLP is fully deductible; SSS with 20% risk weight and JS with 0% risk weight	**3.411%** (1x0.02 + 0.98x (0.9x0.2+0.1x0) x0.08	**1.413%** (1x<u>0.0016</u> + 0.98x (0.9x0.2+0.1x0) x0.08
Same as before but both swaps are collateralised by 0% risk-weighted assets.	2%	FLP is fully deductible both swaps with 0% risk weight	**2%** (1x0.02 + 0.98x (0.9x0+0.1x0) x0.08	**0.16%** (1x<u>0.0016</u> + 0.98x (0.9x0+0.1x0) x0.08

<u>Interest sub-participation</u> of FLP replaces 100% capital deduction of FLP by 8% capital requirement at 100% risk weighting, if interest income is used to compensate FLP holder in the event of default loss. In our example, 0.02x1x0.08=0.0016.

Tab. 4. *Effects of transaction structure on the regulatory capital requirement of securitised credit risk.*

The *fully funded* synthetic equivalent of this form of asset risk transfer (with a SPV) may even further reduce minimum capital requirements. For the same portfolio quality, the associated loss severity[37] in synthetic structures is considered smaller than in true sale transactions due to a more clear definition of default events. With a fully deductible FLP of only 2% and 98% credit risk protection provided by an OECD bank (via a credit default swap (CDS) with 20% risk weighting), the overall capital charge of this *fully funded synthetic* (indirect)[38] transaction would drop to 3.568%

[37] i.e. the aggregate loss of securitised loans after the enforcement of collateral used to secure these loans.
[38] Synthetic transactions come in various structures of security design, which can be specified along three major dimensions: (i) level of funding: unfunded, (fully) funded or partially funded, (ii) involvement of a SPV as issuing agent (indirect or direct securitisation), (iii) degree of collateralisation of funded elements (with or without collateral, e.g. government bonds, guarantees, letter of credit, certificate of indebtedness, *Pfandbriefe*). The classification of *indirect* securitisation refers to the involvement of a SPV as issuing agent. The funding level indicates the degree to which the notional amount of issued debt securities matches up with the volume of the

$(2\% \times 100\% + 98\% \times 20\% \times 8\%)$ of the notional amount of the securitisation transaction. If the CDS was to be secured ("collateralised") with 0% risk-weighted assets (e.g. government debt securities), the issuer would need to provide regulatory capital in the amount of FLP at only 2%. The same capital charge applies to the alternative construct of a *partially funded synthetic* transaction, where the credit risk protection is tailored to cover 98% of the notional value of the underlying reference portfolio, with 2% equity retention by the originator. In this case, 90% of the remaining 98% of the portfolio value is hedged with a super senior swap (SSS) and 10% are refinanced by debt securities on the back of a junior swap (JS) agreement, which results in a risk-weighted capital charge of $2\% \times 100\% + 98\% \times (90\% + 10\%) \times 20\% \times 8\% = 3.568\%$. If the junior CDS was collateralised by 0% risk-weighted assets or supported by a quasi-government agency,[39] the minimum capital requirement would decline to 3.411% $(2\% \times 100\% + 98\% \times (90\% \times 20\% + 10\% \times 0\%) \times 8\%)$. If both CDSs were to be collateralised in a similar fashion the capital charge would be merely 2% $(2\% \times 100\% + 98\% \times (90\% + 10\%) 0\% \times 8\%)$ of the notional value. This straightforward illustration of changes in the computation of regulatory requirements due to different transaction structures has motivated the appellation of securitisation as a regulatory arbitrage tool, which enables issuers to significantly alleviate their regulatory capital burden by means of sophisticated credit risk transfer.

If asset originators and/or issuers should also decide to offer the FLP to capital market investors in a bid to further reduce capital requirements, they would do so by underwriting a so-called *interest sub-participation* agreement as credit enhancement of the FLP as the most junior tranche of the transaction (Böhringer et al., 2001). The interest sub-participation replaces the full capital deduction of FLP at a capital ratio of 8% and 100% risk weighting. In the event of default loss, interest sub-participation requires the issuer to compensate any losses absorbed by FLP investors from generated interest income of the reference portfolio after more senior claims to interest and principal have been satisfied. Although junior noteholders of FLP would loose interest payments on defaulted loans, sub-participation guarantees the repayment of principal. For instance, if a securitised reference portfolio was to be hit by a loss given default of 5% and the annual excess interest income would amount to 0.5% of the original portfolio balance on average, investors would be fully reimbursed after 10 years. The effect of incorporating interest sub-participation in securitisation structures is illustrated in the right-most column of Tab. 4. Note that all calculations above merely offer an indication of the regulatory trade-off in securitisation and how regulatory optimisation translates into a lower capital

underlying reference portfolio of asset exposures. The term "fully funded" refers to a complete refinancing of securitised exposures by issued debt securities.

[39] e.g. the KfW banking group in Germany or one of the federal/state mortgage corporations in the U.S..

charge. We have ignored any transaction costs incurred in the administration and underwriting of securitisation transactions, be they *explicit* (e.g. legal costs, structuring costs, payments to rating agencies and intermediaries/agents, management fees) or *implicit* (e.g. funding cost after securitisation, reputation effects). Moreover, we have considered the level of FLP to be equal to the minimum capital requirement of securitised credit risk, so that issuers and/or originators would not need to hold capital against securitised debt securities whose level of credit enhancement is smaller than the minimum capital requirement of securitised credit risk.

5 CONCLUSION: THE IMPLICATIONS OF THE CURRENT REGULATORY TREATMENT OF ASSET SECURITISATION

The pathological evolution of the securitisation framework under the revised Basle Accord reflects the successive steps the Basle Committee has taken over time to eliminate arbitrage opportunities from loan securitisation under existing provisions for the regulatory treatment of credit risk under the old 1988 Basle Accord and later amendments. Prior to the recent agreement on new capital standards for credit risk, securitisation techniques remedied the glaring incompatibility between the regulatory capital charge and the actual economic cost of credit risk across the spectrum of varying rating grades (i.e. regulatory "mispricing" of credit risk). In absence of risk-sensitive capital adequacy requirements for credit exposures and with little regulatory guidance as to how banks should compute their capital charge for securitised exposures, asset securitisation has been labelled a sensible market reaction to inefficient regulatory governance of credit risk in the banking system. So from a regulatory perspective, securitisation is essentially a child of its own making due to anomalies in the regulatory system giving rise to regulatory arbitrage. Needless to say, this use of securitisation aroused concern among regulators about the troubling prospect of (i) an insufficient provision of minimum capital requirements to absorb actual default loss and (ii) an inadequate treatment of unexpected risk. As regards the latter aspect, regulators specifically worried about the absorption of unexpected losses by more senior tranches held by capital market investors in the event of financial shocks, while originators held merely some concentrated risk exposure of expected losses in the form of a junior claim as first loss position.

The new Basle Accord on the *International Convergence of Capital Measurement and Capital Standards* ("Basle 2") restrains regulatory arbitrage through securitisation along two dimensions. On one hand, the capital charge for on-balance sheet credit exposures has been made more risk-sensitive, and, on the other hand, the regulatory treatment of securitisation transactions has been closely aligned to match the capital requirements for non-securitised credit exposures.[40] In anticipation of imminent regulatory change,[41] asset securitisation no longer appears to deserve the now-hackneyed moniker of a pure (regulatory) arbitrage tool, flaunting the gap between internal default provisions for default loss and external risk assessment methods of risk-weighted assets by offering "regulatory overcharged asset holdings/exposures" to capital market investors.

Given the implementation of discriminatory risk-weightings in the revised Basle Accord and a separate regulatory framework for the treatment of asset securitisation, the prospective change of the current regulatory regime censures institutional arbitrage on regulatory capital requirements, which has hitherto motivated the securitisation of investment-grade loans (see section 2.1). Since a higher capital charge levied on risky assets will also carry larger risk-based *capital haircuts* contingent on the characteristics of collateralisation, the *incentive for the securitisation of non-investment grade loans* rises. The relationship between the risk level of non-investment grade loans and the associated economic capital cost will determine the extent to which banks and other financial institutions are prepared to substitute high-risk assets (i.e. non-investment grade loans with presumably high capital haircuts) for investment grade-related credit exposures on their loan books – a reversal of the present drainage of low-risk loans off the balance sheet. Hence, loan securitisation, originally devised as a remedy to inflexible regulatory capital charges, will be instrumental in the *efficient management of economic capital* for purposes of adequate asset allocation.

With the arbitrage paradigm of securitisation giving way to an envisaged reconciliation of economic and regulatory incentives, the role of securitisation as an efficient mechanism to optimise overall regulatory capital charge looks distinctly uncertain. This development begs the question of whether the fundamental economic rationale of asset securitisation does exist and, if so, whether it remains viable. However, the new reality of a more *responsive regulatory setting* does not invalidate, but rather

[40] Giddy (1997) proffers a new approach to the regulatory treatment of asset securitisation in his definition of "perimeters of bank regulation in securitisation". According to his view, the goal ought to be that the substance and not the form of the asset transfer is what governs capital requirements. Giddy notes in this respect that regulatory authorities may access capital or reserve requirements as if the financing was a secured borrowing in cases when the transfer of assets/asset risk (i) leaves the issuer open to recourse deemed risky by the authorities, and/or (ii) entails the potential for moral hazard, whereby a bank shores up potential or actual losses arising from the securitised exposures in order to protect its name even when not legally required to do so.

[41] The new proposals for the revision of the Basle Accord remedy this shortcoming through the implementation of discriminatory risk-weightings across rating categories. Under this so-called "ratings-based approach" (RBA) risk weights will be more closely aligned to loan grades in the loan book. If the broad-brushed regulatory treatment of loans disappears, banks will increasingly resort to non-investment loan assets to support their securitisation transaction, and by doing so, they will put a premium on the adequate allocation of first loss provision as credit enhancement. Consequently, the incentive to securitise non-investment grade

strengthens, the argument for risk-adjusted *efficiency gains (of economic capital)* from loan securitisation. In spite of regulatory changes underway, securitisation markets betray no visible signs of change. The unfettered popularity of asset securitisation implies that issuers appropriate economic benefits from converting illiquid assets into tradable debt securities in the effort to economise on a predefined level of acceptable first loss exposure. Securitisation also maintains its economic edge, as it enables banks and non-bank financial institutions to reap rewards from advanced approaches in controlling credit risk and reduce inessential non-interest rate expenses.

Additionally, recent empirical evidence about financial innovation in transaction structures testifies to the pervasive adaptability and systemic flexibility of asset securitisation. Although it has become a routine procedure of structured finance, and informed investors have grown familiar with its structural characteristics, loan securitisation has preserved sufficient flexibility to absorb regulatory change. Hence, loan securitisation in its current state is not a permanent account of efforts to achieve marketability of credit exposures, but an example of structured finance of its age (when regulatory arbitrage was possible), with properties that originally fed on the absence of a fair internal ratings-based determination of loan default risk. The current regulatory reform simply inaugurates another round of innovation in security design of loan securitisation. The advocacy of securitisation on the grounds of economic benefits makes this argument even more compelling and imminent. However, as risk-sensitive bank capital charges eliminate the regulatory capital arbitrage paradigm of securitisation, the security design of asset-backed securities can only be sufficiently accommodating of these regulatory changes if the arguments for risk management and efficient asset funding as fundamental economic reasons for securitisation hold.

In a nutshell, it is fair to say that the supervisory responsiveness of the Basle Committee to the accretion of structured finance has led to a more risk sensitive securitisation framework of the agreement on *International Convergence of Capital Measurement and Capital Standards*, which has all but eliminated the optimisation of regulatory capital as an incentive of credit risk transfer through securitisation. Nonetheless, with the problem of insensitive regulatory treatment of credit risk exposures curtailed in the wake of the securitisation framework, the regulatory treatment of securitised exposures falls short of satisfying regimented coherence. The persistent discrepancy of the regulatory capital of similar exposures of securitised debt under the standardised and IRB approaches, and the strategic imbalance implied in the discriminatory derivation minimum capital requirements for credit risk and securitised positions of similar risk, remain sources of continued

loans adds topical significance to the issue of credit enhancement, as the differences between collateral (reference portfolio) quality and desired structured rating is expected to widen in the future.

contention and scrupulous analysis. Given the significant cost of synthetic securitisation, the relationship between security design and the economic cost of securitised exposures as well as derivative elements will become more prominent considerations in structured finance transactions and warrant further regulatory progression.

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7 APPENDIX

7.1 *Appendix 1: Definition of the effective number of exposures and loss-given default*

The effective number of exposures (N) and the exposure-weighted average loss-given-default (LGD) are defined as[42]

$$N = \left(\sum_i EAD_i\right)^2 / \sum_i EAD_i^2$$

and

$$LGD = \left(\sum_i LGD_i \times EAD_i\right) / \sum_i EAD_i \, .$$

EAD_i denotes the exposure-at-default of all exposures to the *i*th obligor in keeping with the general concept of a concentration ratio, where the scale of the weighting factor grows at a geometric rate, and LGD_i denotes the average loss-given-default of all exposures to the *i*th obligor.[43] The thickness of exposures (T) is defined as the ratio of (i) the nominal size C_k of tranche *k* to (ii) the notional amount of securitised exposures C in the underlying reference portfolio

$$T_k = C_k / \sum_{k=1}^{m} C_k \, .$$

7.2 *Appendix 2: Definition of the original Supervisory Formula (SF) and the credit enhancement level according to the Second Working Paper on the Treatment of Asset Securitisation and the (Third) Consultative Paper (CP3)*

The original "supervisory formula" (SF) $S(.)$ is defined as

$$S(L_k) = \begin{cases} L_k & \text{if } L_k \leq K_{IRB} \\ K_{IRB} + K(L_k) - K(K_{IRB}) + (d \times K_{IRB}/\omega)\left(1 - e^{\omega(K_{IRB} - L_k^*)/K_{IRB}}\right) & \text{if } K_{IRB} < L_k \leq L_k^* \\ K_{IRB} + K(L_k^*) - K(K_{IRB}) + (d \times K_{IRB}/\omega)\left(1 - e^{\omega(K_{IRB} - L_k^*)/K_{IRB}}\right) & \\ + (L_k - L_k^*) \times Floor & \text{if } L_k > L_k^* \end{cases}$$

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[42] The Basle Committee also proposed simplified methods for computing N and LGD.

[43] The *Second Working Paper on the Treatment of Asset-Backed Securitisation* also provides a simplified method of computing the effective number of exposures and the exposure-weighted average loss-given-default (Basle Committee, 2002, 36).

where

$$c = K_{IRB}/(1-h)$$

$$h = (1 - K_{IRB}/LGD)^N$$

$$v = K_{IRB}\frac{(LGD - K_{IRB}) + 0.25(1-LGD)}{N}$$

$$f = \left(\frac{(LGD - K_{IRB}{}^2)}{1-h} - c^2\right) + \frac{(1-K_{IRB})K_{IRB} - v}{(1-h)\tau}$$

$$a = \{[(1-c)c]/f - 1\}c$$

$$b = \{[(1-c)c]/f - 1\} \times (1-c)$$

$$d = 1-(1-h)(1-Beta[K_{IRB};a,b])$$

$$K(L_k) = (1-h)((1-Beta[L_k;a,b]) \times L_k + Beta[L_k;a+1,b] \times c)$$

The *credit enhancement level* (L) is measured (in decimal form) as the ratio of (i) the amount of all securitised positions subordinate to tranche *k* to (ii) the notional amount of all securitised exposures, which could also expressed as[44]

$$L_k = \frac{\sum_{k=1}^{k-1} T_k}{\sum_{k=1}^{m} T_k} \; \forall L_k \in [0,1[\text{ and } \begin{cases} \lim\limits_{\sum_{k=1}^{k-1} T_k \to \infty} L_k = 1 & \textit{for } T_k > 0 \\ \lim\limits_{\sum_{k=1}^{k-1} T_k \to 0} L_k = 0 & \textit{for } T_k \geq 0. \end{cases}$$

The supervisory-determined parameters are defined as $Floor = 0.0056$ (lowest capital charge under the ratings-based approach (RBA)), τ=1,000 and $\omega = 20$, and L_k^* solves for the non-linear equation[45]

[44] According to the Basle Committee banks will be required to determine the level of credit enhancement prior to any consideration of effects of any tranche-specific credit enhancements, such as third-party guarantees, which might benefit a single tranche only. Further stipulations exclude any gains-on-sale from the computation of the level of credit enhancement, whereas interest rate and currency swaps more junior than tranche *k* may be only be considered at their current value or be ignored otherwise.

[45] The specification $Beta[L;a,b]$ refers to a cumulative beta distribution function with parameters a and b evaluated at L.

$$Floor = (1-b)\left[\left(1 - Beta\left[L_k^*; a, b\right]\right) + d \times e^{\frac{\omega\left(K_{IRB} - L_k^*\right)}{K_{IRB}}}\right].$$

7.3 *Appendix 3: Definition of the new Supervisory Formula (SF) in the Changes to the Securitisation Framework (2004)*

After elimination of the optimal solution L_k^* to the non-linear definition of some required *Floor*, the new *Supervisory Formula* (SF) according to the *International Convergence of Capital Measurement and Capital Standards* would have been defined as:

$$S(L_k) = \begin{cases} L_k & \text{if } L_k \leq K_{IRB} \\ K_{IRB} + K(L_k) - K(K_{IRB}) + (d \times K_{IRB}/\omega)\left(1 - e^{\omega(K_{IRB}-L_k)/K_{IRB}}\right) & \text{if } L_k < L_k \end{cases}.$$

7.4 *Appendix 4: Definition of the Simplified Supervisory Formula (Simplified SF) in the Changes to the Securitisation Framework (2004)*

The *Simplified Supervisory Formula* ("Simplified SF") fundamentally relies on slicing securitisation exposures into infinitesimally thin tranches ("ITTs") and combines the $\mathit{Risk\ Factor}(L_k) = (12.5 \times K_{IRB})/L_k$ as risk-weight for each ITT given K_{IRB} and $\mathit{Discount\ Factor}(L_k, N) = [(1 - L_k)/(1 - K_{IRB})]^{2\sqrt{N}}$, so that the risk-weight for a securitised position (tranche) $[L_k, L_k + T_k]$ can be approximately derived by averaging the risk-weights from the product of the *Risk Factor* and the *Discount Factor* at the boundaries. The *Simplified SF*

$$0.5\left(\frac{12.5 \times K_{IRB}}{L_k}\right)\left(\frac{1 - L_k}{1 - K_{IRB}}\right)^{2\sqrt{N}} + 0.5\left(\frac{12.5 \times K_{IRB}}{L_k + T_k}\right)\left(\frac{1 - L_k - T_k}{1 - K_{IRB}}\right)^{2\sqrt{N}}$$

could further be extended to an infinite i number of ITTs by conditioning thickness T_K by factor i/I. Note that this approach eliminates exposure-weighted average LGDs from the computation of the capital charge of unrated positions, so that two pools with the same K_{IRB} cannot potentially yield different capital requirements. Hence, in *Changes to the Securitisation Framework* the Basle Committee proposes subjecting N to a cap on its maximum value, mainly because a large effective number N of securitised exposures might yield substantially lower capital charges than the modified SFA; yet, this issue remains to be verified as to its material effects on actual transactions.

CHAPTER III: "ASSET PRICING IN SUBORDINATED LOAN SECURITISATION"

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1 ABSTRACT

Due to both inconsistencies in the regulatory definition of capital adequacy for credit risk and the quest for more efficient refinancing sources collateral loan obligations (CLOs) have become a prominent securitisation mechanism. This chapter presents a single-factor, loss-based asset pricing model for the valuation of constituent tranches within a CLO-style security design. The model specifically examines how tranche subordination translates securitised credit risk into investment risk of issued tranches as beneficial interests on a designated loan pool typically underlying a CLO transaction. We obtain the tranche-specific term structure from the simulation of an i.i.d. sequence of pairwise correlated defaults under both robust statistical analysis and extreme value theory (EVT). In this way, we decompose the securitised default generating asset value prices into a collection of state-contingent debt securities with divergent risk profiles and return expectations. Our estimation results suggest a dichotomous effect of loss cascading, with the default term structure of the most junior tranche of CLO transactions ("first loss position") distinctly different than that of the remaining, more senior "investor tranches". The first loss position carries large expected loss (with high investor return) and low leverage, whereas all other tranches mainly suffer from loss volatility (unexpected loss). These findings might explain why issuers retain the most junior tranche as credit enhancement to attenuate asymmetric information between issuers and investors. We also find that the issuer

discretion in the configuration of loss subordination within particular security design might give rise to implicit investment risk in senior tranches in the event of a systemic shock.

Keywords: securitisation, CLO, CDO, structured finance, default term structure

JEL Classification: C15, C22, D82, F34, G13, G18, G20

2 INTRODUCTION

2.1 The nature of loan securitisation

Asset securitisation – the substitution of market-based finance for credit finance – has recently developed into an efficient funding and capital management alternative for financial institutions and corporations. Conceptually, issuers of a typical asset-backed securitisation (ABS) structure achieve gains by converting regular and classifiable cash flows from a diversified portfolio of illiquid present or future receivables *(liquidity transformation* and *asset diversification process)* of varying maturity and quality *(integration* and *differentiation process)* into negotiable capital market paper ("tranches") with varying risk sensitivity and funding levels.[1] The tranches are sold to capital market investors either by the originator of the securitised assets/receivables or a non-recourse, single-asset finance company ("special-purpose vehicle" (SPV))[2] as subordinated beneficial interests on repayment proceeds from the designated portfolio. The method of payment and loss allocation to these contingent claims is subject to contractual risk sharing between the issuer and investors.

Both the ambivalence in the regulatory definition of capital adequacy for credit risk and the quest for more efficient risk-adjusted refinancing has urged banks to securitise large loan exposures by means of *collateral loan obligations* (CLOs), which represent an expedient structured finance technology that allows issuers to manage economic and regulatory capital costs efficiently. CLOs represent a specialised form of ABS, where investors acquire a structured claim on the cash flows generated from the repayment of interest and principal of a designated reference portfolio of bank loans (Herrmann and Tierney, 1999).[3] While ABS transactions typically involve large reference portfolios of fairly homogenous obligations, CLO transactions allow issuers to refinance large notional pools of a limited number of highly concentrated and heterogeneous credit risk exposures that they have

[1] These positions may take the form of fully/partially funded asset-backed securities or unfunded derivatives.

[2] In the latter case, the securitisation structure involves transfer of assets or the assignment of equitable accessory rights by the sponsor (i.e. the asset originator) to a SPV.

[3] See also Howard and Merritt (1997).

either originated themselves *(balance sheet CLO)* or bought specifically for the purpose of profitable re-packaging of investment exposures *(arbitrage CLO)*. Issuers value this type of loan securitisation not only as an alternative[4] financing tool but also as an efficient structure of credit risk transfer,[5] for reasons mainly to be found in economic capital relief and increased liquidity through alternative market-based financing *(financial objectives)*, improved diversification capabilities *(hedging and risk management objectives)*, enhanced balance sheet management and restructuring opportunities *(accounting objectives)*, optimisation of minimum capital requirements (regulatory capital) required bank regulators *(regulatory objectives)*, mitigation of agency costs of asymmetric information between issuers and external financiers *(capital structure choice)*, lower *agency costs of asymmetric information* in external finance (e.g. "underinvestment" and "asset substitution") and qualitative objectives, such as external effects on corporate ratings and reputation. *Financial objectives*, including tax optimisation, efficient refinancing cost, rating arbitrage as possible incentives, and *hedging and risk management* objectives, such as the diversification of default risk, liquidity risk, interest rate risk and currency risk, are probably the most prominent motives of loan securitisation. By subjecting bank assets to market scrutiny, loan securitisation also facilitates prudent risk management as an effective method of redistributing credit risks to investors and broader capital markets through issued debt securities (Morris and Shin, 2001).

However, since loan securitisation blends asset pricing features of both securitised assets ("credit risk component") and liquid fixed income securities ("security component"), lending relationships might imply private information of asset originators. Issuers commonly adopt contractual measures to mitigate the agency cost of asymmetric information. In a typical CLO transaction structure, the loan originator or a non-recourse single-asset entity (SPV),[6] issues two classes of securities *(tranches)* through actual or synthetic credit risk transfer: debt securities and a first loss position ("equity piece"). While capital market investors receive subordinated debt-like notes as prior claims to the underlying reference portfolio, the issuer commonly retains a residual equity-like class as first loss position *(credit enhancement)* to avert *ex ante* moral hazard and possible adverse selection similar to the

[4] Asset funding through loan securitisation frequently edges out over other funding options available to banks, as the flexible design of ABS structures affords issuers (i) to match the duration of their managed assets and liabilities more closely as well as (ii) customise the transaction structure in order to cater to different investment risk-return appetites. See also Telpner (2003), Zweig (2002), Altrock and Rieso (1999), Everling (1999), Eck (1998), Kohler (1998), Kravit (1997), Cumming (1987), Kendall (1996) and Frankel (1991).
[5] See Bank of England (1989) for an early assessment of risk transfer in asset securitisation and derivative transactions. See also Edwards (2001) and Bund (2000a and 2000b).
[6] If no SPV is used in the administration of the securitisation transaction the sponsoring entity, i.e. the loan-originating financial institution, is also the issuer of the transaction. In the course of this chapter we make no distinction between different types of transaction structures with or without the involvement of an SPV.

"lemons problem" (Akerlof, 1970).[7] Depending on the security design and the kind of securitised asset type, rating agencies commonly require issuers to provide *credit enhancement* through first loss provisions and/or other forms of credit support (e.g. default loss subordination) to cushion investors against potential *ex ante moral hazard* issuers might induce by including poorly performing loans in the transaction in absence of full investor information about securitised loans.[8] Since credit enhancement mainly guards against adverse information constraints originating in the *credit component* of loan securitisation, the risk sharing mechanism between the issuer and investors *(security component)* becomes the decisive element of investment risk in securitisation. Hence, the economic assessment of loan securitisation primarily depends on how a given security design translates the performance of securitised credit risk[9] into the default term structure of issued asset-backed securities. Since issuers choose from a vast variety of transaction structures[10] to subdivide and redirect cash flows and losses from the repayment of securitised assets in a reference portfolio, the transmission between the securitised asset performance and investor returns as contingent claims is acutely relevant for the valuation of CLOs. Given increased regulatory interest in the degree of unexpected risk (loss volatility)[11] in leveraged structured finance investments, we offer a methodology to translate securitised credit risk into investment risk of structured claims as a promising exercise to promote informed investment.

[7] *Credit enhancement* represents the varying willingness of issuers to securitise only part of the structured claim on the selected loan portfolio and retain a marginal equity claim on some portion to provide capital cover for all expected losses. Issuers buy back the most junior securities, while capital market investors hold the remaining tranches of the securitisation transaction. Alternatively, such credit enhancement could also take the form of a standby letter of credit to the securitisation conduit, or by the sponsoring bank. The provision of credit enhancement exposes issuers to some of the default risk of non-performing loans. Since issuers pass on remaining asset claims to capital market investors, any credit enhancement establishes a "collateralisation" of the securitisation transaction. Issuers bear some "sure loss" of concentrated credit risk in the form of credit enhancement, while the risk of corresponding changes in expected losses is implicitly transferred to outstanding claims on the loan portfolio held by outside investors. Hence, it is interesting to analyse the effect of the default term structure of the transaction (which in turn depends on the loss function of the underlying loan pool) on the investment risk securitised debt.

[8] The Basle Committee on Banking Supervision (2002) defines *credit enhancement* as a contractual arrangement in which the bank retains or assumes a securitisation exposure and, in substance, provides some degree of added protection to other parties to the transaction. [...]." See also Basle Committee (2001, 2004a and 2004b). If credit enhancement is achieved through subordination, issuers retain the most junior tranche as "equity tranche", which bears all first losses of the transaction.

[9] Skora (1998) defines credit risk as the risk of loss on a financial or non-financial contract due to the counterparty's failure to perform on that contract. Credit risk breaks down into default risk and recovery risk. Whereas default risk denotes the possibility that a counterparty will fail to meet its obligation, recovery risk is the possibility that the recovery value of the defaulted contract may be less than the promised repayment amount.

[10] Note that the flexibility of issuers to devise a particular security design bears the risk of asymmetric information between issuers and investors as to the default term structure of issued tranches.

[11] Especially since 2001 loan distress in the high-yield structured finance market has focused attention on the issuer's ability to cover expected losses through credit enhancement and, at the same time, avert disproportionately high levels of loss volatility borne by capital market investors due to substandard asset performance.

2.2 Research objective

The main objective of this chapter is to estimate the default term structure and the fair pricing of default sensitive contingent (debt) claims *(tranches)* held by risk-neutral investors in a typical CLO-style loan securitisation transaction on a pooled multi-asset reference portfolio of defaultable exposures. We evaluate, on the basis of a common CLO security design, how the loss sharing effects between issuers and investors through tranche subordination transpose credit risk of securitised assets into investment risk of contingent debt.[12] For this approach to be viable, we equally privilege both the accurate estimation of portfolio credit risk and the distinctive security characteristics of securitisation. Although investors should expect the same returns for similar credit risk exposure in plain vanilla corporate bonds or securitised debt (i.e. tranches), these investment alternatives differ in the way they are valued in response to changes of the underlying (reference) asset. Tranche subordination creates leveraged investment,[13] which makes the risk-return profile of CLO investment different from direct investment in the underlying portfolio. Hence, the seniority and thickness of tranches according to a specific security design imply varying degrees of credit risk leverage of each constituent tranche. Since subordination renders leveraged securitised debt highly sensitive to value changes of a precisely defined reference portfolio (unlike corporate bonds, whose the underlying asset is far less scrutinisable),[14] it is essential to evaluate securitised debt claims at higher confidence levels (i.e. extreme quantiles) of expected loss. Moreover, efforts to diversify as much idiosyncratic risk as possible within a reference portfolio of securitised exposures make CLO tranches (with substantial systematic risk exposure) highly vulnerable to extreme event scenarios associated with systemic shocks. Consequently, the analysis of extreme loss quantiles registers as a vital step towards the accurate estimation of investment risk in loan securitisation. The approximation of large losses at very low tail probabilities requires the specification of a limit law that incorporates the occurrence of extreme values. General limit loss distributions in many existing credit risk models rely on imprecise information about tail properties and fail to capture the empirically stylised fact of heavy-tailed loss

[12] Asset pricing of securitised debt could be approached either from the perspective of (i) *cash flows* generated from the reference portfolio <u>or</u> (ii) *expected losses* from creditor default. Most models in the literature concentrate on the upside of loan securitisation, i.e. the cash flow modelling of distributable interest and principal proceeds to be had from the securitised loan pool (Childs et al., 1996). However, we choose to analyse the default term structure and the value of loan securitisation transactions from the perspective of credit risk by modelling the loss side. By extending accepted principles of asset pricing we derive a default term structure of expected losses, which entail certain credit spreads for the various tranches of a securitisation transaction as investment risk premium.

[13] The lower the level of seniority the higher the ratio of relative (expected and unexpected) losses per tranche (for a given tranche size) to expected portfolio losses (for a given portfolio size) and the higher the portion of expected losses in overall tranche losses.

[14] Payments on securitised debt come from the designated assets backing the debt and not the issuer and they do not capture gains from future investment unlike corporate (unsecured) debt.

distributions.[15] *Extreme value theory* (EVT) is concerned with the modelling of the limiting behaviour of sample extremes beyond historical inference. EVT focuses exclusively on the asymptotic tail shape of loss distributions as a canonical theory of deriving parametric estimates as limit laws for standardised (ordered statistics) maxima of loss generating asset value processes.[16,17] Hence, we postulate *EVT* as an appropriate complementary to the normality paradigm to gauge credit losses at very high levels of confidence based on precise information about the tail behaviour. Moreover, due to the diversified nature of securitised credit risk we couch extreme value analysis in a portfolio-based estimation of loss quantiles in line with the recent credit risk models.

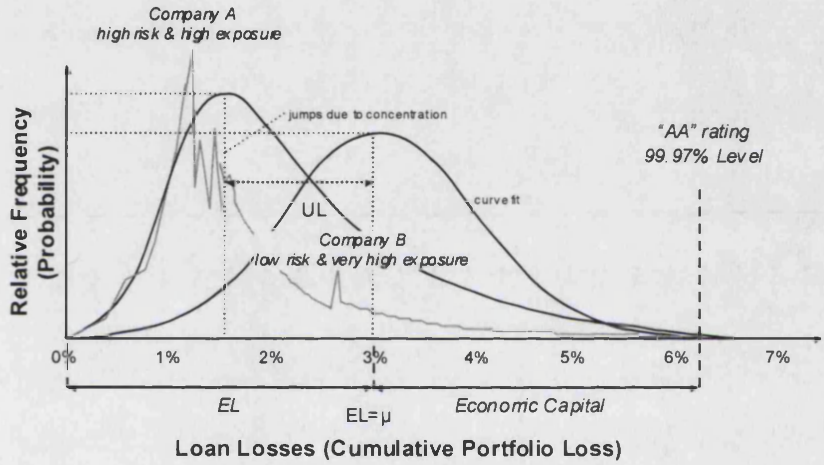

Fig. 1. *Empirical cumulative distribution function of corporate credit portfolio losses.*

Our single-factor, loss-based asset pricing model of CLO tranches as contingent claims held by risk-neutral investors on securitised credit exposures breaks down into three methodological steps. First, in keeping with the diversified nature of securitised debt we generate Monte Carlo simulated random default losses from a pre-defined loss function of an infinitely granular reference loan portfolio with an i.i.d. periodic default process, where a single systematic risk factor drives aggregate (uniform)

[15] If extreme loss quantiles of actual loss distributions suggest a higher frequency of extreme default losses than what could be inferred from the normality paradigm, greater loss volatility warrants an overhaul of conventional portfolio modelling techniques with robust statistical analysis on normally distributed credit losses. Extreme events enter very naturally for a proper understanding of the actual loss distribution function in keeping with the stylised facts of econometrics: market data returns tend to be uncorrelated but dependent at random volatility. Their distribution functions are heavy tailed, with extremes appearing in clusters (Embrechts et al., 2001b).

[16] These maxima would be deemed insignificant outliers in robust statistics of limit distributions with exponentially declining tails.

[17] EVT has claimed prominence in financial research as it complements Value-at-Risk (VaR) measures of risk by making specific assumptions about the tail properties of a loss distribution independent of the overall loss distribution. Note that EVT-based estimates of extreme quantiles should not be viewed in isolation of

default at constant between-asset default correlation.[18] Second, we subject estimated losses to a simplified subordination mechanism commonly found as one form of credit enhancement in CLO transactions, which yields tranche-specific default term structures of expected and unexpected losses over the specified lifetime of the transaction. This approach allows for the decomposition of a CLO transaction into a collection of simpler default sensitive debt securities with divergent risk profiles and expected investor returns. Since the size and seniority of tranches constitutes the subordination routine of loss allocation, the estimated default term structure of individual tranches reflects the transmission mechanism implied by the chosen security design of securitisation. We derive the default term structure under both robust statistics and extreme value analysis for converging tail behaviour of loss severity distributions. This produces more reliable approximations of investment risk of asset-backed securities than previous studies. However, our analysis is not informed primarily by the comparative distinction of different loss functions, but the leverage and transmission effect of subordination on the default term structure of securitised debt at time-varying portfolio quality. Third, the accumulated loss severity of each constituent tranche, discounted by some stochastic risk-free interest rate, determines the return investors would expect as risk-neutral compensation for the estimated default term structure. Since we do not control for the market risk premium of defaultable debt under the risk-neutral measure, we compute "quasi risk-neutral" returns as *physical* discount measure for expected periodic credit loss.

Our findings suggest a dichotomous effect of *loss cascading* on investment risk in loan securitisation, with the most junior tranche of CLO transactions exhibiting a distinctly different default tolerance of unexpected losses than the remaining tranches, becoming more pronounced as the likelihood of extreme loss events increases. Based on this observation, our model delivers a plausible rationale as to why issuers generally retain the most junior tranche as credit enhancement. So far, none of the existing models – even at a possibly more rigorous econometric level with time-varying asset and/or default correlation – have been able to explain the riskiness of first loss provision in response to variations in estimation parameters (e.g. varying portfolio quality, periodic and cumulative expected

estimates from robust statistics of limit distributions, so charges against EVT (Lucas et al., 2002) as an overly sensitive measure to rare events appear overdone.

[18] Since we assume individual risk being perfectly diversified in a pool of a sufficiently large number of independent risks, uniform credit loss exposures with constant pairwise correlation approximate loss estimates under any recent portfolio credit risk measure. Note that over the recent past a portfolio view on credit losses has evolved from the bulk of past research in credit risk management, which mainly concentrated on assessing credit risk of individual exposures in isolation without taking into account co-movement of changes in credit quality and default correlation (Caouette et al., 1998). In spite of the wide variety of portfolio (credit) risk models (see section 3), they all share a common framework of general dependencies of credit risk factors if we considered an infinitely granular portfolio with only one systematic risk factor (Gordy, 2000). See also Koyluoglu and Hickman (1998). We also use a normal inverse distribution (NID) as a conventional approximation for losses given these portfolio assumptions.

and unexpected losses, as well as constant vs. stochastic risk-free discount rates). Moreover, upon imminent changes to the Basle Accord on the regulatory treatment asset securitisation according to the so-called *Securitisation Framework* (Jobst, 2005; Basle Committee, 2004a and 2004b) in 2006,[19] our methodology aids a reasonable estimation of investment risk implied in structured claims on defaultable assets.

3 LITERATURE REVIEW

3.1 Reasons for asset securitisation

Although there is not a single theory that exhaustively explains the economic nature of loan securitisation, research in asset securitisation has so far entertained a diverse range of *corporate finance*-based arguments for securitisation as an efficient means of external finance: (i) issuers exploit private information about securitised assets as a way to mitigate the regulatory capital charge and achieve greater specialisation in areas of comparative advantage (Greenbaum and Thakor, 1987), (ii) issuers avoid asset substitution and underinvestment as they appropriate partial debtholder wealth by carving out a defined portion of pooled assets to satisfy securitised debt (James, 1988; Benveniste and Berger, 1987; Stulz and Johnson, 1985), and (iii) issuers reduce the agency cost of asymmetric information if securitised debt constitutes a safer claim than other forms of external finance (Barnea et al., 1981; Myers and Majluf, 1984). According to Greenbaum and Thakor (1987), private information held about the quality of originated assets would induce financial institutions to prefer securitising better quality (but "regulatory overcharged") assets to mitigate regulatory capital requirements, whilst retaining worse quality assets. For this selective bias to be economically sustainable, issuers must be able to extract positive payoffs from trading off the benefits of securitising low-risk asset exposures with an *ex ante* increase of bankruptcy risk due to higher residual on-balance sheet risk. Private information might also find an outlet in securitisation if issuers aim to achieve greater specialisation in sourcing and monitoring as areas of comparative advantage (Millon and Thakor, 1985).

Asset securitisation might also redress conflicts of interest between creditors and shareholders of firms and associated agency cost induced by risky debt, which would otherwise result in suboptimal investment decisions. James (1988) as well as Benveniste and Berger (1987) show that securitisation tranches resemble secured debt, whose agency cost (from monitoring as well as underinvestment and

[19] See also Basle Committee (2003, 2002a, 2002b, 2001a and 2001b).

asset substitution) may be lower than for unsecured debt (Stulz and Johnson, 1985).[20] Similar to secured debt, securitisation allows issuers to appropriate partial debtholder wealth by carving out a defined portion of pooled assets (i.e. the "reference portfolio") to satisfy securitised debt claims. This prioritisation of debtor claims potentially alleviates underinvestment and renders existing debt less inhibitive on the realisation of new investment opportunities.[21] Since securitised debt does not capture gains from the firm's future investments,[22] it does not contribute to asset substitution unless the use of funds generated from the securitised debt increases the overall riskiness of the issuer by more than what would be warranted to offset underinvestment. Hence, the possible resolution of agency problems of underinvestment and asset substitution in the capital structure choice need to be qualified as to whether securitised debt actually increases firm value and make existing bondholders better off.[23] Any positive effect from the appropriation of debtholder wealth ultimately depends on the way the investment policy of entrenched managers guides the riskiness of the use of securitisation proceeds relative to the *ex ante* riskiness of the issuer.

The use of securitised debt finance constitutes a "nested capital structure decision" whose possible effect on claimholder expropriation depends on the investment policy choice of the issuer. On one hand, the absence of bond covenants to restrict the use of proceeds from securitised debt allows issuers to extract debtholder wealth. Issuers could securitise low risk assets to (i) undertake riskier future investment activities or (ii) pay out securitisation proceeds directly to shareholders at the expense of diluted bondholder claims ("asset substitution"). On the other hand, asset securitisation would put non-value-maximising issuers in a position to monetise balance sheet assets for negative present value investment projects without disciplinary effects of poor performance. Aside from excessive asset substitution, debt repayment from securitisation proceeds further reduces shareholder wealth.[24,25] Consistent with conventional thinking about the capital structure choice, issuers with high

[20] See also Berkovitch and Kim (1990), who find that secured debt lowers the adverse effect of debt finance on firm value in terms of underinvestment.
[21] Additionally, the agency cost of securitised debt might be lower than the cost of bank borrowing and bond debt, mainly because securitised debt does not carry restrictive bond covenants and might be easier to negotiate as it is removed from the conventional capital structure choice. Although reference portfolios underlying securitised debt are heavily scrutinised by rating agencies, with debt claims backed by payments from the reference portfolio backing the transaction and not the issuer, debt holders require less information about the issuing firm than unsecured debt holders of corporate bonds.
[22] Nonetheless, the defined payment stream to investors of securitised debt could directly depend on the business performance of the issuer, such as in whole business ABS and captive finance ABS.
[23] Stulz and Johnson (1985) find that existing debtholders can be made better off by the issuance of secured debt if the financing decision is accompanied by a positive change in investment policy.
[24] See Lang et al. (1995), who argue that asset sales may allow managers to pursue poor projects by creating liquidity for investment. See also Pennacchi (1988).
[25] Alternatively, issuers might also reduce capital market discipline by using securitisation proceeds to lower existing debt (to the detriment of future equity payouts), whose negative effect on shareholder value could be

agency costs of debt (which implies high financial leverage and/or financial distress) and/or low growth prospects have higher incentives of asset substitution and a higher chance of underinvestment. They should be more likely to engage in asset securitisation. Any negative effect of shareholder expropriation by suboptimal investment should increase the higher (lower) the securitisation proceeds (growth prospects).

We also need to investigate the impact of asset securitisation on the capital structure decision from a funding perspective under asymmetric information, which necessarily involves a closer inspection of both the *pecking order theory* and the *trade-off theory*. The *trade-off theory* postulates that managers choose a leverage level where the marginal benefits of debt, such as the interest tax shield, just about outweigh the costs of debt, including agency and financial distress costs ("optimal trade-off").[26] In contrast, the *pecking order theory* (Myers and Majluf, 1984), states that firms prefer internal to external finance due to adverse selection arising from information asymmetry in financial relationships between insiders and outsiders.[27] If external funds are needed to undertake a profitable investment project, firms choose the safest claim (which involves the lowest degree of asymmetric information). Without asset securitisation, the pecking order theory suggests that firms with high internal refinancing cost and low bankruptcy cost generally prefer debt to equity because of lower information costs from valuation uncertainty.[28] However, this form of external finance increases both the balance sheet

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exacerbated by less market monitoring of secured debt as opposed to unsecured debt. See also Lockwood et al. (1996).

[26] Barnea et al. (1981) define this consideration as the optimal trade-off between the agency costs of debt and the benefits associated with different financial contracts in terms of their inherent capacity to resolve agency problems and tax exposure.

[27] In Myers and Majluf (1984) managers have superior knowledge about the value of the firm and act to maximize shareholder value. Due to asymmetric information rational potential investors ("outsiders") would discount the value of any security issue. See also Myers (1977 and 1984).

[28] Hence, rational investor behaviour compels managers to qualify their capital structure choice on actual firm value. Managers are more likely to prefer debt (equity) if they believe the firm to be undervalued (overvalued). In recognition of these strategic alternatives investors would perceive an equity issue an indication of poor quality, which increases the cost of issuing equity. So the hierarchy of funding alternatives in line with the pecking order theory would suggest that firm issue equity only after the chances of issuing debt or hybrid securities, such as convertible bonds, have been exhausted. In accordance with the modified pecking order theory (MPOT) the following empirically testable hypothesis for managerial capital structure decisions would ensue: (i) avoidance of external equity and risky debt, (ii) dividend policies which can be maintained by internally generated equity, (iii) the maintenance of financial slack, and (iv) the acquisition of additional funds with risky debt rather than new equity, given "sticky" dividend payout and variable investment opportunities. These ideas were later refined by Shyam-Sunder and Myers (1999) into a key testable prediction, which states that the incidence of the pecking order in the capital structure decision of firms should yield a strong correlation between net debt issues and the financing deficit of firms.

volume and the debt-to-equity ratio,[29] causing a higher financial distress cost and higher marginal cost of funding.[30]

If issuers face high capital costs of internal funds and severe asymmetric information problems the issuance of asset-backed debt securities registers as a viable source of external refinancing, which comes closest to internal funds in terms of agency cost.[31] Securitised debt may be considered safer than unsecured debt,[32] since investors in securitisation transactions do not directly capture gains from the issuer's reinvestment of funds received from the issue, but receive payment directly from a designated pool of asset exposures insulated from the issuer[33,34] The *trade-off theory* would restrict the assumption of external debt finance to those cases only where the issuer's capital structure reflects an optimal balance of the benefits and drawbacks associated with the agency cost of debt under asymmetric information. So both the pecking order theory and the trade-off theory suggest that asset securitisation is the structured finance instrument of choice for issuers with over-stretched internal funds, and whose high on-balance sheet funding costs, possibly substandard credit (ratings) and high agency costs of asymmetric information debar them from other forms of external finance.[35]

3.2 The valuation of CLO transactions: security design and credit risk management

Despite the abundance of theoretical and empirical research on the motivation of asset securitisation from a corporate finance perspective, gauging investment risk in structured finance has only recently engendered academic interest in the valuation of CLO transactions. The assessment of investment

[29] Furthermore, the credit rating of the newly issued securities may be capped at the issuer's rating.
[30] As existing creditors would command higher debt returns at a higher leverage ratio, the consolidated credit linkage of the unsecured debt to the originator (unlike in off-balance sheet transactions) raises the cost of funding.
[31] Furthermore, the off-balance sheet characteristic of securitisation allows refinancing at a potentially lower cost than equity without attendant balance sheet growth.
[32] This theoretical observation implies a property of securitised debt, which should be most attractive for small corporate and SME issuers, whose firm value is hard to assess.
[33] The straightforward calculation of future cash flows from accrued repayment in a diversified asset portfolio replaces the assessment of the overall business risk and the income generating potential of the issuer.
[34] Also the thorough scrutiny by rating agencies of securitised asset-backed debt claims adds to this assessment.
[35] Issuers can refinance defined asset exposure at lower cost due to a possibly higher standalone rating of secured debt. If the rating of asset-backed securities might supersede the issuer rating thanks to superior quality, securitisation tranches could be sold at tighter spreads and higher prices. This rating effect (*"upgrading"*), known as *credit risk arbitrage* (Bär, 1998 and 1997; Röchling, 2002), stems from mainly from two sources. For one, after issuers parcel out high quality assets or shed defined risk exposure from their risky core business, the issued debt securities are solely supported by the cash flow from underlying reference portfolio (and any asset protection if available) without interference on part of the asset originator, leaving the rating assessment largely unaffected by counterparty risk. Second, if assets are securitised through a true sale transaction, the legal title is irrevocably transferred to investors (via a SPV). This transaction structure precludes any recourse or economic interest on part of the originator. See also Cantwell (1996).

risk of CLO transactions requires a closer inspection of how security design and the risk of securitised credit exposures affect beneficial investor interest. A comprehensive asset pricing methodology in this area would need to transcend three major areas of finance research:[36] (i) *estimation and pricing of (portfolio) credit risk* (Jarrow et al., 1997; Jarrow, 1996; Zhou, 1997 and 2001; Lucas et al., 2001b; Lo and Davis, 2001),[37] (ii) *security design and asset liquidity* (DeMarzo and Duffie, 1997 and 1999; Bhasin and Carey, 1999),[38] and (iii) *information economics in asset securitisation* (Jobst, 2003b; Duffie and Gârleanu, 2001 and 1999; Duffie and Singleton, 1999 and 1998; Riddiough, 1997).[39]

In recognition of agency costs from claimholder expropriation and asymmetric information in the capital structure choice, many theoretical models explain the economic rationale and pricing of asset securitisation on the grounds of an efficient risk sharing mechanism between issuers and investors on the performance of a predefined asset pool. Several asset pricing models have attempted to gauge investment risk of asset-backed securities on the basis of an optimal security design. DeMarzo and Duffie (1999 and 1997) assert that issuers of securitised debt can overcome the "lemons problem" (Akerlof, 1970) of asymmetric information associated with the sale of illiquid assets by bundling and re-packaging payment claims from asset exposures into a basket of different classes of subordinated tranches as collateralised contingent claims (Jobst, 2003a).[40] Riddiough (1997) confirms information benefits from subordinated security design on the grounds of the non-verifiability of liquidation motives if subordination allows issuers to internalise some or all of the adverse selection risk, which would otherwise apply in a straightforward asset sale.[41] Issuers would appropriate economic rents from their information advantage about asset quality depending on the degree of subordination and their willingness to retain the most junior claim *(credit enhancement)* on the performance of securitised

[36] Also fundamental principles of financial intermediation and underwriting (Diamond and Rajan, 1998; Gande et al., 1999; Gorton and Pennacchi, 1995; Diamond, 1991; Allen, 1990) are of tangential importance in this case.
[37] see Caouette et al. (1998) for an overview. See also Allen and Gale (1995)
[38] see also Clemenz (1986), Bolton and Scharfstein (1990), Rajan (1992), Holmström and Tirole (1998), Park (2000) and Wolfe (2000) in this regard.
[39] In a more comprehensive approach also issues of market structure and competition (Oldfield, 2000) would need to be taken into account.
[40] The par value of these tranches depends on designated coupon and pro-rated principal payments from expected cash flows of the securitised assets ("reference portfolio") as well as the level of prepayments and asset default. Most asset securitisation transactions also include financial securities generating regular income or other financial commitments to additionally "collateralise" these proceeds from the reference portfolio.
[41] Packaging strategies, such as pool diversification and loan bundling, amplify the subordination effect and increase "liquidation proceeds" from the reference portfolio (Riddiough, 1997). Additionally, further structural elements of the typical the CLO security design, such as early amortisation triggers and credit risk coverage, help avert possible mispricing of loan securitisation due to private information.

assets.[42] Childs et al. (1996) propose a structural model for pricing commercial mortgage-backed securities (CMBS) through Monte Carlo simulation of a portfolio of individually correlated mortgages in order to derive an optimal security with asset retention by the issuer.[43]

More recently, the default-based valuation of securitised debt has benefited from the emergence of portfolio credit risk models, which assume a stochastic process of asset value change and default-correlated credit risk exposure. Past research in this area has generated a wide range of different structural approaches (Black and Cox, 1976; Brennan and Schwarz, 1978; Leland, 1994 and 1998), which can be broadly classified into three categories (by mathematical technique used): (i) *standard intensity-based models*,[44] (ii) *copula models*[45] and (iii) *Markov chain*[46] and *contagion models*.[47] Industrial applications have simplified these approaches into endogenous models (e.g. credit migration approach and structural approach), actuarial models and econometric models.[48] Many of these

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[42] Riddiough (1997) claims that a junior claim has a vital function as credit risk protection in the security governance of asset-backed securities, mainly because it allows issuers to use better asset value information about securitised asset exposure by retaining the credit enhancement to issue completely risk-free security on the proceeds of the reference portfolio. Moreover, this bid for an efficient design of asset-backed securities proves to be robust if junior security holders control the debt negotiation process with pooled debt structures.

[43] Childs et al. (1996) aggregate the value of each mortgage in order to determine the available amount of asset proceeds supporting each class of debt securities issued as contingent claims on the performance of the reference portfolio.

[44] *Standard intensity-based models* determine credit risk with conditionally independent defaults (Duffie and Singleton, 1999; Lando, 1998) or correlated defaults in the case of an intensity-based approximation of default-correlated assets as in Egami and Esteghamat (2003). See also Zhou (1997 and 2001) who proposes an analytical formula for calculating default correlations based on a "first-passage-time model" of correlated firm values. Lucas et al. (2001b) refine this stream of research by suggesting a factor model for an infinite number of individual exposures as an analytic characterisation of the credit loss distribution. See also Basle Committee (1999, 1993 and 1991).

[45] In *copula models* the marginal distributions of asset exposures and the dependence structure between them are specified separately in a multivariate distribution, i.e. the copula distribution function couples a joint distribution function with its univariate margins. Many useful properties of copulas include uniform continuity and existence of all partial derivatives. Nelsen (1999) provides a good introduction to the copula approach. See also Li (2001) and Embrechts et al. (2001a and 2001b). For instance, Schönbucher and Schubert (2001) present a copula-based model, which allows a specification of the joint dynamics of credit returns and default intensities beyond the assumption of normal (i.e. Gaussian) dependence. This approach also includes a specification of the infection dynamics which cause credit spreads to widen at defaults of other obligors.

[46] *Markov (chain) models* use the dynamics of credit ratings as an indicator of default probability. However, existing Markov models cannot be applied to the evaluation of credit-sensitive asset portfolios. Kijima et al. (2002) present a single-index, multivariate Markov chain model with counterparty risk to simulate default probabilities through the dynamics of correlated credit ratings of multiple firms. See also Jarrow et al. (1997) for a multivariate Markov model for the term structure of credit risk spreads.

[47] Davis and Lo (2001) develop a multivariate Markov model for *collateralised bond obligations* (CBOs). They quantify default correlation in medium-sized bond portfolios in terms of *contagion*, which stems from an intra-industry "infection mechanism".

[48] *Endogenous* credit risk models are specified either by the *credit migration approach*, which measures default risk by means of the rating transition probability of assets within a given time horizon (*CreditMetrics* by Gupton et al., 1997), or the *option pricing approach/structural approach*, which generates a "distance-to-default" measure from the probability of firm value to fall below some critical level. This asset value model originally proposed by Merton (1974) assumes that the capital structure of a given firm follows an endogenous default process. See also Wall and Fung (1987), Iben and Brotheron-Ratcliffe (1994) as well as Duffee (1996), who discuss credit risk as it

models have been used to derive a default-based valuation of asset securitisation transactions, such as an intensity-based approximation of defaults within a jump-diffusion process of a securitised loan pool (Egami and Esteghamat, 2003) or with default correlation from Moody's diversity score (Duffie and Gârleanu, 2001).[49] Egami and Esteghamat (2003) approximate the value of a basket of default-correlated debt assets in *collateralised debt obligations* (CDOs) by means of calibrating a pricing model to a pure intensity-based simulation of defaults. Duffie and Gârleanu (2001) employ the diversity score approach devised by rating agencies to calculate the default intensity processes for single debt obligations. They extend the estimation of individual asset exposure to obtain the aggregate default intensity of a portfolio of securitised assets in a similar analytical form before simulating efficient prices of subordinated security classes (tranches). However, many straightforward loss-based pricing methodologies of *collateralised debt obligations* (CDOs) and alternative asset pricing techniques[50] are scarce or at least contentious (Fidler and Boland, 2002), mainly because the valuation of contingent claims on the performance of multi-asset portfolios defies a closed-form solution in most cases. While analytically tractable pricing models with common risk factors (Gibson, 2004) tend to be overly simplistic, simulative robust statistical analysis (of standard intensity-based models) attributes little probability to extreme loss scenarios.

In this chapter, we offer a new contribution to traditional valuation models of asset-backed securities. We incorporate extreme loss events in a single-factor, default-based asset pricing method of subordinated contingent claims on an infinitely granular multi-asset portfolio of securitised assets with constant pairwise default correlation, assuming general dependencies of credit risk factors. We depart from the normality paradigm and attach more weight to the limiting (tail) behaviour of extreme losses in order to account for the high risk sensitivity of leveraged investment in subordinated debt structures.[51] We find that the analytical latitude of estimating the sensitivity of the tranche-specific default term structure to changes in the periodic default rate under different limit

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applies to portfolio risk management. The *actuarial approach* applied by Credit Suisse in *CreditRisk+* (Credit Suisse Financial Products, 1997) only focuses on default for individual bonds or loans, which is assumed to follow an exogenous Poisson process. Finally, the *econometric approach* proposed in *CreditPortfolio View* by McKinsey (Wilson, 1997a and 1997b) follows a discrete time multi-period model, where default probabilities are conditional on macroeconomic variables. See also Hamerle and Rösch (2004) for an interesting approach in how these industrial applications of structural credit risk models could be reconciled in new parametric credit risk model with maximum likelihood estimation.

[49] Note that Gibson (2004) presents an analytical pricing model of synthetic CDOs without the use of Monte Carlo simulation of asset defaults by assuming asset default correlation to be driven by a known diffusion process of a single common factor.

[50] Fidler and Boland (2002) issue critical comments on existing asset pricing methodologies of asset securitisation.

[51] The reason for extreme value theory (EVT) as a methodology is straightforward. In the course of proper asset pricing of leveraged contingent claims on a defined loan pool with a defined credit event extreme value analysis enters very naturally in order to examine how security design provisions impact on investment risk.

distributions (NID and EVT) in a simulative approach overwhelms the benefit of analytical reliability of static, closed form pricing models (Gibson, 2004). For a given default profile of tranche-specific expected losses, we compute the compensatory return of risk-neutral investors by reversing Jarrow and Turnbull (1995) and Leland and Toft (1996), who back out an arbitrage-free pseudo-probability of default from the term structure of credit spreads of corporate bonds.[52] In this way, we decompose subordinated claims into a collection of simpler, state-contingent debt securities with divergent risk profiles and return expectations on the basis of fixed and stochastic[53] risk-free discount rates.[54]

The rest of the chapter is organised in six sections. We present the model specification of a loss-based valuation of subordinated CLO tranches as a phased integration of three analytical steps. First, we simulate aggregate default losses under extreme value analysis and robust statistical analysis based on a one-factor asset value model at constant and time-varying periodic default probability. Subsequently, we allocate the estimated default losses to constituent tranches according to the subordinated security design. In the third part, we derive tranche-specific default term structures, which imply the compensatory return risk-neutral investors would expect from holding these securities.[55] Then we complete a "reality check" of our estimation results. We draw on the "adjusted short rate approach" of credit spread modelling (Duffie and Singleton, 1999) to benchmark the default term structure of CLO tranches to zero-coupon bonds at matched moments.[56] In the penultimate section, we analyse the relationship of expected and unexpected losses as well as the leverage of investment returns across tranches with different seniority. Finally, in a post-simulation assessment, we discuss incentives for both issuers and investors to acquire certain tranches on the

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[52] This approach is similar to, though econometrically different from, Jarrow et al. (1997), who introduce a univariate Markov model for the term structure of credit risk returns, where rating agencies' default rates and bond prices serve as input variables, so that investors' risk premium can explicitly estimated for static and variable risk-free interest rates. See also Arvanitis et al. (1999) as well as Madan and Unal (1998).

[53] Das and Tufano (1996) price credit-sensitive debt on the basis of stochastic interest rates, credit ratings and credit spreads. See also Ramaswamy and Sundaresan (1986). In pricing contingent claims on default-correlated assets, we also incorporate specific considerations, which have emerged in discussions of credit risk modelling in Cossin (1997), Madan (1998) as well as Madan and Unal (1994). For further information in context of gauging the impact of credit risk on structured finance instruments, we refer readers to Hull and White (1995) as well as Cooper and Martin (1996), who make several important observations about credit risk and how it affects the price of over-the-counter derivatives. With respect to credit risk hedging, readers might find it worthwhile to consider Sorensen and Bollier (1994) for a practical explanation of pricing the credit risk in an over-the-counter swap.

[54] Additionally, we rely on other research along the lines of the so-called "yield spread approach" by Litterman and Iben (1991), Das and Tufano (1996), Artzner and Delbaen (1994), Nielsen and Ronn (1996) as well as Duffee (1996).

[55] We also use of a stochastic discount rate as an extension to the valuation of tranche returns for risk-neutral investors.

[56] See also Bielecki and Rutkowski (2000), Pugachevsky (1999) as well as Balland and Hughston (2000). See also Duffie (1996).

theory of information asymmetries. In conclusion, we revisit important findings and propose to possible extensions.[57]

4 MODEL

4.1 Loss distribution of a uniform reference portfolio

As the first component of the CLO pricing model, we specify the distribution function of default losses in the securitised reference portfolio. For this purpose, we resort to a normal inverse distribution and a quasi-Pareto distribution from extreme value theory to simulate the loss profile of a perfectly diversified reference portfolio of credit exposures. In keeping with past attempts to simulate the credit risk of standard (bank) loan portfolios, we assume individual risk to be perfectly diversified in an infinitely granular portfolio, so that we can consider the reference portfolio to be of uniform credit risk with equal pairwise asset correlation. Once we have computed expected and unexpected losses, we determine the periodic default losses for the transaction and the constituent tranches by means of a certain loss allocation routine.

4.1.1 Normal inverse distribution (NID)

Standard credit portfolio models suggest that, as the number of loans grows to infinity, credit portfolios of independent samples and different granularity converge to a uniform portfolio with homogenous asset exposures and normally distributed losses. Vasicek (1987), Finger (1999) as well as Overbeck and Wagner (2001) derive default losses from a normal inverse distribution function $NID(p,\rho)$ with default probability $p>0$ as mean and equal pairwise asset correlation $\rho<1$ for a portfolio of h loans with equal exposure $1/h$ for $h \to +\infty$ and portfolio losses $0 \leq x \leq 1$ [58] denoted by

$$NID(x,p,\rho) = N\left(\left(\sqrt{1-\rho}N^{-1}(x) - N^{-1}(p)\right)\Big/\sqrt{p}\right) \qquad (1)$$

with density function

[57] See also Barnhill and Maxwell (2002).

[58] In section 4.2.1 we estimate credit losses as uniformly distributed random variables by means of a Monte Carlo simulation.

$$\phi(x,p,\rho)=(1-\rho)/\rho\times\left(n\left(N^{-1}(x)\right)\right)^{-1}\times n\left(\left(\sqrt{1-\rho}N^{-1}(x)-N^{-1}(p)\right)/\sqrt{\rho}\right), \quad (2)$$

where the standard deviation $\sigma=\sqrt{N_2\left(N^{-1}(p),N^{-1}(p);\rho\right)-p^2}$ is derived from the bivariate normal distribution $N_2(x,y;\rho)$ of correlated defaults with a zero expectation vector.[59] However, since the occurrence of extreme events takes a pivotal role in the accurate approximation of credit portfolio losses, we need to extend this approach to take account of the extreme tail behaviour of credit events. As an alternative to the normal inverse distribution of random variables on a uniform space, we propose extreme value theory (EVT) in the next section to model the loss distribution function of credit portfolios.

4.1.2 Extreme value theory (EVT)

Merton-based credit risk models rely on distributional assumptions[60] that imply an underlying stochastic process of reasonable asset volatility around some mean expectation, which covers the entire spectrum of likely asset outcomes. With the stochastic dynamics $dV_0/V_t=\mu dt+\sigma dW_t$ (where W_t is a standard Brownian motion) representing what is known to be the most familiar way of modelling diffusion processes (Karatzas and Shreve, 1991), the discrete approximation of changes in the asset value V supports the theory of averages, where the frequency and size of random observations $S_n=X_1+...+X_n$ define quantiles as multiples of standard deviations around the mean of some probability distribution. The stochastic convenience of generating limit distributions, comes at the cost of having only general knowledge about asymptotic tail behaviour ("dependent tail behaviour") (Login, 1996).[61] However, it has become a stylised fact that the tail behaviour of an

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[59] The bivariate normal distribution has a symmetric covariance matrix displaying the correlation factor ρ off and covariances on the diagonal. Even though the respective density function $\phi(x,p,\rho)$ of the NID could be calculated by product folding, a closed form display of the results does not seem possible and numerical computation is warranted (Overbeck and Wagner, 2001).

[60] In the light of the empirically doubtful assumption of the probability of credit losses to follow the symmetric profile of a normal or quasi-normal distribution, Hull and White (1998) proffer a modification of standard distributional assumptions of the Value-at-Risk computation for high-frequency market variables. They propose a concrete functional transformation of measured returns, where at least one of the functional transformations is normal.

[61] The methodological elegance of estimating extreme events by detaching the probability of extreme events from dependent tail behaviour of stochastic processes in turn also entails a critical drawback. For instance, EVT features substantial intrinsic model risk (Embrechts, 2000), because it requires mathematical assumptions about the tail behaviour, whose estimation beyond or at the limit of available data defies reliable verification in practice. The absence of an optimal canonical choice (as to the threshold above which data is to be used) imposes deliberate exogeneity, which could further limit EVT as regards non-linearities (Resnik, 1998). However, one common caveat to EVT, does not apply in our model. Since we model rare events of loan

actual credit loss distribution significantly differs from the tail behaviour of a normal distribution or similar limit distributions with identical mean and variance. Empirical evidence about the actual loss profile of credit exposures suggests a higher likelihood of extreme single loss events than what would be implied by normally distributed credit loss.[62] In order to efficiently approximate the probability density at very high confidence levels (i.e. very low tail probabilities (Lucas et al., 2002)), we need to specify a limit law that incorporates the occurrence of extreme values. Instead of modifying the quantile calculations for an entire probability distribution to account for rare loss events,[63] we resort to extreme value analysis, which allows the direct estimation of the tail behaviour of portfolio distributions with observations in extreme quantiles. *Extreme value theory* (EVT) parametrically approximates the occurrence of extreme events of a specific asset process over time. For a given sample, EVT[64] helps translate random phenomena into a tail shape, irrespective of the distribution function, by solving the right (or left) limit behaviour of scaled maxima $M_n = \max(X_1,...,X_n)$ (or minima $M_n = \min(X_1,...,X_n)$) drawn from positive (negative) random variables.[65] While extreme observations (outliers) are underestimated in robust statistics, they receive most of the attention in EVT. Since extreme loss events are acutely relevant to highly leveraged tranches, EVT claims methodological attractiveness due to ease of application and flexibility in model calibration.[66] In the remainder of this section, we exploit the stylised fact of heavy-tailed credit losses to elicit a loss distribution with polynomial tail decay as a specialised form of a *general Pareto distribution* (GPD). This is an *exceedance function* within the domain of attraction of the *generalised extreme value distribution* (GEV). We thus improve on the normal inverse distribution (NID) as a basis for the estimation of extreme

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default in a uniform credit portfolio, high dimensional portfolios cannot impair the assessment of stochastic properties of extreme events (Embrechts et al., 1999a, 1999b and 1999c).

[62] In other words, extreme loss quantiles are farther removed from expected losses than the standard deviation implied by a certain level of confidence under a normal loss distribution. Standard distributional assumptions based on tail probabilities of 5%, 1% or 0.5% fall short of properly measuring loss quantiles at extremely high levels of confidence.

[63] As an alternative to EVT in the context of modelling credit loss distributions, one could derive a closed from solution to the credit loss limit law by Lucas et al. (2001b) based on the *CreditMetrics* setting, which would not only require assumptions about the probability distribution of the latent variable triggering credit migrations and defaults (Lucas et al., 2002), but also imposes computational burden for generating a sufficient number of simulation iterations to back out small tail probabilities. See also (Lucas et al., 2001a).

[64] Embrechts (2000) describes EVT as a "canonical theory for the (limit) distribution of normalised maxima of independent, identically distributed random variables." Although EVT has been used for many years in statistical analysis, it has been applied only several years ago in credit risk management.

[65] Note here that *multivariate* EVT as an advanced form of estimating the extreme events in a random setting (Embrechts et al., 1999c), would translate the behaviour of such rare events into stochastic processes, evolving dynamically in time and space, by considering issues such as the shape of the distribution density function (skewness and kurtosis) and its variability in stress scenarios.

[66] Nevertheless, EVT certainly falls short of representing the ultimate panacea of risk management due to a multitude of unresolved theoretical issues, such as multiple risk factors and possible computational instability, e.g. if maximum likelihood (ML) estimated parameters do not converge (Embrechts, 2000).

quantiles consistent with Lucas et al. (2001b), who have formally shown that credit loss distributions are fat-tailed.[67]

We define extreme value analysis as a general statistical concept of deriving a limit law for sample maxima $R_x \in \mathbb{R}$ (Fisher and Tippett, 1928), which prescribes a parametric fit to exceedances over a sufficiently large threshold[68] to characterise the tail behaviour of extreme order statistics (Vandewalle et al., 2004).[69] This limiting behaviour establishes a general theorem on the convergence of asymptotic tail behaviour for observations beyond historical inference. The *generalised extreme value distribution* (GEV) (Jenkinson, 1955)[70] establishes the domain of attraction for three possible classes of limit distributions[71] of normalised maxima or minima drawn from random variables, whose limiting behaviour depends on the rate of estimated tail decay.[72] Let $X_1, X_2, ..., X_n$ be a sequence of i.i.d. random variables with a common unknown distribution function $F(.)$ and the corresponding ascending order statistics $X_{1,n} \leq ... \leq X_{n,n}$ with normalised sample maxima $X_{n,n} = \max\{X_1, X_2, ..., X_n\}$ converging to a non-degenerate limit distribution[73]

$$H_\xi(R_x) = \lim_{n \to \infty} P\left(\frac{X_{n,n} - b_n}{a_n} \leq R_x\right) \tag{3}$$

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[67] i.e. they decline polynomially to zero and <u>not</u> at an exponential rate as a normal distribution tail would imply.

[68] The characterisation of an EVT-based tail distribution, however, requires strong distributional assumptions. For loss of less presumptive models with equal predictive power the stochastic methodology of EVT comes to matter as it best describes the stochastic behaviour of extreme events in heavy tailed distributions.

[69] For further references on the application of EVT in the estimation of heavy tailed financial returns and market risk see also Longin and Solnik (2001), Longin (2000), Embrechts, et al. (1999a, 1999b and 1999c), McNeil (1999), McNeil and Frey (1999), Adler et al. (1998), Diebold et al. (1998), Danielsson and de Vries (1997a and 1997b), Embrechts et al. (1997), Resnik (1992), Longin (1996) and Leadbetter et al. (1983).

[70] We dismiss a normal (elliptic) distribution function $f(x) \sim N(\mu, \sigma)$ for the estimation of extreme loss quantiles. We justify the application of EVT to model the tail behaviour on the grounds of periodic credit losses x_j yielding $\int_0^\infty x_j^a f(x) dx \to +\infty$ for some positive integer *a*.

[71] See Resnick (1992) for a formal proof of the theorem. See also Resnick (1998).

[72] For statistical inference on extreme quantiles EVT assumes precise knowledge about the tail behaviour for extreme events. Since a wide class of distributional models coincide in their tail behaviour, the implementation of EVT is independent of the overall probability distribution of losses, i.e. we do not need to know the entire loss distribution but the existence of heavy tails of a stochastic process.

[73] See also Vandewalle et al. (2004).

for a sequence of constants $a_n > 0$, $b_n \in \mathbb{R}$ and $n \to \infty$. If $F(.)$ satisfies this expression, it falls within the maximum domain of attraction of $H_\xi(\mathrm{R}_x)$, so that $F \in D(H_\xi)$. Assuming stationarity and ergodicity[74] the limit distribution above transforms to the GEV distribution

$$H_\xi(\mathrm{R}_x) = \begin{cases} \exp\left[-(1+\xi R_x)^{-\xi^{-1}}\right] & 1+\xi R_x > 0, \xi > 0 \\ \exp\left[-\exp(-\mathrm{R}_x)\right] & \mathrm{R}_x \in \mathbb{R}, \xi = 0 \end{cases}, \tag{4}$$

where the location parameter ("tail index") ξ specifies the size and frequency of extreme events of the asymptotic tail behaviour for the probability distribution, while $\xi \geq 0$ and $\xi < 0$ indicate heavy and light tails respectively. The limit distribution function is positively skewed and has a peak at $x = \xi$, which defines the velocity of the decreasing (asymptotic) probability density in the extreme end of the tail – the heavier the tail the slower the speed at which the tail approaches its peak x at y-value of 0, and the smaller the absolute value of the tail index parameter.[75]

A large class of limit distributions in excess of a sufficiently high threshold conform to the limiting behaviour of GEV.[76] $H_\xi(\mathrm{R}_x)$ subsumes the different tail curvatures of alternative distributions (*Gumbel/Fisher-Tippett*, *Fréchet*, *Weibull* and *Pareto*) and, by definition, almost all concrete probability distributions, since both normal and exponential distributions lie in the domain of the attraction of the *Gumbel* function.[77] Depending on the value of the tail index, the tail behaviour of extreme events fits one of the three parametric models for $\xi = 1/k$:

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[74] Ergodicity is an attribute of a stochastic system, which has a unique stationary distribution to which it will converge from any initial state; i.e. an ergodic system tends in probability to a limiting form (steady state) independent of the initial conditions, so that there is some time after which, whatever the initial state was, one has a non-zero possibility of being in any state.

[75] The tail index parameter also indicates the number of moments of the distribution, e.g. if $\xi = 2$, the first moment (mean) and the second moment (variance) exist, but higher moments have a finite value.

[76] This limiting behaviour is reminiscent of the *Central Limit Theorem*, which states that the average of a large enough number of independent samples of almost any limit distribution converges to normality.

[77] Gnedenko (1943) establishes the necessary and sufficient conditions for this assertion of the generalised extreme value theory to capture the characteristics of each concrete probability distribution, i.e. the tail behaviour of all concrete distributions converges in one of the three limit distributions of GEV, with the tail index (and the implicit threshold level M) as the only distinguishing factor(s). The following matched pairs exist for the distribution of the tails: normal, lognormal, logistic, gamma and exponential distributions → *Gumbel* distribution; *Student's t*, *Pareto*, loggamma, *Burr* and *Cauchy* distributions → *Fréchet* distribution (where the reciprocal of the tail index is equivalent to the degrees of freedom and the standard exponent respectively); uniform and beta distributions → *Weibull* distribution (where we observe a finite upper limit on the range of variables).

$$\text{for } \xi = 0 : F(R_x) = \exp(-\exp(-R_x)) \quad [\textit{Gumbel/Fisher-Tippett} \text{ (type 1) distribution}],^{78} \tag{5}$$

$$\text{for } \xi > 0 : F(R_x) = \begin{cases} 0 & \textit{for } R_x \leq 0 \\ \exp(-R_x^{-k}) & \textit{for } R_x > 0, k > 0 \end{cases} \quad [\textit{Fréchet} \text{ (type 2) distribution}], \tag{6}$$

$$\text{for } \xi < 0 : F(R_x) = \begin{cases} \exp(-(-R_x)^{-k}) & \textit{for } R_x < 0, k < 0 \\ 1 & \textit{for } R_x \geq 0 \end{cases} \quad [\textit{Weibull} \text{ (type 3) distribution}], \tag{7}$$

where the *Fréchet* (type 2) and *Weibull* (type 3) distributions approximate the *Gumbel/Fisher-Tippett* (type 1) distribution for small values of the tail index, i.e. thick tails.

In absence of exploratory analysis from empirical credit loss data and for the sake of simplicity, we use modified form of a *generalised Pareto distribution* (GPD)[79] as the loss function instead of a GEV distribution for purposes of extreme value analysis. GPD is an exceedance distribution within the maximum domain of attraction $F \in D(H_\xi)$. In order to specify the tail behaviour of standardised maxima of potential loss levels capped at the asset portfolio size set to unity as upper bound, we re-write $H_\xi(R_x)$ to

$$G(x,\xi,\beta) = \begin{cases} 1-(1+\xi x/\beta)^{-\xi^{-1}} & \text{for} \quad \xi \neq 0 \\ 1-\exp(-x/\beta) & \text{for} \quad \xi = 0 \end{cases}, \tag{8}$$

with $R_x \equiv -(x-\xi)/\beta$, scale parameter $\beta > 0$, as well as $x \geq 0$ for $\xi \geq 0$ and $0 \leq x \leq -\beta/\xi$ for $\xi < 0$.[80] For loss distribution function $L(x)$ with the same tail behaviour, we allow for a non-zero peak by expanding the support of GPD to $\mathbb{R}$, so that

[78] with integrateable density function $f(x) = \beta^{-1}\{-\exp(-(x-\xi)/\beta) - (x-\xi)/\beta\}$.

[79] Note that we derive GPD on the basis of the one-dimensional Pareto-like distribution $G(x,\xi,\beta) = 1-(1+\xi x/\beta)^{-\xi^{-1}}$ for $\xi \neq 0$ and $x \geq 0$, with density function $Par(x,\xi,\beta) = g(x) = \xi/\beta\,(\beta/x)^{\xi+1} \Leftrightarrow \xi\beta^\xi/x^{\xi+1}$, and $\beta \leq x \leq +\infty$, where $\beta > 0$, $\xi > 0$ and distribution function $G(x) = 1-(\beta/x)^\xi$. Please refer to Pickands (1975) for a first account of statistical inference testing using extreme order statistics based on GPD.

[80] For the treatment of $\xi \leq 0$ see Junker and Szimayer (2001).

$$L(x,\xi,\beta,s,\rho)=1-\left(1+\frac{\xi\times\left((x-\rho)+\sqrt{(x-\rho)^2+s^2}\right)}{2\beta\times\left(1+\exp\left(-\xi(x-\rho)/\beta\right)\right)}\right)^{-\xi^{-1}}. \tag{9}$$

In addition to the scale parameter $s>0$, we introduce $\rho\in\mathbb{R}$ as adjustment factor in the subsequent mapping procedure of $L(x)$ with portfolio losses $0\leq x\leq 1$.[81] Mapping the loss distribution function *L(x)* above onto the inverse uniform distribution $U_d^{-1}(u)$ with random variable $u\in[0,1]$ and $x\in[-d;d]$ as upper and lower bounds $(\min=-d,\max=d)$ of $U_d^{-1}(u)$ yields

$$L_d(x)=\frac{L(x)-L(-d)}{L(d)-L(-d)}\quad\text{for } x\sim U_d^{-1}(u).\text{[82]} \tag{10}$$

$\rho_u=U_d^{-1}(\rho)$ is obtained through re-parameterisation, where both β and s depend on the level of d.[83] Our parameterisation,[84] which will be used for the simulation in the next section, results in $1-L(d)=6\cdot 10^{-7}$, which leaves the loss tail shape unaffected by the truncation.[85]

4.2 Simulation model and loss allocation

We now simulate uniformly distributed random defaults to estimate expected and unexpected losses under both loss functions of the securitised loans along two dimension – *time* and *security design*. We derive periodic losses by "time slicing" estimated total default loss over a discrete time grid until maturity in order to determine the residual value of the securitised reference portfolio (and the principal value of issued tranches) after periodic loan default at the end of each period. These periodic losses are then allocated to the different tranches by order of seniority according to a *subordination mechanism* similar to the waterfall mechanism of damage claims in a sequence of default-

[81] Neither the GDP nor the transformed GDP presented in this model are derived from a multi-dimensional distribution with dependent tail events (Embrechts, 2000), even though we value contingent claims on a multi-asset portfolio of securitisable loans affected by default losses. This methodology is justified on the grounds of the stochastic characteristics of the reference portfolio. See also Embrechts et al. (1999a, 1999b and 1999c).

[82] For the remainder of the chapter the EVT loss function carries no special marker indicating the mapping procedure.

[83] e.g. for d' we obtain $\beta'=\beta\times d'/d$ and $s'=s\times d'/d$ respectively.

[84] The following parameters have been chosen: $\xi=0.4$, $\beta=26$, $s=7.5$, $\rho_u=10^{-4}$ and $d=10^4$.

correlated reinsurance contracts. The loss bearing capacity of each tranche in relation to its level of subordination finally determines the tranche-specific default term structure over time.

4.2.1 *Monte Carlo simulation*

We Monte Carlo simulate the aggregate loss given default $0 \leq x \leq 1$ of a equally-weighted pool with h number of loans from an i.i.d. sequence of correlated defaults with default probability $p > 0$ under both robust statistical analysis (NID) and extreme value theory (EVT). In the case of NID, we derive the p-quantile estimate of periodic losses for each time step j from the transformation

$$x = NID^{-1}(z, p, \rho) = N\left(\left(N^{-1}(p_j) - \sqrt{\rho_j} N^{-1}(z)\right) \Big/ \sqrt{1 - p_j}\right) \tag{11}$$

by drawing pairwise correlated uniformly distributed random variables Z~U(0,1) and choosing the parameters of the loss distribution function such that the first two moments match the ones obtained from the NID. For EVT, the transformation and mapping procedure in section 4.1.2 applies analogously. We ignore the effects of loss recovery, prepayments and amortisation on the notional amount of portfolio value.[86] Defaults are assumed to take place at the end of each period j to ensure consistency in the approximation of relative portfolio losses per period against the background of a declining principal balance. We let the default probability (PD)[87] for each period be either constant or time-varying (increasing vs. declining). The latter assumption of time-dependent risk exposure is fundamental to a dynamic estimation of the default term structure and its attendant effect on periodic loss cascading over the life of the securitisation transaction. The PD equates to expected loss given default with initial notional portfolio size set to unity.

4.2.2 *Time slicing*

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[85] Since $L(-d) = 0.05$ the density of L_u does not revert to zero at point $u = 0$, which corresponds to the practical intuition of portfolio losses (reality check of uniform mapping assumption for the distribution of random variables on the uniform interval [0,1]).

[86] Amid this simplification of the actual accumulation of proceeds and default losses, this approach recognises the fact that prepayment speed higher than scheduled amortisation might not necessarily reduce aggregate losses, since loan claims with a high default probability are least likely to be prepaid.

[87] In accordance with the weighted-average rating of the most recent CLO transactions by European issuers and default correlation in industrial application of intensity-based portfolio credit risk models we chose the portfolio parameters $p = 0.0026$ and $\rho = 0.17$ in NID and the analogous representation through the size and shape parameters under EVT.

Assuming a discrete time grid $t_0 < t_1 < t_j < ... < t_{n-1} < t_n$, losses are accumulated for h number of obligations in the portfolio to arrive at total estimated loss

$$\tilde{L} = \sum_{j=1}^{n} \prod_{i=0}^{j-1} (1 - X_i) X_j \,, \tag{12}$$

over the time horizon n, where $X_j \sim NID(x, p, \rho)$ and $X_j \sim L(x, \xi, \beta, s, \rho)$ denote the relative loss (on the residual exposure $1 - X_i$) at time period $j \in n$ for both loss distributions, after previous losses at $i = j - 1$ have been subtracted from portfolio value. [88]

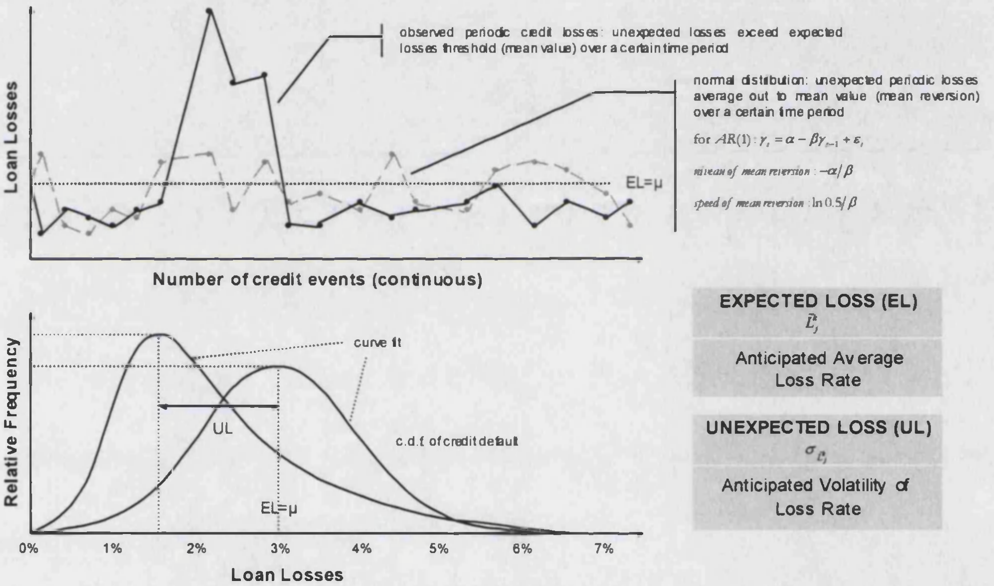

Fig. 2. *Volatility of credit losses as a measure of credit risk.*

We ignore the effects of loss recovery, prepayments and amortisation on the notional amount of portfolio value.[89] Defaults are assumed to take place at the end of each period j to ensure consistency in the approximation of relative portfolio losses per period against the background of a declining

[88] This approach is in line with the determination of the so-called *conditional default rate* (CDR) used by commercial banks to calculate the loss scenarios of particular loan portfolios. They define periodic default loss as the product of a certain default probability (according to some portfolio credit risk function) and the loss severity percentage (i.e. loss severity assumptions of projected loan claims) that is incurred with respect to aggregate outstanding principal balance of the securitised portfolio at the time of default.

[89] Amid this simplification of the actual accumulation of proceeds and default losses, this approach recognises the fact that prepayment speed higher than scheduled amortisation might not necessarily reduce aggregate losses, since loan claims with a high default probability are least likely to be prepaid.

principal balance. We let the default probability (PD)[90] for each period be either constant or time-varying (increasing vs. declining). The latter assumption of time-dependent risk exposure is fundamental to a dynamic estimation of the default term structure and its attendant effect on periodic loss cascading over the life of the securitisation transaction.

4.2.3 Loss cascading

Based on these aggregated losses we allocate periodic default losses to the different constituent tranches in order of seniority. This *subordination mechanism* of "loss cascading" is frequently found as one form of credit enhancement in CLO transactions and resembles the waterfall mechanism of damage claims in a sequence of default-correlated reinsurance contracts.[91] Subordination in our model means that portfolio losses $\tilde{L}$ are allocated successively to the constituent tranches according to the level of seniority, so that tranches more senior than the lowest (i.e. most junior) tranche only bear losses once the all tranches more junior have been fully wiped out by default losses.[92] In our specification, investors in tranche $k \in m$ have to bear aggregate losses up to $\alpha_k\%$ of the total default losses on outstanding notional value of the transaction. Any remaining losses we allocated to the more senior tranche $k+1$ up to the amount of $\alpha_{k+1}\%$. So if the notional size ("tranche thickness") of tranche k has been fully exhausted (denoted by the interval $\alpha_k - \alpha_{k-1}$ as the loss bearing capacity of tranche k),[93] further losses are allocated to the subsequent, senior tranche. This bottom-up cascading process perpetuates until all losses for a certain period are allotted to the relevant tranches. This allocative routine[94] determines the expected credit loss per tranche in time period j,

$$\tilde{L}^k = \sum_{j=1}^{n} \tilde{L}_j^k = \sum_{j=1}^{n} \int \frac{\left(x_j - \alpha_{k-1}\right)^+ \wedge \left(\alpha_k - \alpha_{k-1}\right)}{\alpha_k - \alpha_{k-1}} f(x)dx\,, \tag{13}$$

[90] In accordance with the weighted-average rating of the most recent CLO transactions by European issuers and default correlation in industrial application of intensity-based portfolio credit risk models, we chose the portfolio parameters $p = 0.0026$ (for a AAA-rated reference portfolio) and $\rho = 0.17$ in NID and the analogous representation through the size and shape parameters under EVT.

[91] Hence, tranche subordination would compare to a duration-matched set of reinsurance contracts on the same underlying risk.

[92] The notional amount of all tranches junior to a certain tranche is commonly termed "enhancement level" (Basle Committee, 2004a and 2004b).

[93] in terms of estimated losses as reflected in default tolerance of the structured rating.

[94] See Overbeck and Wagner (2001) for an abridged representation of this method of loss cascading.

where the meet $\left(x_j-\alpha_{k-1}\right)^+ \wedge \left(\alpha_k-\alpha_{k-1}\right)$ denotes the periodic default loss in time step *j* as the proportional default loss of the reference portfolio borne by tranche *k*. We consider the tranche sizes $0 \le \alpha_0 < \alpha_1 < ...\alpha_{m-1} < \alpha_m$ as time-invariant boundaries (i.e. attachment points) of loss allocation, which have been chosen on a historical basis from a weighted-average market benchmark of the typical security design of CLO transactions since 1997. The "first loss position" has been set to the interval of [0-2.4%] (Tranche 1) of notional transaction value, while "investor tranches" are represented by [2.4-3.9%], [3.9-6.5%], [6.5-9.0%], [9.0-10.5%] and [10.5-100%] (Tranches 2-6). These boundaries are time-invariant and lack the notation *j* for the time period. The issuer commonly retains the lowest, most junior tranche (commonly termed the "equity piece") with a default loss tolerance of $\alpha_0-\alpha_1$ as "first loss position" as a commitment to bear part of the losses due to *expected* non-performance of the reference portfolio. This prioritisation of structured claims reduces (increases) the default tolerance (investment leverage) of the successive tranches, which will be discussed later in this chapter.[95]

5 ESTIMATION RESULTS

5.1 Default term structure of tranches

We derive the term structure of expected losses from a Monte Carlo simulation with one million iterations of relative portfolio losses X_j for $j=1,...,n$ on the basis of two loss distribution functions – a normal inverse distribution (NID) (see section 4.1.1) and a GEV distribution from extreme value analysis (see section 4.1.2). Tabs. 11 and 14 (Appendix 1) exhibit how the subordinated transaction structure affects the development of the principal balance of a securitised reference loan portfolio over time, as periodic default losses are allocated to tranches according to seniority and loss bearing capacity. The first column denotes the year and the second shows the respective (forward) default rate *p*, while the third and fourth columns list the mean and standard deviation of the cumulative and periodic default loss of all tranches (i.e. estimated expected loss $\tilde{L}_j$ and unexpected loss $\sigma_{\tilde{L}_j}$, see Fig. 2 below). The remaining columns report relative and proportional expected default loss $\tilde{L}_j^k$ for

[95] The mezzanine tranches with low and medium investment grade rating are usually sold to capital market investors as notes and commercial paper (in the case of highly rated senior notes). The most senior tranches are securitised in the form of a credit default swap with a equally or lower risk-weighted counterparty by means of a credit default swap or some other method of structural provision, such as a bilateral credit guarantee.

each of the six different tranches with respect to their notional value and total periodic losses (see Tabs. 15-20, Appendix 1). We also provide the same breakdown for unexpected losses $\sigma_{\tilde{L}_j^k}$.

Both loss functions yield similar approximations of periodic portfolio losses (expected loss $\tilde{L}_j^k$ and unexpected loss $\sigma_{\tilde{L}_j^k}$). The first moment of estimated expected loss $\tilde{L}_j^k$ per tranche (slope of estimated losses) increases under both loss functions. The periodic loss of the first loss piece [0-2.4%], though, flattens from the fifth year onwards as accumulated losses begin to exhaust the notional amount of the most junior tranche. (see section 4.2.3). As tranches gain in seniority, the default term structures under the chosen loss distributions deviate from each other at an increasing rate, especially in the mezzanine tranche [6.5-9.0%]. Although the cumulative tranche-based loss allocation increases monotonously, we observe a distinctive dichotomy of default tolerance between the most junior (equity) tranche (reflected in the first tranche [0-2.4%] $\tilde{L}_j^1$) and the remaining "investor tranches" (see Appendix 2, Fig. 5 for EVT and Fig. 6 for NID). While the expected loss for the first tranche follows a linear function, expected losses of more senior tranches increase in an exponential fashion over time. The disparate loss profiles of tranches are attributable to the gradual erosion of the loss absorbing capacity of the most junior tranche, which in turn is caused by the security design of subordination and, to a lesser degree, by the distribution of default losses. Since the cumulative incidence of credit losses is skewed towards the extreme end of the distribution, an EVT-based loss function seems to reflect the "loss reality" more truthfully than the Gaussian assumptions of generalised asymptotic tail behaviour in standard limit distribution functions.[96,97] The proposed specialised form of a generalised extreme value distribution emphasizes extreme loss scenarios, which increase the default rates for more senior "investor tranches". The first loss position under EVT is almost entirely exhausted by estimated default losses, while more moderate loss events under NID leave a good part of the most junior tranche untouched.

96 See also Altman and Saunders (1998).

97 In Overbeck and Wagner (2001) the *q-q*-plot of the beta distribution versus the negative binomial distribution tends to indicate a high degree of similarity on the basis of matched first two moments, with cumulative probabilities reaching levels in the tune of 99.995%, after discrete losses obtained from the negative-binomial distribution have been adjusted by the some large number s (e.g. $s = 1,000$ generated the parameter values $\alpha = 0.323278$ and $\beta = 80.4258$ (Overbeck and Wagner, 2001). Note that the observations tend to fall slightly below the diagonal in the *q-q*-plot due to the cut-off value of s.

5.2 Variable portfolio quality – default losses of all tranches

In cognisance of time-dependent variation of default risk we also consider variable portfolio quality as a sequential upward and downward drift of one-year default probabilities under both distribution functions. These scenarios of impetuously improving and decreasing portfolio quality have been modelled in a way that the weighted-average default probability matches the periodic default probability for the case of a constant rate of portfolio loss over the life of the transaction. For a deteriorating (improving) portfolio quality the initial default probability is lower (higher) than in the case of a constant default probability. In the following section we investigate the (tranche-specific) default term structure for a strictly deteriorating asset portfolio ("back loaded") and a strictly improving portfolio ("front loaded") as two extreme cases of how changes in securitised asset risk translate into expected and unexpected losses. Tabs. 5-6 (EVT) and Tabs. 8-9 (NID) in Appendix 1 and Figs. 10-13 in Appendix 2 display our estimation results and the corresponding plots of a deteriorating and improving portfolio.

We saw in section 5.1 that periodic expected losses subside asymptotically for a constant default rate under both EVT and NID loss distributions, mainly because accumulated losses almost fully exhaust the notional amount of the most junior tranche before subsequent tranches bear any losses. This property is reflected in the concave shape of the default term structure curve for cumulative default losses. We find that a gradual increase of the periodic default rate partially reverses the term structure of the most junior (equity) tranche during the first three periods in the case of NID, but finally follows the term structure for a constant default probability. Under EVT, periodic expected losses allocated to the equity tranche [0-2.4%] and the investor tranche [2.4-3.9%] are positively concave (but remain constant under NID) for an overall deteriorating portfolio quality. The main investor tranches [3.9-6.5%], [6.5-9%], [9-10.5%] and [10.5-100%] maintain an almost constant periodic default profile under both EVT and NID. In contrast, improving portfolio quality induces a negatively convex term structure of periodic losses for the most junior (equity) tranche [0-2.4%] under both loss distributions. The periodic default term structure of the subsequent tranche [2.4-3.9%] changes from being positively convex to positively concave after three periods for NID, while it remains negatively convex for EVT throughout all periods of the simulation. We also observe a constant periodic default loss of more senior investor tranches [3.9-6.5%], [6.5-9%], [9-10.5%] and [10.5-100%] for a decreasing portfolio default rate, too.

These periodic loss profiles of constituent tranches for time-varying default rates translate into a default term structure of cumulative losses, which differs significantly from our findings in the case of a constant annual default rate (see Appendix 2, Figs. 5-7). As cumulative losses borne gradually absorb the notional amount of the first tranche, the more senior [2.4-3.9%] and [3.9-6.5%] tranches have to shoulder a disproportionately higher degree of default loss under both EVT and NID. The rapid increase of expected losses carried by the [3.9-6.5%] tranche compared to the next senior [6.5-9%] tranche (particularly for NID-distributed losses, less so for EVT) warrants particular attention, with potential insights into the implications of a varying default rate for the simulated term structure. At a continuously decreasing loan default rate, high initial cumulative loss burden by the first loss tranche precludes high loss allocation during later periods, so that the default term structure begins to flatten half way through the life of the transaction. At the same time, the [2.4-3.9%] tranche in particular picks up most of the loss exposure, leaving less expected losses for more senior [3.9-6.5%] and [6.5-9%] tranches.

Generally, relatively high (low) levels of early (late) loss absorption for a "front loaded" ("back loaded") default profile of improving (deteriorating) and deteriorating time-varying portfolio quality induce negative second moments of cumulative expected loss allocated to the most junior (equity) tranche. In both cases of varying portfolio quality we discern a stark contrast between the lowest tranche and more senior investor tranches, which is explained by rapid exhaustion of limited loss absorbing capacity of the former. Although varying periodic default drives a wedge between the loss tolerance of the issuer and investors, it is less pronounced in the case of a varying periodic default rate than with a constant default rate over the life of the transaction (see section 5).

5.3 Leverage effect

The estimated default term structure testifies to the structural risk sharing arrangement of loss allocation through subordinated tranches in CLOs and other types of ABS transactions. This security design concentrates expected losses in a small first loss position, which bears the majority of the credit exposure, and shifts most unexpected risk to larger, more senior tranches, which display distinctly different risk profiles. Such a *leverage effect* assumes a typical three-tier securitisation structure of junior, mezzanine and senior tranches, where senior tranches represent about 80-90% of the entire notional amount of securitised debt. Most importantly, security design-induced leverage imposes distinct risk-return profiles on constituent tranches, which differs from direct investment in the underlying portfolio of securitised exposures. On a notional basis investors should expect the same returns for CLOs as for similar credit risk exposure in plain vanilla debt. However, the risk profile of CLOs tranches varies dramatically in response to changes in the valuation of the underlying (reference) asset depending on individual "tranche thickness" (i.e. notional size). We define the leveraged exposure by tranche seniority as the ratio of relative expected and unexpected losses per tranche to relative portfolio losses for each period. The relative (expected and unexpected) losses of the most junior tranches are higher than relative overall portfolio losses, which imply a disproportionately large exposure. As opposed to a static closed-form CDO pricing model (with one common risk factor-based default) in Gibson (2004), our approach is not limited to a one-period loss scenario of expected and unexpected losses. Under the assumption of time-varying portfolio quality of securitised assets we analyse the *time dimension* of leveraged exposure for both a cumulative and periodic default term structure based on the reduced-form simulation of two different loss distributions (EVT and NID). Since most of the investment in the loan securitisation is "buy and hold", the time variation of leverage to portfolio losses is highly relevant to investors and regulators alike. We find that tranche leverage decreases (increases) by absolute measure the higher (lower) the level of seniority, with all tranches but the most junior tranche exhibiting higher multiples for unexpected losses than for expected losses (see Tabs. 10-15 (Appendix 1)). At a constant default probability over time, the leverage ratio of unexpected and expected losses increases over time across all tranches but the most senior and junior tranches. The multiples of unexpected and expected losses decrease in the case of the lowest tranche and remain nearly constant for the most senior tranche. If we let the default probability vary, all "investor tranches" but the most senior tranche gain appreciably in expected loss leverage (and less so for unexpected losses leverage). The expected loss leverage of the most junior and senior tranches are close to invariant to either a deteriorating or improving portfolio quality. This also applies to unexpected loss leverage of the most senior tranche, but not to the most junior tranche. Mezzanine investors, then, seem to bear the brunt of adverse effects on investment leverage from varying portfolio quality. Interestingly, "investor tranches" exhibit a higher first moment of leverage for periodic expected losses than periodic unexpected losses. The computation of investment risk in contingent claims becomes more intricate for senior tranches with lower loss sensitivity, if we consider the relative importance of loss volatility at each tranche level as the ratio of unexpected to expected losses. Loss volatility contributes the lion's share to total investment risk in more senior tranches, which exhibit higher relative exposure to unexpected loss. Their large tranche size of senior tranches also generates low notional exposure to expected loss, which camouflages leveraged exposure to almost pure risk volatility.[98] If marginal increases in asset correlation induce a higher conditional probability of default within the securitised asset pool, only a slight change of the default term structure increases total losses of senior tranches

[98] The development of periodic loss leverage over time qualifies our earlier observation of leveraged unexpected loss exposure in more senior tranches. An optimal low risk volatility strategy would prescribe short-term investment in more junior tranches (due to low absolute expected losses during the initial investment periods and a higher portion of expected losses than unexpected losses) until a higher first moment

disproportionately by absolute measure the higher the share of unexpected risk borne by investors.[99] This makes senior tranches highly risk-sensitive, particularly in times of appreciable market volatility and escalating exposure to unexpected losses during changes in the credit cycle. Hence, our findings suggest that a notional-sized based valuation of leveraged exposures poorly informs a fair assessment of the actual the risk profile of senior tranches and fosters dangerously improvident investment in CLO tranches.

6 PRICING OF CLO TRANCHES FOR RISK-NEUTRAL INVESTORS

In the first part of this section, we propose a simple pricing method to value CLO tranches at a riskless term structure. Based on the simulation results of various default term structures of CLO tranches (see section 4), this pricing model allows us to compute quasi risk-neutral spreads over the risk-free reference rate investors would expect as compensation for expected default losses. We do not take into account risk premia for market risk. In the second part, we compare this required internal rate of return of each tranche to the risk-neutral prices of bonds of comparable quality and maturity for matched first moments.

Despite major advances in credit risk modelling from a portfolio view (e.g. copula-dependent default risk estimation in Schönbucher and Schubert (2001), credit risk analytics have only recently been transposed into the context of loan securitisation, such as the intensity-based approximation of portfolio defaults, through either a jump-diffusion process of a securitised loans (Egami and Esteghamat, 2003) or the degree of diversification, e.g. the diversity score approach devised by rating agencies for single debt obligations (Duffie and Gârleanu, 2001). The absence of a longstanding record of tried and tested analytical approaches of CLO structures may leave leveraged investment in securitisation transactions subject to notorious mispricing if securitised asset exposures are underestimated. We derive risk-adjusted returns from the default term structure as a sensible approach to the pricing of CLO tranches in order to foster informed investment about this structured finance technology.

Based on the simulated default term structures under different default scenarios, we propose a simple pricing method to value CLO tranches at a riskless term structure in order to foster informed

of expected loss leverage warrants switching the investment to more senior tranches, where unexpected losses claim a greater share of investment risk and their leverage is subject to lower periodic changes over time.

[99] The impact of tranche leverage confirms that extreme value analysis is most amenable for modelling the highly risk-sensitive nature of securitised debt as leveraged investment.

investment about this structured finance technology. In keeping with Jarrow et al. (1997), we compute the hypothetical spread over the risk-free rate that risk-neutral investors would normally expect as compensation for expected default losses allocated periodically to each tranche according to the designated subordination mechanism. The expected loss associated with a time-varying, physical default probability reduces the notional tranche amount (i.e. expected cash flows) over time. The risk premium of each individual tranche solves for the rate of return that offsets periodic losses of a certain default term structure, so that the net present value of the residual principal portfolio balance discounted at a (fixed and stochastic) risk-free rate yields the riskless term structure[100] that satisfies

$$\sum_{m=1}^{n-1}\frac{\left(1-\sum_{j=1}^{m}\tilde{L}_j^k\right)r_k}{\prod_{l=1}^{m}\left(1+r_{f_l}\right)}+\frac{\left(1-\sum_{j=1}^{n}\tilde{L}_j^k\right)\left(1+r_k\right)}{\prod_{l=1}^{n}\left(1+r_{f_l}\right)}=\sum_{m=1}^{n}\frac{\left(1-\sum_{j=1}^{m}\tilde{L}_j^k\right)r_k}{\prod_{l=1}^{n}\left(1+r_{f_l}\right)}+\frac{\left(1-\sum_{j=1}^{n}\tilde{L}_j^k\right)}{\prod_{l=1}^{n}\left(1+r_{f_l}\right)}=1, \quad (14)$$

where $\sum_{j=1}^{m}\tilde{L}_j^k$ denotes the accumulated expected loss in the tranche k up to year $j=7$ and risk-free forward rate r_f (fixed or stochastic). Note that our calculated return for risk-neutral investors is not inclusive of a market risk premium and only represents the fair rate of return as compensation for the physical default term structure of securitised tranches. Since our tranche returns are not derived as risk premia under the risk-neutral measure, we will use the term "quasi risk-neutral returns" for the remainder of the chapter. Tab. 1 below reports tranche-specific risk-adjusted returns under both NID- and EVT-based loan default at constant, gradually increasing and decreasing periodic default rates according to our estimated default term structures in Tabs. 4-9 (see Appendix 1) and constant risk-free rate $r_{f_l}=r_f=5.0\%$. The most junior [0-2.4%] tranche absorbs most of the periodic losses over the life of the transaction and commands quasi risk-neutral return of 21.35% (EVT) and 20.56% (NID) for cumulative average annual losses with constant periodic default probability. Successive tranches claim lower investment returns as their decreasing default tolerance of accumulated credit loss induces quasi risk-neutral returns ranging from 6.29% (EVT) and 6.79% (NID) for the [2.4-3.9%] tranche to almost the risk-free rate of return for the most senior [10.5-100%] tranche.[101]

[100] This approach reverses the methodologies in Jarrow and Turnbull (1995) as well as Leland and Toft (1996), who derive an arbitrage free pseudo-probability of default from a given the term structure of credit spreads.
[101] According to Burghardt (2001) especially senior tranches of CLOs are regarded as virtually risk-free.

We find that the estimated investor returns vary significantly by type of loss function. Since extreme value theory assigns higher probability to rare events with high loss severity ("thick tail"), EVT-simulated losses yield higher quasi risk-neutral returns than NID-based credit losses at a constant forward rate of default in the most senior "investor tranches" [6.5-9.0%], [9.0-10.5%] and [10.5-100%]. Conversely, the equity tranche [0-2.4%] and the mezzanine "investor tranches" [2.4-3.9%] and [3.9-6.5%] exhibit lower returns under the EVT approach than under the NID approach due to high initial loss absorption of the most junior tranches. However, we cannot infer a higher degree of estimated default for the first loss position under the EVT approach than under the NID approach unless we extend the exposition of expected quasi risk-neutral returns per tranche to the cases of deteriorating and improving portfolio quality.

Distribution and collateral performance			**Quasi risk-neutral returns per tranche** *(constant discount rate)*					
Allocated tranche losses	**Reference portfolio quality**	**Loss distribution**	**0-2.4%**	**2.4-3.9%**	**3.9-6.5%**	**6.5-9%**	**9-10.5%**	**10.5-100%**
cumulative L_j^k	*constant*	EVT	21.34747%	6.28610%	5.25952%	5.06849%	5.03009%	5.00145%
		NID	20.56017%	6.79431%	5.33870%	5.05067%	5.01109%	5.00011%
	deteriorating	EVT	37.49613%	10.81930%	5.69241%	5.11364%	5.03974%	5.00167%
		NID	30.43862%	11.19511%	6.78903%	5.39333%	5.10093%	5.00127%
	improving	EVT	49.12123%	9.87893%	5.60218%	5.10820%	5.03821%	5.00157%
		NID	42.75610%	10.94419%	6.00440%	5.06577%	5.00648%	5.00004%

Tab. 1. *Quasi risk-neutral returns for the various tranches under two different default distributions (EVT and NID) at cumulative constant, increasing and decreasing forward rates of loan default.*

The stark contrast between quasi risk-neutral returns of the most junior tranche retained by issuers and mezzanine and senior tranches held by outside investors also persists for varying portfolio quality. A varying periodic forward rate of defaults entails higher returns for almost all tranches,[102] irrespective of whether the first moment of the term structure is positive or negative, and decreases in the seniority of a tranche. The equity tranche commands quasi risk-neutral returns well beyond 30% (40%) per period for a deteriorating (improving) portfolio quality, which reduces the yield associated with lower default exposure by mezzanine and senior tranches accordingly.[103] Returns for mezzanine and senior tranches are lower under improving rather than deteriorating portfolio quality (under both EVT and NID), as expected.

[102] Only the most senior "investor tranches" tranches [9.0-10.5%] and [10.5-100%] for NID-based losses exhibit lower spreads for a decreasing forward rate of default rather than a constant periodic rate of default.
[103] The high level of early loss absorption (at a low discount rate) of the most junior tranche in the case of improving portfolio quality results in a higher return overall compared to the case of decreasing portfolio quality.

Although the level of quasi risk-neutral returns (especially the equity tranche) is mainly driven by design of the securitisation transaction (i.e. the relative thickness and seniority of constituent tranches), the specification of the loss profile for varying portfolio quality explains the plausibility of this counterintuitive result. As opposed to constant portfolio quality, our simulated default term structure of an improving portfolio involves a higher than average default probability (and higher quasi risk-neutral returns) during the initial periods. This relationship gradually reverses as the transaction matures. The same logic applies to deteriorating portfolio quality. Since the high initial default rate of an improving portfolio is not discounted less heavily during the initial periods, the early exhaustion of the most junior tranche translates into higher quasi risk-neutral returns[104] in all junior and mezzanine tranches up to the [6.5-9.0%] tranche. Conversely, a low initial default rate in the case of increasing default should result in quasi risk-neutral returns similar to those observed in the case of a constant default rate. This is mainly because increased default loss goes hand in hand with higher periodic discounting. Since higher back-loaded default losses for a deteriorating portfolio are subject to higher discount rates than front-loaded default losses of similar degree for an improving portfolio, a deteriorating portfolio produces lower compensation for default losses over time and, thus, should display lower quasi risk-neutral returns than an improving portfolio. Nonetheless, both cases induce a higher quasi risk-neutral premium than a constant rate of decline in portfolio quality according to our model set-up. According to these specifications, deteriorating portfolio quality is more favourable for bearers of the most junior tranche,[105] which requires a lower default tolerance (and lower quasi risk-neutral returns per period) for a deteriorating than for an improving portfolio. This effect is pronounced by the tail behaviour of the EVT-based loss function, which attributes higher probability to extreme losses and increases the chances of the equity tranche becoming fully exhausted by default loss early on. Overall, the returns of the small equity tranche are most sensitive to changes in the portfolio quality and stochastic interest rates, whereas the largest nominal share of the transaction held by the most senior [10.5-100%] tranche is hardly sensitive to varying levels of periodic default loss.

[104] This means that the second moment of the default rate of an improving portfolio is smaller than the second moment of the periodic discount rate. The first period default rate establishes an initial portfolio quality such that a declining rate of default over the life of the transaction is insufficient to offset past losses in order reach the same discounted default term structure as a constant default rate.

[105] At the same time, the returns of the equity tranche would be less sensitive to a reduction in the portfolio default rate.

7 REALITY CHECK

7.1 Ratio of estimated and unexpected losses

			unexpect./ expect. losses	$\sigma_{\tilde{L}_j^k} / \tilde{L}_j^k$ **per tranche**					
cum./per.	**Yr**	ρ_u	$\sigma_{\tilde{L}_j} / \tilde{L}_j$	**0-2.4%**	**2.4-3.9%**	**3.9-6.5%**	**6.5-9%**	**9-10.5%**	**10.5-100%**
cumulative	1	0.0026	**0.763279**	0.255607	16.263974	28.619048	48.085333	69.218085	152.600000
periodic			***0.763279***	*0.255607*	*16.263974*	*28.619048*	*48.085333*	*69.218085*	*152.600000*
cumulative	2	0.0026	**0.228911**	0.859840	10.230629	18.791386	33.048934	47.305970	98.304348
periodic			***0.714920***	*0.459298*	*6.133831*	*10.981481*	*19.687204*	*28.056075*	*56.538462*
cumulative	3	0.0026	**0.022952**	0.675790	7.315276	14.005584	25.507508	37.172840	73.972973
periodic			***0.586400***	*0.297389*	*4.078485*	*7.770894*	*14.272897*	*20.613821*	*34.000000*
cumulative	4	0.0026	**0.887564**	0.557873	5.532941	10.073340	20.854564	30.547269	62.568627
periodic			***0.481139***	*0.186807*	*2.970847*	*5.970406*	*10.492447*	*16.424342*	*32.428571*
cumulative	5	0.0026	**0.794226**	0.470644	4.309588	9.041288	17.595607	26.108359	53.970149
periodic			***0.419977***	*0.093721*	*2.244714*	*4.734199*	*9.296296*	*13.679412*	*26.562500*
cumulative	6	0.0026	**0.722162**	0.399835	3.416399	7.486572	15.254047	23.085506	48.500000
periodic			***0.360865***	*0.001989*	*0.723790*	*3.812629*	*7.762673*	*12.145658*	*24.066667*
cumulative	7	0.0026	**0.666226**	0.339409	2.741779	6.277775	13.313522	20.677388	43.887755
periodic			***0.329339***	*-0.093422*	*0.329880*	*3.190448*	*6.678236*	*10.823821*	*20.250000*

Tab. 2. $\sigma_{\tilde{L}_j^k} / \tilde{L}_j^k$ *ratio for each tranche based on simulated constant forward probability rates (EVT distribution of portfolio losses).*

Empirical evidence indicates that CLO tranches actually offer investors higher returns and defy the above assumption of a risk-free term structure of CLO tranches (Batchvarov et al., 2000). This observation is not too surprising given the inherent complexity of securitisation structures and the degree of simplification used in the proposed pricing model. For instance, investors might command higher returns for CLO tranches as liquidity premium or as premium for the leveraged exposure of tranches to changes in underlying portfolio quality as the degree of unexpected loss increases at a higher rate relative to expected loss (see section 5.3).[106]

[106] Synthetic bank CLOs feature even higher spreads than traditional CLOs. This pricing disparity is frequently attributed to the fact that lower secondary liquidity, a less receptive investor base for credit derivative based products and additional risk arising from the increased leverage of the senior tranches in partially funded structures are prime characteristics bearing additional exposure for investors in synthetic CLOs.

In this section, we investigate one aspect of investment risk that might cause generic asset-backed structures to usually be priced cheaper than plain vanilla corporate bonds. We regard the relationship between unexpected and expected loss (ratio of $\sigma_{\tilde{L}_j^k} / \tilde{L}_j^k$) as a margin of error in the estimation of default losses. If applied to each level of tranche seniority under both loss functions for cumulative as well as periodic losses, this measure could possibly serve as a reality check of quasi risk-neutral returns.

			unexpect./expect. losses	$\sigma_{\tilde{L}_j^k} / \tilde{L}_j^k$ **per tranche**					
cum./per.	**Yr**	ρ_u	$\sigma_{\tilde{L}_j} / \tilde{L}_j$	**0-2.4%**	**2.4-3.9%**	**3.9-6.5%**	**6.5-9%**	**9-10.5%**	**10.5-100%**
cumulative	1	0.000100	**0.763279**	0.255607	16.263974	28.619048	48.085333	69.218085	152.600000
periodic			***0.763279***	*0.255607*	*16.263974*	*28.619048*	*48.085333*	*69.218085*	*152.600000*
cumulative	2	0.001231	**0.051203**	0.704859	9.838950	18.219563	32.094838	46.721550	99.869565
periodic			***0.287503***	*0.882510*	*15.965496*	*27.951550*	*48.636612*	*67.781726*	*139.500000*
cumulative	3	0.001945	**0.748019**	0.470625	6.449506	13.138343	24.876912	37.061256	79.911765
periodic			***0.019617***	*0.729154*	*15.505726*	*28.742072*	*53.073955*	*74.791139*	*147.111111*
cumulative	4	0.002469	**0.590130**	0.327399	4.196237	9.579945	19.604386	30.192623	65.836735
periodic			***0.928408***	*0.645643*	*15.242741*	*28.180797*	*50.666667*	*72.567251*	*153.900000*
cumulative	5	0.002771	**0.495414**	0.218772	2.644871	6.944703	15.613388	24.977401	55.088235
periodic			***0.888280***	*0.604602*	*14.944818*	*27.693204*	*48.589041*	*69.369792*	*144.363636*
cumulative	6	0.002954	**0.432260**	0.124650	0.597561	4.951671	12.406935	20.858994	47.307692
periodic			***0.866515***	*0.581594*	*14.912923*	*27.253534*	*48.254011*	*68.587629*	*140.750000*
cumulative	7	0.003055	**0.383209**	0.049212	0.918913	3.444438	9.855055	17.573901	40.622807
periodic			***0.798923***	*0.568850*	*14.858882*	*27.277831*	*49.988473*	*72.104046*	*130.250000*

Tab. 3. $\sigma_{\tilde{L}_j^k} / \tilde{L}_j^k$ *ratio for each tranche based on simulated increasing forward probability rates of a deteriorating portfolio (EVT distribution of portfolio losses).*

EVT estimates of expected losses seem to reduce their margin of error much faster than estimates based on NID (see Appendix 2, Fig. 4). The different results for EVT and NID in Tabs. 11-16 (Appendix 1) and Fig. 4 (Appendix 2) derive from the EVT-based emphasis on the limiting behaviour of normalised maxima, which assigns more weight to credit losses of extreme events to be absorbed by the most junior tranche, which reduces the default risk of more senior "investor tranches". The asymptotic development of unexpected losses borne by the most junior tranche complements a strong decrease of unexpected losses relative to expected losses and a flattening of the default term structure. As shown in Tabs. 2-4 and Fig. 4 (Appendix 2), all $\sigma_{\tilde{L}_j^k} / \tilde{L}_j^k$ ratios decrease over time but differ considerably in orders of magnitude of decline. In contrast to the whole portfolio and the first loss position [0-2.4%], which yield a balanced ratio of $\sigma_{\tilde{L}_j^k} / \tilde{L}_j^k$ in the order of one on the basis of cumulative losses, the second tranche [2.4-3.9%] exhibits a $\sigma_{\tilde{L}_j^k} / \tilde{L}_j^k$ ratio in the order of 10, while in the remaining, more senior tranches, $\sigma_{\tilde{L}_j^k}$ grows roughly twice as fast as $\tilde{L}_j^k$ over time.

			unexpect./ expect. losses	$\sigma_{\tilde{L}_j^k} / \tilde{L}_j^k$ **per tranche**					
cum./per.	**Yr**	ρ_u	$\sigma_{\tilde{L}_j} / \tilde{L}_j$	**0-2.4%**	**2.4-3.9%**	**3.9-6.5%**	**6.5-9%**	**9-10.5%**	**10.5-100%**
cumulative	1	0.003673	**0.753206**	0.506580	14.352758	26.824931	47.851852	69.401099	190.555556
periodic			**0.753206**	*0.506580*	*14.352758*	*26.824931*	*47.851852*	*69.401099*	*190.555556*
cumulative	2	0.002669	**0.574541**	0.357976	7.715834	15.906011	30.903587	45.892601	109.900000
periodic			***0.884208***	*0.618676*	*14.844493*	*26.840553*	*49.311111*	*70.421348*	*139.222222*
cumulative	3	0.001945	**0.503138**	0.280376	4.807617	10.152034	23.062020	35.704185	83.000000
periodic			***0.019617***	*0.729154*	*15.505726*	*28.742072*	*53.073955*	*74.791139*	*147.111111*
cumulative	4	0.001538	**0.463234**	0.218916	3.163151	8.202436	17.983011	29.099426	65.085106
periodic			***0.140216***	*0.810642*	*15.621353*	*27.935294*	*49.544928*	*72.911243*	*142.555556*
cumulative	5	0.001231	**0.439645**	0.164063	2.161659	6.233524	14.607002	24.314133	54.969697
periodic			***0.287503***	*0.882510*	*15.965496*	*27.951550*	*48.636612*	*67.781726*	*139.500000*
cumulative	6	0.000940	**0.422698**	0.116298	0.534117	4.837969	12.123443	20.791274	48.581395
periodic			***0.393729***	*0.963640*	*15.829859*	*27.698656*	*48.480769*	*70.579545*	*176.000000*
cumulative	7	0.000834	**0.407827**	0.075640	0.113930	3.803633	10.217695	18.053308	43.813084
periodic			***0.435650***	*0.992830*	*16.071904*	*28.449848*	*49.002740*	*68.743590*	*157.727273*

Tab. 4. $\sigma_{\tilde{L}_j^k} / \tilde{L}_j^k$ *ratio for each tranche based on simulated decreasing forward probability rates of an improving portfolio (EVT distribution of portfolio losses).*

In general, we find that the impact of $\sigma_{\tilde{L}_j^k}$ on the default term structure declines as the CLO transaction matures, whereas the variation of unexpected losses around the expected value increases with seniority. The term structure of unexpected losses vis-à-vis expected losses has critical implications for the analysis of the security design of securitisation transactions. Our results support the notion that issuers, who usually retain the most junior tranche as a first loss position in the transaction, are only exposed to a constant first moment of expected losses, while investors holding mezzanine (and senior) claims on the reference portfolio might face the prospect of a non-linear increase of losses over time due to an "implicit transfer" of unexpected losses by issuers.

7.2 Comparison to zero-bonds

A disproportionate development of unexpected losses (loss volatility) in relation to expected defaults (average losses) of the reference portfolio ($\sigma_{\tilde{L}_j^k} / \bar{\tilde{L}}_j^k$, i.e. the ratio of unexpected to expected losses) per period might be indicative of abnormal returns on CLO tranches over risk-neutral returns. However, as any difference between the observed returns in the CLO market and the calculated quasi risk-neutral returns depends on the assumptions entering the loss function, the default rates per tranche and the corresponding quasi risk-neutral returns should be subjected to pseudo-empirical scrutiny. Since the calculation of quasi risk-neutral returns on CLO tranches rekindles the derivation of the yield-to-maturity of equally-rated zero-coupon bonds, we benchmark the term structure of periodic default probabilities of selected tranches to comparable zero-bonds, whose internal rate of return is calibrated based on the default rates for rating classes published in the rating reports of *Moody's Investor Services*. This is accomplished by matching the first moments of either the one-year default probability ("lower boundary") or the accumulated seven-year default probability ("upper boundary") assigned by Moody's to a suitable corporate bond[107] with the expected loss of the respective CLO tranche according to the following scaling (see Appendix 2, Figs. 9-10).

Bond benchmarks for CLO tranche returns		
Rating category [Moody's rating]	*Quasi risk-neutral return*	*Bond benchmark for upper/ lower bound of tranche-based default term structure*
Aaa	5.00074%	
Aa1	5.00771%	
Aa2	5.01596%	
Aa3	**5.03278%**	upper bound Tranche 4 [6.5-9%]
A1	**5.05892%**	upper bound Tranche 4[6.5-9%]
A2	5.10357%	
A3	**5.16282%**	upper bound Tranche 3 [3.9-6.5%]
Baa1	5.24663%	
Baa2	**5.35818%**	lower bound Tranche 3 [3.9-6.5%] & Tranche 4 [6.5-9%]
Baa3	5.65911%	
Ba1	**6.10601%**	upper bound Tranche 1 [0-2.4%]
Ba2	**6.73539%**	lower bound Tranche 2 [2.4-3.9%]
Ba3	7.47054%	
B1	8.41114%	
B2	9.52890%	
B3	**11.33656%**	upper bound Tranche 1 [0-2.4%]
Caa	**20.15625%**	lower bound Tranche 1 [0-2.4%]

Tab. 5. *Quasi risk-neutral returns on zero-coupon bonds with a common rating-specific default term structure (Moody's Investor Services), matched with the CLO tranches at the first moment in either the first or seventh period.*

[107] See also Wilson and Fabozzi (1995).

The bond default rate per period matched to the one-year-default rate as lower boundary $\tilde{L}_1^k / \tilde{L}_1^{Bond_{high}} \times \tilde{L}_j^{Bond}$ and the bond default rate per period matched to the seven-year-default rate as upper boundary $\tilde{L}_7^k / \tilde{L}_7^{Bond_{low}} \times \tilde{L}_j^{Bond}$, where the exponential growth of default losses allocated to CLO tranches suggests to use the high expected loss of a lower rated bond as a matching first moment for the seven-year-default rate and the low default rate of a higher rated bond as a matching first moment for the one-year-default rate. The approximation of default rate patterns of zero-bonds and CLO tranches establishes an orientation as to the lower and upper boundaries of the CLO term structure if it had the same expected loss properties as zero-bonds. Hence, the following steps have been completed:

(i) a comparison of default term structure of varying rating classes of zero-bonds (according to *Moody's*) and the estimated expected default term structure based on NID and EVT distributions *(for constant, deteriorating and improving reference portfolio quality)*, and

(ii) a comparison of calculated quasi risk-neutral returns of both zero-bonds and different CLO tranches *(and consideration of deteriorating and improving reference portfolio quality).*

Figs. 9 and 10 (Appendix 2) illustrate the term structure of expected default loss allocated to CLO tranches, with first moments matched to the default term structure of comparable zero-bonds according to Tab. 5. This comparison captures both the equity tranche [0-2.4%] and the "investor tranches" [2.4-3.9%], [3.9-6.5%], [6.5-9.0%] for an EVT-based loss function with a constant forward default rate. The same methodology has been extended for an increasing and decreasing forward default rate.

	Benchmark boundaries	**Quasi risk-neutral zero-bond returns**			
		0-2.4%	**2.4-3.9%**	**3.9-6.5%**	**6.5-9%**
Zero-bond benchmarks	*upper bound of returns* (rating class)	20.15625% [Caa]	6.73539% [Ba2]	5.35818% [Baa2]	5.05892% [A1]
	lower bound of returns (rating class)	11.33656% [B3]	6.10601% [Ba1]	5.16282% [A3]	5.03278% [Aa3]

Tab. 6. *Zero-bond benchmarks of quasi risk-neutral returns of CLO tranches.*

Tab. 6 exhibits the upper and lower boundaries of quasi risk-neutral returns with matched first moments to selected zero-coupon bonds (which have been chosen as close matches to the default term structures in Appendix 2, Figs. 5-7). These boundaries allow for a comparative analysis of the term structure of CLO tranches and zero-bonds of similar quality. In contrast to zero-bonds, whose periodic default rate increases linearly over time, structured default tolerance rises exponentially over time for all tranches but the most junior (first loss position) [0-2.4%]. The "investor tranches" display a similar degree of convexity for both loss distributions, which contrasts sharply with the linear (and in some cases concave) increase of cumulative expected losses of the first loss provision held by the sponsor of the CLO transaction.

Once suitable "benchmark" zero-bonds have been identified, we can examine the implications of the divergent default structures of CLO tranches and zero-bonds on the derivation of quasi risk-neutral returns (see section 6). Tab. 6 (above) matches the default term structure of selected "benchmark" zero-coupon bonds as the upper and lower boundaries to estimated CLO tranche returns.

It appears that the observed difference between quasi risk-neutral returns of CLO tranches and suitable zero-coupon bonds reflects the exponential nature of expected losses associated with the loss cascading effect as a *pars pro toto* of subordination in structured finance transactions *ex ceteris paribus* (see Appendix 2, Fig. 9-10). In the case of a constant forward rate, simulated quasi-risk-neutral returns display the smallest degree of deviation from return expectations for linearly increasing cumulative defaults of zero-coupon bonds, where EVT commands higher returns for the first loss position [0-2.4%] and the most senior "investor tranche" [6.5-9.0%] than NID. This difference increases as we introduce a varying periodic default rate to take account of either a deteriorating or improving portfolio quality over time.

8 EXTENSION: INTRODUCTION OF STOCHASTIC RISK-FREE INTEREST RATES

In this section we allow for a varying risk-free interest rate per period. In simulation of the interest rate r_{f_t}, we need to distinguish between two cases: (i) a variable (stochastic) risk-free interest rate based on the fitted distribution of observed LIBOR rates and (ii) a constant risk-free rate as a stochastic average (level) across time. Since the United Kingdom has left the *European Monetary System (EMS)* as of 16 September 1992 (Jorion, 2001),[108] we restrict the database of interest rates to 12-month LIBOR rates quoted at the daily market's closing from 4 January 1993 to 2 October 2001 (see

[108] One could also argue in favour of using observations only after the Madrid Summit in December 1995, mainly because it was then that a concrete timetable for the introduction of the euro was agreed upon and much of the detailed preparatory work was set in motion. At this point in time, some have argued, the convergence process of European monetary policy commences, as the implications of the 1992 ERM crisis gradually began to be offset by visible evidence of practical advances in the introducing the euro.

Fig. 3) in order to avoid the distortionary effect of a structural break in the time series of observed daily interest rates.[109]

The observed data points do not display significant historical bias ("momentum effect") and heteroskedasticity is low, such that they can be safely regarded i.i.d. With only the first 1,000 observations containing 460 zero returns, the simulation of stochastic interest rates for the given investment horizon requires the transformation of daily LIBOR rates to end-of-the week quotes. Since intra-week rates do not fluctuate, a particular end-of-week effect of daily 12-month LIBOR rates can be confidently ruled out and the statistical validity of extrapolating future interest rates is not impeded. After this conversion of daily rates will are still left with 447 observations to substantiate the simulation.

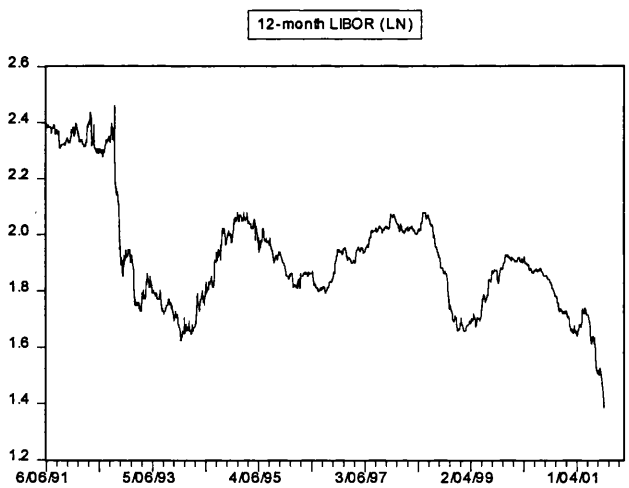

Fig. 3. *Time series of daily LIBOR interest rates (logarithmic scale).*

Generally speaking, interest rate models focus on forecasting returns on fixed income securities in relation to their maturity. The most common approach would assume one or more factors to explain the interest rate term structure. After the time-varying dynamics of a single- or multi-factor model have been specified, the imposition of certain expectation hypotheses yields an explicit result for future interest rates. Thus, we employ the interest rate model

$$d\ln r = \left[\theta(t) - a\ln r\right]dt + \sigma dz, \tag{15}$$

[109] This starting date of the time series was chosen insofar as some time is needed for the event – the U.K. left the *European Monetary System* (EMS) on 16 September 1992 – to manifest itself in the new model.

proposed by Hull and White (1995),[110] where mean reversion is permitted for $a>0$ in the above specification of the stochastic differential equation of interest rate dynamics. Logarithmic interest rates $d\ln r$ instead of nominal r prevent negative interest rates. We substitute the constant μ for the term structure parameter $\theta(t)$, given that the objective of this exercise is predicated on the simulation of the 12-month interest rate at a certain point rather than an entire yield curve. This discretisation yields the AR(1) process

$$\begin{aligned}&\ln r_{t+1}-\ln r_t=\theta(t)-a\ln r_t+\sigma\varepsilon_t=\mu-a\ln r_t+\sigma\varepsilon_t\\&\Leftrightarrow \ln r_{t+1}=\mu-a\ln r_t+\sigma\varepsilon_t+\ln r_t=\mu+(1-a)\ln r_t+\sigma\varepsilon_t\\&\Leftrightarrow \ln r_{t+1}=\mu+a\ln r_t+\sigma\varepsilon_t,\end{aligned} \tag{16}$$

where $r_1,\varepsilon_t\ (t=1,...,T)$ are i.i.d. with expected mean value of 0, standard deviation σ and $a>0$.[111] Visual inspection of logarithmic end-of-week LIBOR interest rates above exhibits only weak level stationarity.[112] The parameter estimate of the return time series of 12-month LIBOR rates

$$R_t=(z_t-z_{t-1})/z_{t-1}\quad \text{for } \hat{z}_t=(1+\hat{\mu}+\hat{\sigma}\varepsilon)z_{t-1}, \tag{17}$$

borders to non-stationarity with coefficient value a close to 0, indicating low mean reversion of LIBOR rates over a sample period T of almost nine years (see Fig. 2). The maximum likelihood (ML) estimation of the probability distribution for AR(1) residuals of logarithmic LIBOR interest rates proves to be inconclusive due to weak mean reversion, which is affirmed by $E_\alpha|\hat{\alpha}-\alpha|^m\to 0\quad (T\to\infty)\quad \forall m\geq 1$ of the *Yule Walker* starting estimator for α:[113]

$$\hat{\alpha}=\left(\sum_{t=1}^{T-1}\ln r_{t+1}\ln r_t\right)\Big/\sum_{t=1}^{T}\ln r_t^2, \tag{18}$$

---

[110] At this point one could certainly consider more advanced interest rate models, such as the *Cox-Ingersoll-Ross* (CIR) model (1985). See also Hull (1993 and 1997).

[111] We abstain from imposing normality on uniformly distributed values of ε_t, because no option prices are determined in the course of this analysis.

[112] It takes about two years on average until the level of LIBOR rates has returned to the original base level.

[113] The *Yule Walker* starting estimator (Miyata, 2001; Nakatuka, 1978) is bounded at $|\hat{\alpha}|\leq 1$, where $\hat{\alpha}-\alpha=-\alpha\left(\ln r_T^2\Big/\sum_{t=1}^{T}\ln r_t^2\right)+\sum_{t=1}^{T-1}\ln r_t\varepsilon_t\Big/\sum_{t=1}^{T}\ln r_t^2$ and $\hat{\alpha}\to\alpha$ follow from $(1/T)\sum_{t=1}^{T}\ln_t^2\to\sigma^2/(1-\alpha^2)$ and $(1/T)\sum_{t=1}^{T-1}\ln r_t\varepsilon_t\to 0$.

parameter	$\hat{\alpha}$	$\hat{a}$
estimator	0.977686	0.022314
std. error	0.027836	0.027836
t-value	35.12	0.80

Tab. 7. *Yule Walker estimation results for mean reversion.*

The residuals of $R_t = \ln r_t - \hat{\alpha} \ln r_{t-1}$ are clearly heavy tailed, as the *q-q* plot (Fig. 4 below) demonstrates. Since positive and negative deviations of observed LIBOR rates from the standard normal distribution appear to be symmetric at the extreme quantiles, we fit a *t*-distribution on mean-adjusted and scaled residuals of the observed data points (Sandmann, 1999; Campell et al., 1997), such that

$$R = \mu + \sigma \varepsilon_t \quad \text{for } \varepsilon_t \sim t_v. \tag{19}$$

The estimated parameters for the 12-month LIBOR interest rate are listed in Tab. 8 below, where the estimated chi-square statistic χ^2_{19} is 24.52 (*p*-value of 0.1769). We simulate one million paths of estimated 12-month LIBOR interest rates over seven years, i.e. 350 time increments, based on the presented model. Given the estimated default term structure in section 4, we estimate the quasi risk-neutral returns per tranche (see Tab. 9 below) if stochastic stochastic risk-free interest is applied to the quasi risk-neutral pricing method in section 6 for both loss distributions (EVT and NID) and all three possibilities of portfolio quality (constant, deteriorating, improving). For illustrative purposes, quasi risk-neutral returns per tranche have also been computed at the average stochastic interest-rate $\exp(\mu/a) = 6.174769\%$ as constant risk-free rate (see Tab. 10). As opposed to the case of a fixed risk-free rate r_{f_l} per period (see section 6), we now introduce stochastic interest rates. Although the summation of stochastic interest rates equates to the summation of constant risk-free interest rates due to mean reversion for $t \to \infty$ in general and $m \to \infty$ in our model, the variation of stochastic interest rates over time results in $r_{f_l} \neq r_{f_{l+1}}$. If we substitute stochastic periodic interest rates for constant risk-free interest rates r_{f_l}, the discount factor $\prod_{l=1}^{m}(1 + r_{f_l})$ is generally smaller for stochastic interest rates and yields lower quasi risk-neutral investor returns.

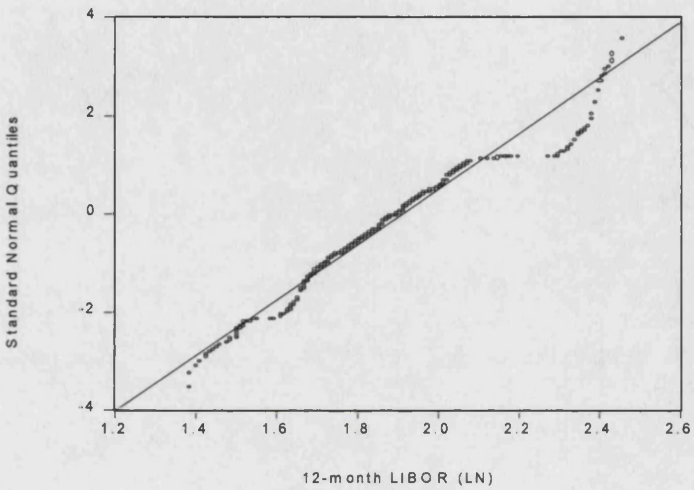

Fig. 4. *q-q plot of observed distribution of LIBOR rates and a standard normal distribution.*

The effect of a lower periodic discount rate will also become more pronounced as the CLO transaction matures. This has a significant bearing on the distinctive term structures of tranches, where the first loss position displays constant expected losses per period, as opposed to "investor tranches", which exhibit a non-linear increase of expected losses per period. In the case of stochastic interest rates, returns for the first loss position will decline more than for mezzanine and senior tranches. Since we benchmark the default term structure of each CLO tranche to comparable zero bonds, we might also enlist the pricing behaviour of bonds to explain the difference in returns by the choice of constant or stochastic risk-free interest rates as periodic discount rate. Investment in bonds is safer (and generates lower returns) at constant periodic discount rates as opposed to time-varying interest rates due to the intrinsic value of volatility. Consequently, a stochastic interest rate, be it periodic or average-weighted, would lead to a marginal decrease of the periodic discount rate and higher calculated returns of tranches than in the case of constant interest rates.

	$\hat{\mu}$	$\hat{\sigma}$	$\hat{v}$
estimator	0.040622	0.011517	2643781
std. error	0.000674	0.000791	0.419292
t-value	60.26	14.55	3.92

Tab. 8. *Estimation of residuals for a fitted t-distribution on 12-month LIBOR.*

Distribution and collateral performance			Quasi risk-neutral returns per tranche *(at average stochastic risk-free rate as discount rate)*					
Allocated tranche losses	Reference portfolio quality	Loss distribution	0-2.4%	2.4-3.9%	3.9-6.5%	6.5-9%	9-10.5%	10.5-100%
cumulative L_j^k	*constant*	EVT	22.39463%	7.30974%	6.29268%	6.10283%	6.06451%	6.03589%
		NID	21.62188%	7.81517%	6.37059%	6.08477%	6.04547%	6.03454%
	deteriorating	EVT	38.26656%	11.74418%	6.71721%	6.14718%	6.07401%	6.03609%
		NID	31.38123%	12.15254%	7.79993%	6.42232%	6.13398%	6.03570%
	improving	EVT	50.15165%	10.84695%	6.63082%	6.14206%	6.07255%	6.03599%
		NID	43.89018%	11.92903%	6.92431%	6.09964%	6.04086%	6.03446%

Tab. 9. *Expected quasi risk-neutral returns per tranche based on the average variable (stochastic) risk-free rate as constant discount rate.*

Distribution and collateral performance			Quasi risk-neutral returns per tranche *(at stochastic risk-free rate as discount rate)*					
Allocated tranche losses	Reference portfolio quality	Loss distribution	0-2.4%	2.4-3.9%	3.9-6.5%	6.5-9%	9-10.5%	10.5-100%
cumulative L_j^k	*constant*	EVT	22.62031%	7.45478%	6.43406%	6.24347%	6.20499%	6.17623%
		NID	21.84458%	7.96229%	6.51219%	6.22531%	6.18585%	6.17488%
	deteriorating	EVT	38.56835%	11.90002%	6.85962%	6.28793%	6.21451%	6.17644%
		NID	31.65209%	12.31435%	7.94590%	6.56384%	6.27462%	6.17605%
	improving	EVT	50.54813%	11.00315%	6.77326%	6.28283%	6.21305%	6.17634%
		NID	44.25293%	12.09255%	7.06783%	6.24022%	6.18122%	6.17480%

Tab. 10. *Expected quasi risk-neutral returns per tranche based on the periodically variable (stochastic) risk-free rate.*

9 CONCLUSION

The main objective of this chapter was the development of a single-factor asset pricing model of subordinated, default-sensitive debt claims *(tranches)* in CLO-style securitisation from a simulated default term structure, under both robust statistical analysis and extreme value theory (EVT). In a general valuation model, we investigated how loss sharing between issuers and investors through subordination effects the way securitisation translates securitised credit risk exposure into leveraged investment risk of issued debt securities. We first completed a Monte Carlo simulation of random default losses from two distinct loss functions of an infinitely granular reference loan portfolio with an i.i.d. periodic default process, where a single systematic risk factor drives aggregate (uniform) default at constant between-asset default correlation. Subsequently, we allocated estimated losses according to tranche subordination to derive the periodic and cumulative default term structure of each tranche over the specified lifetime of the transaction and the corresponding rates of return of risk-neutral investors. This approach allowed us to decompose the default-generating asset value process of securitised loans into a collection of default sensitive debt securities with divergent risk profiles and expected investor returns. The estimated default term structure of individual tranches reflected the transmission mechanism implied by the chosen security design of securitisation. The combination of robust statistics and extreme value analysis for the estimation of the default term structure yielded insights about both the sensitivity of estimation results to the limiting behaviour of extreme events and the leverage effect from subordinated investment at a certain default term structure for different loss profiles and time-varying portfolio quality.

Our findings clearly flag a dichotomy of expected losses per tranche (and associated quasi risk-neutral returns) between the first loss position *(equity tranche)* and more senior "investor tranches," mainly because the subordination of tranches concentrates expected losses in the small first loss position, shifting most unexpected risk to the larger, more senior tranches. The default term structure of cumulative loan loss allocated to the first tranche increases linearly and appears to be more sensitive to varying default rates of the underlying reference portfolio than the more senior "investor tranches", whose expected losses increase in a non-linear fashion over time. The most junior tranche of CLO transactions also exhibits a distinctly different default tolerance of unexpected losses compared to the remaining tranches, which is even more pronounced as the likelihood of extreme loss events increases. Hence, relative loss volatility increases exponentially for tranches beyond the first loss position, where lower unexpected losses imply a more accurate calculation of quasi risk-neutral tranche returns. As unexpected risk becomes a more important component of investment risk than expected losses, more senior investors also experience higher leveraged exposure from unexpected losses than they would on expected losses. We find that as the level of seniority decreases (i) the leverage of relative expected and unexpected losses per tranche to relative portfolio losses increases, (ii) the ratio of unexpected to expected losses decreases, and (iii) the share of expected losses out of overall portfolio losses carried by the respective tranche increases. Against the background of potential agency problems between issuers and investors in securitisation structures, our observations might explain why issuers generally retain the most junior tranche as credit enhancement. The retention of the lowest tranche is tantamount to the acceptance of a calculable "sure loss", which allows issuers to implicitly transfer most of the loss volatility associated with securitised loans to investor tranches.

Since empirical evidence suggests higher stochastic weight associated with extreme events, the gulf between the default term structures of the most junior tranche and the remaining tranches is expected to widen in stress scenarios. Hence, in the context of leveraged investment, the need for precise knowledge about the tail behaviour of default losses makes the case for using an EVT-based approach even more compelling vis-à-vis standard limit distributions, which merely assume moderate deviations around expected losses. Although the effect of subordination remains most distinctive for the most junior tranche irrespective of the type of loss function used to simulate the default term structure, EVT concentrates more expected cumulative losses on the most junior tranche (especially for a changing default rate to reflect time-varying reference portfolio quality) than a normal distribution function, with marginal periodic losses declining asymptotically. So, if issuers properly account for expected losses by providing optimal first loss protection at a certain projected default profile, they benefit from an almost complete removal of unexpected losses from securitised loans. Since our estimation results suggest that 60% to 98% of expected losses are concentrated in the most junior tranche, issuers could potentially offload most unexpected losses to investors.

The impact of tranche subordination on investment risk in our analysis underscores the significance of the transaction structure for the marketability of credit risk exposures via loan securitisation. The retention of first losses from securitised loans seems to be largely motivated by incentives that extend beyond an effort to mitigate the agency cost of asymmetric information associated with the "credit component" of loan securitisation (e.g. information constraints of lending relationships). A subordinated security design supports an efficient placement of debt securities, while the significant decline of marginal unexpected losses of the first loss position over time affords issuers more predictable investment risk than capital market investors, who hold the mezzanine and senior tranches ("investor tranches"). Conversely, careless management of unexpected risk of securitised loans would curtail the issuer's structural discretion to assign specific loss tolerance to each constituent tranche within a particular security design.

Given the inherent ambiguity of the securitised asset quality in CLO markets (especially in bank-based financial systems with relationship lending characteristics) due to insufficient standardisation of accounting practices and reporting standards, our analysis highlights the importance of a careful review of the loss sharing provisions between issuers and investors of securitised debt for the risk assessment of securitised loans.

Our loss-based pricing methodology for securitised tranches presents an instructive blueprint for the estimation of the default term structure of securitised loans. A more comprehensive asset pricing model might also allow for variations in the security design of CLO transactions. Further extensions might include the substitution of time-varying variance and autocorrelation modelling for the simplifying assumption of an infinitely granular portfolio and an i.i.d. sequence of periodic default losses from a single macro-economic risk factor. So far, the presented model has been confined to different periodic default rates with constant pairwise default correlation. The assumption of intertemporal changes of between-asset correlation would provide another contingency on the variation of leveraged exposure of subordinated tranches in loan securitisation, which would certainly guide investor understanding of loss sharing in structured finance products further and promote informed investment.

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11 APPENDIX

11.1 Appendix 1: Tables

			Expected and unexpected losses		$\bar{L}_j^k$ per tranche (in % of tranche volume)						$\bar{L}_j^k$ per tranche (abs. share of total exp. losses per period)					
cum./per.	Yr	ρ_H	$\bar{L}_j$	$\sigma_{\bar{L}_j}$	0-2.4%	2.4-3.9%	3.9-6.5%	6.5-9%	9-10.5%	10.5-100%	0-2.4%	2.4-3.9%	3.9-6.5%	6.5-9%	9-10.5%	10.5-100%
cumulative	1	0.0026	**0.002598**	0.004581	0.104285	0.003095	0.000987	0.000375	0.000188	0.000010	0.002503	0.000046	0.000026	0.000009	0.000005	0.000009
periodic			***0.002598***	*0.004581*	*0.104285*	*0.003095*	*0.000987*	*0.000375*	*0.000188*	*0.000010*	*0.002503*	*0.000046*	*0.000026*	*0.000009*	*0.000005*	*0.000009*
cumulative	2	0.0026	**0.005299**	0.006512	0.207327	0.007653	0.002229	0.000797	0.000402	0.000023	0.004976	0.000115	0.000058	0.000020	0.000010	0.000020
periodic			***0.002701***	*0.001931*	*0.103042*	*0.004558*	*0.001242*	*0.000422*	*0.000214*	*0.000013*	*0.002473*	*0.000068*	*0.000032*	*0.000011*	*0.000005*	*0.000012*
cumulative	3	0.0026	**0.007799**	0.007978	0.308168	0.014546	0.003940	0.001332	0.000648	0.000037	0.007396	0.000218	0.000102	0.000033	0.000016	0.000033
periodic			***0.002500***	*0.001466*	*0.100841*	*0.006893*	*0.001711*	*0.000535*	*0.000246*	*0.000014*	*0.002420*	*0.000103*	*0.000044*	*0.000013*	*0.000006*	*0.000012*
cumulative	4	0.0026	**0.010397**	0.009228	0.406098	0.024665	0.006204	0.001994	0.000952	0.000051	0.009746	0.000370	0.000161	0.000050	0.000024	0.000045
periodic			***0.002598***	*0.001250*	*0.097930*	*0.010119*	*0.002264*	*0.000662*	*0.000304*	*0.000014*	*0.002350*	*0.000152*	*0.000059*	*0.000017*	*0.000008*	*0.000012*
cumulative	5	0.0026	**0.012990**	0.010317	0.500079	0.039278	0.009131	0.002777	0.001292	0.000067	0.012002	0.000589	0.000237	0.000069	0.000032	0.000059
periodic			***0.002593***	*0.001089*	*0.093981*	*0.014613*	*0.002927*	*0.000783*	*0.000340*	*0.000016*	*0.002256*	*0.000219*	*0.000076*	*0.000020*	*0.000009*	*0.000014*
cumulative	6	0.0026	**0.015581**	0.011252	0.589083	0.060005	0.012995	0.003645	0.001649	0.000082	0.014138	0.000900	0.000338	0.000091	0.000041	0.000073
periodic			***0.002591***	*0.000935*	*0.089004*	*0.020727*	*0.003864*	*0.000868*	*0.000357*	*0.000015*	*0.002136*	*0.000311*	*0.000100*	*0.000022*	*0.000009*	*0.000013*
cumulative	7	0.0026	**0.018168**	0.012104	0.671323	0.088676	0.018083	0.004711	0.002052	0.000098	0.016112	0.001330	0.000470	0.000118	0.000051	0.000087
periodic			***0.002587***	*0.000852*	*0.082240*	*0.028671*	*0.005088*	*0.001066*	*0.000403*	*0.000016*	*0.001974*	*0.000430*	*0.000132*	*0.000027*	*0.000010*	*0.000014*

			Expected and unexpected losses		$\sigma_{\bar{L}_j^k}$ per tranche (in % of tranche volume)						$\sigma_{\bar{L}_j^k}$ per tranche (abs. share of total exp. losses per period)					
cum./per.	Yr	ρ_H	$\bar{L}_j$	$\sigma_{\bar{L}_j}$	0-2.4%	2.4-3.9%	3.9-6.5%	6.5-9%	9-10.5%	10.5-100%	0-2.4%	2.4-3.9%	3.9-6.5%	6.5-9%	9-10.5%	10.5-100%
cumulative	1	0.0026	0.002598	**0.004581**	0.130941	0.050337	0.028247	0.018032	0.013013	0.001526	0.003143	0.000755	0.000734	0.000451	0.000325	0.001351
periodic			*0.002598*	***0.004581***	*0.130941*	*0.050337*	*0.028247*	*0.018032*	*0.013013*	*0.001526*	*0.003143*	*0.000755*	*0.000734*	*0.000451*	*0.000325*	*0.001351*
cumulative	2	0.0026	0.005299	**0.006512**	0.178268	0.078295	0.041886	0.026340	0.019017	0.002261	0.004278	0.001174	0.001089	0.000659	0.000475	0.002001
periodic			*0.002701*	***0.001931***	*0.047327*	*0.027958*	*0.013639*	*0.008308*	*0.006004*	*0.000735*	*0.001136*	*0.000419*	*0.000355*	*0.000208*	*0.000150*	*0.000650*
cumulative	3	0.0026	0.007799	**0.007978**	0.208257	0.106408	0.055182	0.033976	0.024088	0.002737	0.004998	0.001596	0.001435	0.000849	0.000602	0.002422
periodic			*0.002500*	***0.001466***	*0.029989*	*0.028113*	*0.013296*	*0.007636*	*0.005071*	*0.000476*	*0.000720*	*0.000422*	*0.000346*	*0.000191*	*0.000127*	*0.000421*
cumulative	4	0.0026	0.010397	**0.009228**	0.226551	0.136470	0.068699	0.041584	0.029081	0.003191	0.005437	0.002047	0.001786	0.001040	0.000727	0.002824
periodic			*0.002598*	***0.001250***	*0.018294*	*0.030062*	*0.013517*	*0.007608*	*0.004993*	*0.000454*	*0.000439*	*0.000451*	*0.000351*	*0.000190*	*0.000125*	*0.000402*
cumulative	5	0.0026	0.012990	**0.010317**	0.235359	0.169272	0.082556	0.048863	0.033732	0.003616	0.005649	0.002539	0.002146	0.001222	0.000843	0.003200
periodic			*0.002593*	***0.001089***	*0.008808*	*0.032802*	*0.013857*	*0.007279*	*0.004651*	*0.000425*	*0.000211*	*0.000492*	*0.000360*	*0.000182*	*0.000116*	*0.000376*
cumulative	6	0.0026	0.015581	**0.011252**	0.235536	0.205001	0.097288	0.055601	0.038068	0.003977	0.005653	0.003075	0.002529	0.001390	0.000952	0.003520
periodic			*0.002591*	***0.000935***	*0.000177*	*0.035729*	*0.014732*	*0.006738*	*0.004336*	*0.000361*	*0.000004*	*0.000536*	*0.000383*	*0.000168*	*0.000108*	*0.000319*
cumulative	7	0.0026	0.018168	**0.012104**	0.227853	0.243130	0.113521	0.062720	0.042430	0.004301	0.005468	0.003647	0.002952	0.001568	0.001061	0.003806
periodic			*0.002587*	***0.000852***	*-0.007683*	*0.038129*	*0.016233*	*0.007119*	*0.004362*	*0.000324*	*-0.000184*	*0.000572*	*0.000422*	*0.000178*	*0.000109*	*0.000287*

Tab. 11. *Simulation of constant forward probability rates (EVT loss function as distribution of portfolio losses) of default losses on a cumulative and periodic basis – losses per tranche with either the tranche % or the absolute value of losses per period as reference base.*

			Expected and unexpected losses		$\tilde{L}_j^k$ per tranche (in % of tranche volume)						$\tilde{L}_j^k$ per tranche (abs. share of total exp. losses per period)					
cum./per.	**Yr**	ρ_H	$\tilde{L}_j$	$\sigma_{\tilde{L}_j}$	**0-2.4%**	**2.4-3.9%**	**3.9-6.5%**	**6.5-9%**	**9-10.5%**	**10.5-100%**	**0-2.4%**	**2.4-3.9%**	**3.9-6.5%**	**6.5-9%**	**9-10.5%**	**10.5-100%**
cumulative	1	0.00010	**0.002598**	0.004581	0.104285	0.003095	0.000987	0.000375	0.000188	0.000010	0.002503	0.000046	0.000026	0.000009	0.000005	0.000009
periodic			***0.002598***	*0.004581*	*0.104285*	*0.003095*	*0.000987*	*0.000375*	*0.000188*	*0.000010*	*0.002503*	*0.000046*	*0.000026*	*0.000009*	*0.000005*	*0.000009*
cumulative	2	0.00123	**0.006191**	0.006508	0.248098	0.008190	0.002382	0.000833	0.000413	0.000023	0.005954	0.000123	0.000062	0.000021	0.000010	0.000020
periodic			***0.003593***	*0.004626*	*0.145561*	*0.003188*	*0.001032*	*0.000366*	*0.000197*	*0.000012*	*0.003452*	*0.000076*	*0.000036*	*0.000011*	*0.000006*	*0.000012*
cumulative	3	0.00195	**0.010473**	0.007834	0.416846	0.018131	0.004431	0.001373	0.000653	0.000034	0.010004	0.000272	0.000115	0.000034	0.000016	0.000030
periodic			***0.004282***	*0.004366*	*0.174498*	*0.003318*	*0.000946*	*0.000311*	*0.000158*	*0.000009*	*0.004050*	*0.000149*	*0.000053*	*0.000014*	*0.000006*	*0.000010*
cumulative	4	0.00247	**0.015278**	0.009016	0.598044	0.039707	0.007968	0.002189	0.000976	0.000049	0.014353	0.000596	0.000207	0.000055	0.000024	0.000043
periodic			***0.004805***	*0.004461*	*0.196124*	*0.003444*	*0.000979*	*0.000336*	*0.000171*	*0.000010*	*0.004349*	*0.000324*	*0.000092*	*0.000020*	*0.000008*	*0.000013*
cumulative	5	0.00277	**0.020389**	0.010101	0.770975	0.088717	0.014413	0.003391	0.001416	0.000068	0.018503	0.001331	0.000375	0.000085	0.000035	0.000060
periodic			***0.005111***	*0.004540*	*0.208625*	*0.003570*	*0.001030*	*0.000365*	*0.000192*	*0.000011*	*0.004150*	*0.000735*	*0.000168*	*0.000030*	*0.000011*	*0.000017*
cumulative	6	0.00295	**0.025679**	0.011100	0.908023	0.195662	0.026506	0.005249	0.002007	0.000091	0.021793	0.002935	0.000689	0.000131	0.000050	0.000081
periodic			***0.005289***	*0.004583*	*0.215965*	*0.003606*	*0.001061*	*0.000374*	*0.000194*	*0.000012*	*0.003289*	*0.001604*	*0.000314*	*0.000046*	*0.000015*	*0.000020*
cumulative	7	0.00306	**0.031064**	0.011904	0.981059	0.389878	0.049962	0.008072	0.002774	0.000114	0.023545	0.005848	0.001299	0.000202	0.000069	0.000101
periodic			***0.005386***	*0.004303*	*0.220174*	*0.003614*	*0.001051*	*0.000347*	*0.000173*	*0.000008*	*0.001753*	*0.002913*	*0.000610*	*0.000071*	*0.000019*	*0.000020*

			Expected and unexpected losses		$\sigma_{\tilde{L}_j^k}$ per tranche (in % of tranche volume)						$\sigma_{\tilde{L}_j^k}$ per tranche (abs. share of total exp. losses per period)					
cum./per.	**Yr**	ρ_H	$\tilde{L}_j$	$\sigma_{\tilde{L}_j}$	**0-2.4%**	**2.4-3.9%**	**3.9-6.5%**	**6.5-9%**	**9-10.5%**	**10.5-100%**	**0-2.4%**	**2.4-3.9%**	**3.9-6.5%**	**6.5-9%**	**9-10.5%**	**10.5-100%**
cumulative	1	0.00010	0.002598	**0.004581**	0.130941	0.050337	0.028247	0.018032	0.013013	0.001526	0.003143	0.000755	0.000734	0.000451	0.000325	0.001351
periodic			*0.002598*	***0.004581***	*0.130941*	*0.050337*	*0.028247*	*0.018032*	*0.013013*	*0.001526*	*0.003143*	*0.000755*	*0.000734*	*0.000451*	*0.000325*	*0.001351*
cumulative	2	0.00123	0.006191	**0.006508**	0.174874	0.080581	0.043399	0.026735	0.019296	0.002297	0.004197	0.001209	0.001128	0.000668	0.000482	0.002033
periodic			*0.003593*	***0.004626***	*0.128459*	*0.050898*	*0.028846*	*0.017801*	*0.013353*	*0.001674*	*0.001054*	*0.000454*	*0.000394*	*0.000218*	*0.000157*	*0.000682*
cumulative	3	0.00195	0.010473	**0.007834**	0.196178	0.116936	0.058216	0.034156	0.024201	0.002717	0.004708	0.001754	0.001514	0.000854	0.000605	0.002405
periodic			*0.004282*	***0.004366***	*0.127236*	*0.051448*	*0.027190*	*0.016506*	*0.011817*	*0.001324*	*0.000511*	*0.000545*	*0.000385*	*0.000186*	*0.000123*	*0.000372*
cumulative	4	0.00247	0.015278	**0.009016**	0.195799	0.166620	0.076333	0.042914	0.029468	0.003226	0.004699	0.002499	0.001985	0.001073	0.000737	0.002855
periodic			*0.004805*	***0.004461***	*0.126626*	*0.052496*	*0.027589*	*0.017024*	*0.012409*	*0.001539*	*-0.000009*	*0.000745*	*0.000471*	*0.000219*	*0.000132*	*0.000450*
cumulative	5	0.00277	0.020389	**0.010101**	0.168668	0.234645	0.100094	0.052945	0.035368	0.003746	0.004048	0.003520	0.002602	0.001324	0.000884	0.003315
periodic			*0.005111*	***0.004540***	*0.126135*	*0.053353*	*0.028524*	*0.017735*	*0.013319*	*0.001588*	*-0.000651*	*0.001020*	*0.000618*	*0.000251*	*0.000148*	*0.000460*
cumulative	6	0.00295	0.025679	**0.011100**	0.113185	0.312582	0.131249	0.065124	0.041864	0.004305	0.002716	0.004689	0.003412	0.001628	0.001047	0.003810
periodic			*0.005289*	***0.004583***	*0.125604*	*0.053776*	*0.028916*	*0.018047*	*0.013306*	*0.001701*	*-0.001332*	*0.001169*	*0.000810*	*0.000304*	*0.000162*	*0.000495*
cumulative	7	0.00306	0.031064	**0.011904**	0.048280	0.358264	0.172091	0.079550	0.048750	0.004631	0.001159	0.005374	0.004474	0.001989	0.001219	0.004098
periodic			*0.005386*	***0.004303***	*0.125246*	*0.053700*	*0.028669*	*0.017346*	*0.012474*	*0.001050*	*-0.001558*	*0.000685*	*0.001062*	*0.000361*	*0.000172*	*0.000289*

Tab. 12. *Simulation of increasing forward probability rates (EVT loss function as distribution of portfolio losses) of default losses on a cumulative and periodic basis – losses per tranche with either the tranche % or the absolute value of losses per period as reference base.*

			Expected and unexpected losses		$\bar{L}_j^k$ per tranche (in % of tranche volume)						$\bar{L}_j^k$ per tranche (abs. share of total exp. losses per period)					
cum./per.	Yr	ρ_H	$\bar{L}_j$	$\sigma_{\bar{L}_j}$	0-2.4%	2.4-3.9%	3.9-6.5%	6.5-9%	9-10.5%	10.5-100%	0-2.4%	2.4-3.9%	3.9-6.5%	6.5-9%	9-10.5%	10.5-100%
cumulative	1	0.00367	**0.006005**	0.004523	0.245673	0.003844	0.001091	0.000378	0.000182	0.000009	0.005896	0.000058	0.000028	0.000009	0.000005	0.000008
periodic			***0.006005***	*0.004523*	*0.245673*	*0.003844*	*0.001091*	*0.000378*	*0.000182*	*0.000009*	*0.005896*	*0.000058*	*0.000028*	*0.000009*	*0.000005*	*0.000008*
cumulative	2	0.00267	**0.011014**	0.006328	0.445650	0.012637	0.003011	0.000892	0.000419	0.000020	0.010696	0.000190	0.000078	0.000022	0.000010	0.000018
periodic			***0.005009***	*0.004429*	*0.204375*	*0.003659*	*0.001085*	*0.000360*	*0.000178*	*0.000009*	*0.004799*	*0.000132*	*0.000050*	*0.000013*	*0.000006*	*0.000010*
cumulative	3	0.00195	**0.015296**	0.007696	0.608457	0.030299	0.005900	0.001564	0.000693	0.000032	0.014603	0.000454	0.000153	0.000039	0.000017	0.000028
periodic			***0.004282***	*0.004366*	*0.174498*	*0.003318*	*0.000946*	*0.000311*	*0.000158*	*0.000009*	*0.003907*	*0.000265*	*0.000075*	*0.000017*	*0.000007*	*0.000011*
cumulative	4	0.00154	**0.019189**	0.008889	0.742734	0.063996	0.010507	0.002531	0.001046	0.000047	0.017826	0.000960	0.000273	0.000063	0.000026	0.000042
periodic			***0.003894***	*0.004440*	*0.158171*	*0.003325*	*0.001020*	*0.000345*	*0.000169*	*0.000009*	*0.003223*	*0.000505*	*0.000120*	*0.000024*	*0.000009*	*0.000013*
cumulative	5	0.00123	**0.022782**	0.010016	0.846424	0.121583	0.017450	0.003799	0.001493	0.000066	0.020314	0.001824	0.000454	0.000095	0.000037	0.000058
periodic			***0.003593***	*0.004626*	*0.145561*	*0.003188*	*0.001032*	*0.000366*	*0.000197*	*0.000012*	*0.002489*	*0.000864*	*0.000181*	*0.000032*	*0.000011*	*0.000017*
cumulative	6	0.00094	**0.026099**	0.011032	0.917378	0.206659	0.027686	0.005460	0.002017	0.000086	0.022017	0.003100	0.000720	0.000137	0.000050	0.000076
periodic			***0.003317***	*0.004623*	*0.134103*	*0.003262*	*0.001042*	*0.000364*	*0.000176*	*0.000010*	*0.001703*	*0.001276*	*0.000266*	*0.000042*	*0.000013*	*0.000018*
cumulative	7	0.00083	**0.029309**	0.011953	0.961671	0.318082	0.042558	0.007584	0.002645	0.000107	0.023080	0.004771	0.001107	0.000190	0.000066	0.000095
periodic			***0.003209***	*0.004607*	*0.129703*	*0.003157*	*0.000987*	*0.000365*	*0.000195*	*0.000011*	*0.001063*	*0.001671*	*0.000387*	*0.000053*	*0.000016*	*0.000019*

			Expected and unexpected losses		$\sigma_{\bar{L}_j^k}$ per tranche (in % of tranche volume)						$\sigma_{\bar{L}_j^k}$ per tranche (abs. share of total exp. losses per period)					
cum./per.	Yr	ρ_H	$\bar{L}_j$	$\sigma_{\bar{L}_j}$	0-2.4%	2.4-3.9%	3.9-6.5%	6.5-9%	9-10.5%	10.5-100%	0-2.4%	2.4-3.9%	3.9-6.5%	6.5-9%	9-10.5%	10.5-100%
cumulative	1	0.00367	0.006005	**0.004523**	0.124453	0.055172	0.029266	0.018088	0.012631	0.001715	0.002987	0.000828	0.000761	0.000452	0.000316	0.001518
periodic			*0.006005*	***0.004523***	*0.124453*	*0.055172*	*0.029266*	*0.018088*	*0.012631*	*0.001715*	*0.002987*	*0.000828*	*0.000761*	*0.000452*	*0.000316*	*0.001518*
cumulative	2	0.00267	0.011014	**0.006328**	0.159532	0.097505	0.047893	0.027566	0.019229	0.002198	0.003829	0.001463	0.001245	0.000689	0.000481	0.001945
periodic			*0.005009*	***0.004429***	*0.126442*	*0.054316*	*0.029122*	*0.017752*	*0.012535*	*0.001253*	*0.000842*	*0.000635*	*0.000484*	*0.000237*	*0.000165*	*0.000427*
cumulative	3	0.00195	0.015296	**0.007696**	0.170597	0.145666	0.065797	0.036069	0.024743	0.002656	0.004094	0.002185	0.001711	0.000902	0.000619	0.002351
periodic			*0.004282*	***0.004366***	*0.127236*	*0.051448*	*0.027190*	*0.016506*	*0.011817*	*0.001324*	*0.000266*	*0.000722*	*0.000466*	*0.000213*	*0.000138*	*0.000405*
cumulative	4	0.00154	0.019189	**0.008889**	0.162596	0.202429	0.086183	0.045515	0.030438	0.003059	0.003902	0.003036	0.002241	0.001138	0.000761	0.002707
periodic			*0.003894*	***0.004440***	*0.128220*	*0.051941*	*0.028494*	*0.017093*	*0.012322*	*0.001283*	*-0.000192*	*0.000851*	*0.000530*	*0.000236*	*0.000142*	*0.000357*
cumulative	5	0.00123	0.022782	**0.010016**	0.138867	0.262821	0.108775	0.055492	0.036301	0.003628	0.003333	0.003942	0.002828	0.001387	0.000908	0.003211
periodic			*0.003593*	***0.004626***	*0.128459*	*0.050898*	*0.028846*	*0.017801*	*0.013353*	*0.001674*	*-0.000569*	*0.000906*	*0.000587*	*0.000249*	*0.000147*	*0.000504*
cumulative	6	0.00094	0.026099	**0.011032**	0.106689	0.317039	0.133944	0.066194	0.041936	0.004178	0.002561	0.004756	0.003483	0.001655	0.001048	0.003698
periodic			*0.003317*	***0.004623***	*0.129227*	*0.051637*	*0.028862*	*0.017647*	*0.012598*	*0.001760*	*-0.000772*	*0.000813*	*0.000654*	*0.000268*	*0.000141*	*0.000487*
cumulative	7	0.00083	0.029309	**0.011953**	0.072741	0.354321	0.161875	0.077491	0.047751	0.004688	0.001746	0.005315	0.004209	0.001937	0.001194	0.004149
periodic			*0.003209*	***0.004607***	*0.128773*	*0.050739*	*0.028080*	*0.017886*	*0.013405*	*0.001735*	*-0.000815*	*0.000559*	*0.000726*	*0.000282*	*0.000145*	*0.000451*

Tab. 13. *Simulation of decreasing forward probability rates (EVT loss function as distribution of portfolio losses) of default losses on a cumulative and periodic basis – losses per tranche with either the tranche % or the absolute value of losses per period as reference base.*

			Expected and unexpected losses		$\tilde{L}_j^k$ per tranche (in % of tranche volume)						$\tilde{L}_j^k$ per tranche (abs. share of total exp. losses per period)					
cum./per.	**Yr**	p	$\tilde{L}_j$	$\sigma_{\tilde{L}_j}$	**0-2.4%**	**2.4-3.9%**	**3.9-6.5%**	**6.5-9%**	**9-10.5%**	**10.5-100%**	**0-2.4%**	**2.4-3.9%**	**3.9-6.5%**	**6.5-9%**	**9-10.5%**	**10.5-100%**
cumulative	1	0.0026	**0.002593**	0.004588	0.104352	0.004135	0.000830	0.000157	0.000041	0.000001	0.002504	0.000062	0.000022	0.000004	0.000001	0.000001
periodic			***0.002593***	*0.004588*	*0.104352*	*0.004135*	*0.000830*	*0.000157*	*0.000041*	*0.000001*	*0.002504*	*0.000062*	*0.000022*	*0.000004*	*0.000001*	*0.000001*
cumulative	2	0.0026	**0.005186**	0.006491	0.206350	0.010987	0.002129	0.000389	0.000110	0.000001	0.004952	0.000165	0.000055	0.000010	0.000003	0.000001
periodic			***0.002593***	*0.001903*	*0.101998*	*0.006852*	*0.001299*	*0.000232*	*0.000069*	*0.000000*	*0.002448*	*0.000103*	*0.000034*	*0.000006*	*0.000002*	*0.000000*
cumulative	3	0.0026	**0.007771**	0.007921	0.304995	0.021439	0.004068	0.000683	0.000177	0.000002	0.007320	0.000322	0.000106	0.000017	0.000004	0.000002
periodic			***0.002585***	*0.001430*	*0.098645*	*0.010452*	*0.001939*	*0.000294*	*0.000067*	*0.000001*	*0.002367*	*0.000157*	*0.000050*	*0.000007*	*0.000002*	*0.000001*
cumulative	4	0.0026	**0.010356**	0.009126	0.399452	0.036819	0.006922	0.001108	0.000261	0.000003	0.009587	0.000552	0.000180	0.000028	0.000007	0.000003
periodic			***0.002585***	*0.001205*	*0.094457*	*0.015380*	*0.002854*	*0.000425*	*0.000084*	*0.000001*	*0.002267*	*0.000231*	*0.000074*	*0.000011*	*0.000002*	*0.000001*
cumulative	5	0.0026	**0.012934**	0.010181	0.488493	0.058068	0.010884	0.001691	0.000392	0.000004	0.011724	0.000871	0.000283	0.000042	0.000010	0.000004
periodic			***0.002578***	*0.001055*	*0.089041*	*0.021249*	*0.003962*	*0.000583*	*0.000131*	*0.000001*	*0.002137*	*0.000319*	*0.000103*	*0.000015*	*0.000003*	*0.000001*
cumulative	6	0.0026	**0.015500**	0.011127	0.570866	0.086047	0.016401	0.002502	0.000559	0.000006	0.013701	0.001291	0.000426	0.000063	0.000014	0.000005
periodic			***0.002566***	*0.000946*	*0.082373*	*0.027979*	*0.005517*	*0.000811*	*0.000167*	*0.000002*	*0.001977*	*0.000420*	*0.000143*	*0.000020*	*0.000004*	*0.000002*
cumulative	7	0.0026	**0.018059**	0.011991	0.645940	0.121363	0.023847	0.003575	0.000777	0.000008	0.015503	0.001820	0.000620	0.000089	0.000019	0.000007
periodic			***0.002559***	*0.000864*	*0.075074*	*0.035316*	*0.007446*	*0.001073*	*0.000218*	*0.000002*	*0.001802*	*0.000530*	*0.000194*	*0.000027*	*0.000005*	*0.000002*

Tab. 14. *Simulation of constant forward probability rates (NID) of default losses on a cumulative and periodic basis – losses per tranche with either the tranche % or the absolute value of losses per period as reference base.*

			Expected and unexpected losses		$\tilde{L}_j^k$ per tranche (in % of tranche volume)						$\tilde{L}_j^k$ per tranche (abs. share of total exp. losses per period)					
cum./per.	**Yr**	p	$\tilde{L}_j$	$\sigma_{\tilde{L}_j}$	**0-2.4%**	**2.4-3.9%**	**3.9-6.5%**	**6.5-9%**	**9-10.5%**	**10.5-100%**	**0-2.4%**	**2.4-3.9%**	**3.9-6.5%**	**6.5-9%**	**9-10.5%**	**10.5-100%**
cumulative	1	0.0026	**0.002593**	0.004579	0.104369	0.004101	0.000831	0.000147	0.000039	0.000001	0.002505	0.000062	0.000022	0.000004	0.000001	0.000001
periodic			***0.002593***	*0.004579*	*0.104369*	*0.004101*	*0.000831*	*0.000147*	*0.000039*	*0.000001*	*0.002505*	*0.000062*	*0.000022*	*0.000004*	*0.000001*	*0.000001*
cumulative	2	0.0026	**0.006178**	0.007552	0.241895	0.016947	0.003589	0.000685	0.000200	0.000004	0.005805	0.000254	0.000093	0.000017	0.000005	0.000004
periodic			***0.003585***	*0.002973*	*0.137526*	*0.012846*	*0.002758*	*0.000538*	*0.000161*	*0.000003*	*0.003301*	*0.000193*	*0.000072*	*0.000013*	*0.000004*	*0.000003*
cumulative	3	0.0026	**0.010451**	0.010198	0.393470	0.045190	0.010055	0.001928	0.000516	0.000008	0.009443	0.000678	0.000261	0.000048	0.000013	0.000007
periodic			***0.004273***	*0.002646*	*0.151575*	*0.028243*	*0.006466*	*0.001243*	*0.000316*	*0.000004*	*0.003638*	*0.000424*	*0.000168*	*0.000031*	*0.000008*	*0.000004*
cumulative	4	0.0026	**0.015207**	0.012650	0.542116	0.096050	0.023047	0.004522	0.001182	0.000016	0.013011	0.001441	0.000599	0.000113	0.000030	0.000014
periodic			***0.004756***	*0.002452*	*0.148646*	*0.050860*	*0.012992*	*0.002594*	*0.000666*	*0.000008*	*0.003568*	*0.000763*	*0.000338*	*0.000065*	*0.000017*	*0.000007*
cumulative	5	0.0026	**0.020238**	0.014826	0.673930	0.172279	0.044946	0.009036	0.002325	0.000030	0.016174	0.002584	0.001169	0.000226	0.000058	0.000027
periodic			***0.005031***	*0.002176*	*0.131814*	*0.076229*	*0.021899*	*0.004514*	*0.001143*	*0.000014*	*0.003164*	*0.001143*	*0.000569*	*0.000113*	*0.000029*	*0.000012*
cumulative	6	0.0026	**0.025426**	0.016816	0.780726	0.271508	0.078663	0.016656	0.004250	0.000054	0.018737	0.004073	0.002045	0.000416	0.000106	0.000048
periodic			***0.005188***	*0.001990*	*0.106796*	*0.099229*	*0.033717*	*0.007620*	*0.001925*	*0.000024*	*0.002563*	*0.001488*	*0.000877*	*0.000191*	*0.000048*	*0.000021*
cumulative	7	0.0026	**0.030681**	0.018618	0.860469	0.386342	0.125166	0.028539	0.007366	0.000094	0.020651	0.005795	0.003254	0.000713	0.000184	0.000083
periodic			***0.005255***	*0.001802*	*0.079743*	*0.114834*	*0.046503*	*0.011883*	*0.003116*	*0.000040*	*0.001914*	*0.001723*	*0.001209*	*0.000297*	*0.000078*	*0.000035*

Tab. 15. *Simulation of increasing forward probability rates (NID) of default losses on a cumulative and periodic basis – losses per tranche with either the tranche % or the absolute value of losses per period as reference base.*

			Expected and unexpected losses		$\tilde{L}_j^k$ per tranche (in % of tranche volume)						$\tilde{L}_j^k$ per tranche (abs. share of total exp. losses per period)					
cum./per.	**Yr**	p	$\tilde{L}_j$	$\sigma_{\tilde{L}_j}$	**0-2.4%**	**2.4-3.9%**	**3.9-6.5%**	**6.5-9%**	**9-10.5%**	**10.5-100%**	**0-2.4%**	**2.4-3.9%**	**3.9-6.5%**	**6.5-9%**	**9-10.5%**	**10.5-100%**
cumulative	1	0.0026	**0.005992**	0.006269	0.241622	0.010208	0.001379	0.000144	0.000023	0.000000	0.005799	0.000153	0.000036	0.000004	0.000001	0.000000
periodic			***0.005992***	*0.006269*	*0.241622*	*0.010208*	*0.001379*	*0.000144*	*0.000023*	*0.000000*	*0.005799*	*0.000153*	*0.000036*	*0.000004*	*0.000001*	*0.000000*
cumulative	2	0.0026	**0.010961**	0.008220	0.431596	0.032250	0.004144	0.000389	0.000061	0.000000	0.010358	0.000484	0.000108	0.000010	0.000002	0.000000
periodic			***0.004969***	*0.001951*	*0.189974*	*0.022042*	*0.002765*	*0.000245*	*0.000037*	*0.000000*	*0.004559*	*0.000331*	*0.000072*	*0.000006*	*0.000001*	*0.000000*
cumulative	3	0.0026	**0.015214**	0.009431	0.580569	0.068669	0.008830	0.000719	0.000097	0.000001	0.013934	0.001030	0.000230	0.000018	0.000002	0.000000
periodic			***0.004253***	*0.001211*	*0.148973*	*0.036419*	*0.004686*	*0.000330*	*0.000037*	*0.000000*	*0.003575*	*0.000546*	*0.000122*	*0.000008*	*0.000001*	*0.000000*
cumulative	4	0.0026	**0.019060**	0.010333	0.698890	0.121829	0.016286	0.001245	0.000147	0.000001	0.016773	0.001827	0.000423	0.000031	0.000004	0.000001
periodic			***0.003846***	*0.000902*	*0.118321*	*0.053160*	*0.007456*	*0.000526*	*0.000050*	*0.000000*	*0.002840*	*0.000797*	*0.000194*	*0.000013*	*0.000001*	*0.000000*
cumulative	5	0.0026	**0.022595**	0.011046	0.790304	0.190679	0.027340	0.002020	0.000225	0.000001	0.018967	0.002860	0.000711	0.000051	0.000006	0.000001
periodic			***0.003535***	*0.000713*	*0.091414*	*0.068850*	*0.011054*	*0.000775*	*0.000078*	*0.000000*	*0.002194*	*0.001033*	*0.000287*	*0.000019*	*0.000002*	*0.000000*
cumulative	6	0.0026	**0.025819**	0.011616	0.857477	0.270135	0.042336	0.003105	0.000323	0.000001	0.020579	0.004052	0.001101	0.000078	0.000008	0.000001
periodic			***0.003224***	*0.000570*	*0.067173*	*0.079456*	*0.014996*	*0.001085*	*0.000098*	*0.000000*	*0.001612*	*0.001192*	*0.000390*	*0.000027*	*0.000002*	*0.000000*
cumulative	7	0.0026	**0.028936**	0.012125	0.907148	0.359962	0.062859	0.004687	0.000454	0.000002	0.021772	0.005399	0.001634	0.000117	0.000011	0.000002
periodic			***0.003117***	*0.000509*	*0.049671*	*0.089827*	*0.020523*	*0.001582*	*0.000131*	*0.000000*	*0.001192*	*0.001347*	*0.000534*	*0.000040*	*0.000003*	*0.000000*

Tab. 16. *Simulation of decreasing forward probability rates (NID) of default losses on a cumulative and periodic basis – losses per tranche with either the tranche % or the absolute value of losses per period as reference base.*

			Expected and unexpected losses		EL leverage: relative tranche loss to relative portfolio $\tilde{L}_j^k/\tilde{L}_j$ multiple						UL leverage: relative tranche loss to relative portfolio $\sigma_{\tilde{L}_j^k}/\sigma_{\tilde{L}_j}$ multiple					
cum./per.	**Yr**	ρ_{it}	$\tilde{L}_j$	$\sigma_{\tilde{L}_j}$	**0-2.4%**	**2.4-3.9%**	**3.9-6.5%**	**6.5-9.0%**	**9.0-10.5%**	**10.5-100%**	**0-2.4%**	**2.4-3.9%**	**3.9-6.5%**	**6.5-9.0%**	**9.0-10.5%**	**10.5-100%**
cumulative	1	0.0026	0.002598	0.004581	40.140	1.191	0.380	0.144	0.072	0.004	28.583	10.988	6.166	3.936	2.841	0.333
periodic			*0.002598*	*0.004581*	*40.140*	*1.191*	*0.380*	*0.144*	*0.072*	*0.004*	*28.583*	*10.988*	*6.166*	*3.936*	*2.841*	*0.333*
cumulative	2	0.0026	0.005299	0.006512	39.126	1.444	0.421	0.150	0.076	0.004	27.375	12.023	6.432	4.045	2.920	0.347
periodic			*0.002701*	*0.001931*	*38.150*	*1.688*	*0.460*	*0.156*	*0.079*	*0.005*	*24.509*	*14.479*	*7.063*	*4.302*	*3.109*	*0.381*
cumulative	3	0.0026	0.007799	0.007978	39.514	1.865	0.505	0.171	0.083	0.005	26.104	13.338	6.917	4.259	3.019	0.343
periodic			*0.002500*	*0.001466*	*40.336*	*2.757*	*0.684*	*0.214*	*0.098*	*0.006*	*20.456*	*19.177*	*9.070*	*5.209*	*3.459*	*0.325*
cumulative	4	0.0026	0.010397	0.009228	39.059	2.372	0.597	0.192	0.092	0.005	24.550	14.789	7.445	4.506	3.151	0.346
periodic			*0.002598*	*0.001250*	*37.694*	*3.895*	*0.871*	*0.255*	*0.117*	*0.005*	*14.635*	*24.050*	*10.814*	*6.086*	*3.994*	*0.363*
cumulative	5	0.0026	0.012990	0.010317	38.497	3.024	0.703	0.214	0.099	0.005	22.813	16.407	8.002	4.736	3.270	0.350
periodic			*0.002593*	*0.001089*	*36.244*	*5.636*	*1.129*	*0.302*	*0.131*	*0.006*	*8.088*	*30.121*	*12.725*	*6.684*	*4.271*	*0.390*
cumulative	6	0.0026	0.015581	0.011252	37.808	3.851	0.834	0.234	0.106	0.005	20.933	18.219	8.646	4.941	3.383	0.353
periodic			*0.002591*	*0.000935*	*34.351*	*8.000*	*1.491*	*0.335*	*0.138*	*0.006*	*0.189*	*38.213*	*15.756*	*7.206*	*4.637*	*0.386*
cumulative	7	0.0026	0.018168	0.012104	36.951	4.881	0.995	0.259	0.113	0.005	18.825	20.087	9.379	5.182	3.505	0.355
periodic			*0.002587*	*0.000852*	*31.790*	*11.083*	*1.967*	*0.412*	*0.156*	*0.006*	*-9.018*	*44.752*	*19.053*	*8.356*	*5.120*	*0.380*

Tab. 17. *Leveraged expected and unexpected loss exposure of constituent tranches through time for constant forward probability rates (EVT loss function of default losses on a cumulative and periodic basis, see Tab. 11).*

			Expected and unexpected losses		EL leverage: relative tranche loss to relative portfolio $\tilde{L}_j^k/\tilde{L}_j$ multiple						UL leverage: relative tranche loss to relative portfolio $\sigma_{\tilde{L}_j^k}/\sigma_{\tilde{L}_j}$ multiple					
cum./per.	Yr	ρ_u	$\tilde{L}_j$	$\sigma_{\tilde{L}_j}$	0-2.4%	2.4-3.9%	3.9-6.5%	6.5-9.0%	9.0-10.5%	10.5-100%	0-2.4%	2.4-3.9%	3.9-6.5%	6.5-9.0%	9.0-10.5%	10.5-100%
cumulative	1	0.00010	0.002598	0.004581	40.140	1.191	0.380	0.144	0.072	0.004	28.583	10.988	6.166	3.936	2.841	0.333
periodic			*0.002598*	*0.004581*	*40.140*	*1.191*	*0.380*	*0.144*	*0.072*	*0.004*	*28.583*	*10.988*	*6.166*	*3.936*	*2.841*	*0.333*
cumulative	2	0.00123	0.006191	0.006508	40.074	1.323	0.385	0.135	0.067	0.004	26.871	12.382	6.669	4.108	2.965	0.353
periodic			*0.003593*	*0.004626*	*40.512*	*0.887*	*0.287*	*0.102*	*0.055*	*0.003*	*27.769*	*11.003*	*6.236*	*3.848*	*2.887*	*0.362*
cumulative	3	0.00195	0.010473	0.007834	39.802	1.731	0.423	0.131	0.062	0.003	25.042	14.927	7.431	4.360	3.089	0.347
periodic			*0.004282*	*0.004366*	*40.752*	*0.775*	*0.221*	*0.073*	*0.037*	*0.002*	*29.142*	*11.784*	*6.228*	*3.781*	*2.707*	*0.303*
cumulative	4	0.00247	0.015278	0.009016	39.144	2.599	0.522	0.143	0.064	0.003	21.717	18.480	8.466	4.760	3.268	0.358
periodic			*0.004805*	*0.004461*	*40.817*	*0.717*	*0.204*	*0.070*	*0.036*	*0.002*	*28.385*	*11.768*	*6.184*	*3.816*	*2.782*	*0.345*
cumulative	5	0.00277	0.020389	0.010101	37.813	4.351	0.707	0.166	0.069	0.003	16.698	23.230	9.909	5.242	3.501	0.371
periodic			*0.005111*	*0.004540*	*40.819*	*0.698*	*0.202*	*0.071*	*0.038*	*0.002*	*27.783*	*11.752*	*6.283*	*3.906*	*2.934*	*0.350*
cumulative	6	0.00295	0.025679	0.011100	35.361	7.620	1.032	0.204	0.078	0.004	10.197	28.161	11.824	5.867	3.772	0.388
periodic			*0.005289*	*0.004583*	*40.833*	*0.682*	*0.201*	*0.071*	*0.037*	*0.002*	*27.407*	*11.734*	*6.309*	*3.938*	*2.903*	*0.371*
cumulative	7	0.00306	0.031064	0.011904	31.582	12.551	1.608	0.260	0.089	0.004	4.056	30.096	14.457	6.683	4.095	0.389
periodic			*0.005386*	*0.004303*	*40.879*	*0.671*	*0.195*	*0.064*	*0.032*	*0.001*	*29.107*	*12.480*	*6.663*	*4.031*	*2.899*	*0.244*

Tab. 18. *Leveraged expected and unexpected loss exposure of constituent tranches through time for increasing forward probability rates (EVT loss function of default losses on a cumulative and periodic basis, see Tab. 12).*

			Expected and unexpected losses		EL leverage: relative tranche loss to relative portfolio $\tilde{L}_j^k/\tilde{L}_j$ multiple						UL leverage: relative tranche loss to relative portfolio $\sigma_{\tilde{L}_j^k}/\sigma_{\tilde{L}_j}$ multiple					
cum./per.	Yr	ρ_u	$\tilde{L}_j$	$\sigma_{\tilde{L}_j}$	0-2.4%	2.4-3.9%	3.9-6.5%	6.5-9.0%	9.0-10.5%	10.5-100%	0-2.4%	2.4-3.9%	3.9-6.5%	6.5-9.0%	9.0-10.5%	10.5-100%
cumulative	1	0.00367	0.006005	0.004523	40.911	0.640	0.182	0.063	0.030	0.001	27.516	12.198	6.470	3.999	2.793	0.379
periodic			*0.006005*	*0.004523*	*40.911*	*0.640*	*0.182*	*0.063*	*0.030*	*0.001*	*27.516*	*12.198*	*6.470*	*3.999*	*2.793*	*0.379*
cumulative	2	0.00267	0.011014	0.006328	40.462	1.147	0.273	0.081	0.038	0.002	25.210	15.409	7.568	4.356	3.039	0.347
periodic			*0.005009*	*0.004429*	*40.802*	*0.730*	*0.217*	*0.072*	*0.036*	*0.002*	*28.549*	*12.264*	*6.575*	*4.008*	*2.830*	*0.283*
cumulative	3	0.00195	0.015296	0.007696	39.779	1.981	0.386	0.102	0.045	0.002	22.167	18.927	8.550	4.687	3.215	0.345
periodic			*0.004282*	*0.004366*	*40.752*	*0.775*	*0.221*	*0.073*	*0.037*	*0.002*	*29.142*	*11.784*	*6.228*	*3.781*	*2.707*	*0.303*
cumulative	4	0.00154	0.019189	0.008889	38.706	3.335	0.548	0.132	0.055	0.002	18.292	22.773	9.695	5.120	3.424	0.344
periodic			*0.003894*	*0.004440*	*40.619*	*0.854*	*0.262*	*0.089*	*0.043*	*0.002*	*28.878*	*11.698*	*6.418*	*3.850*	*2.775*	*0.289*
cumulative	5	0.00123	0.022782	0.010016	37.153	5.337	0.766	0.167	0.066	0.003	13.865	26.240	10.860	5.540	3.624	0.362
periodic			*0.003593*	*0.004626*	*40.512*	*0.887*	*0.287*	*0.102*	*0.055*	*0.003*	*27.769*	*11.003*	*6.236*	*3.848*	*2.887*	*0.362*
cumulative	6	0.00094	0.026099	0.011032	35.150	7.918	1.061	0.209	0.077	0.003	9.671	28.738	12.141	6.000	3.801	0.379
periodic			*0.003317*	*0.004623*	*40.429*	*0.983*	*0.314*	*0.110*	*0.053*	*0.003*	*27.953*	*11.170*	*6.243*	*3.817*	*2.725*	*0.381*
cumulative	7	0.00083	0.029309	0.011953	32.811	10.853	1.452	0.259	0.090	0.004	6.086	29.643	13.543	6.483	3.995	0.392
periodic			*0.003209*	*0.004607*	*40.419*	*0.984*	*0.308*	*0.114*	*0.061*	*0.003*	*27.952*	*11.013*	*6.095*	*3.882*	*2.910*	*0.377*

Tab. 19. *Leveraged expected and unexpected loss exposure of constituent tranches through time for decreasing forward probability rates (EVT loss function of default losses on a cumulative and periodic basis, see Tab. 13).*

			Expected and unexpected losses		EL leverage: relative tranche loss to relative portfolio $\tilde{L}^k_j/\tilde{L}_j$ multiple					
cum./per.	**Yr**	p	$\tilde{L}_j$	$\sigma_{\tilde{L}_j}$	**0-2.4%**	**2.4-3.9%**	**3.9-6.5%**	**6.5-9.0%**	**9.0-10.5%**	**10.5-100%**
cumulative	1	0.0026	**0.002598**	0.004581	40.244	1.595	0.320	0.061	0.016	0.000
periodic			***0.002598***	*0.004581*	*40.244*	*1.595*	*0.320*	*0.061*	*0.016*	*0.000*
cumulative	2	0.0026	**0.005299**	0.006512	39.790	2.119	0.411	0.075	0.021	0.000
periodic			***0.002701***	*0.001931*	*39.336*	*2.642*	*0.501*	*0.089*	*0.027*	*0.000*
cumulative	3	0.0026	**0.007799**	0.007978	39.248	2.759	0.523	0.088	0.023	0.000
periodic			***0.002500***	*0.001466*	*38.161*	*4.043*	*0.750*	*0.114*	*0.026*	*0.000*
cumulative	4	0.0026	**0.010397**	0.009228	38.572	3.555	0.668	0.107	0.025	0.000
periodic			***0.002598***	*0.001250*	*36.540*	*5.950*	*1.104*	*0.164*	*0.032*	*0.000*
cumulative	5	0.0026	**0.012990**	0.010317	37.768	4.490	0.842	0.131	0.030	0.000
periodic			***0.002593***	*0.001089*	*34.539*	*8.242*	*1.537*	*0.226*	*0.051*	*0.000*
cumulative	6	0.0026	**0.015581**	0.011252	36.830	5.551	1.058	0.161	0.036	0.000
periodic			***0.002591***	*0.000935*	*32.102*	*10.904*	*2.150*	*0.316*	*0.065*	*0.001*
cumulative	7	0.0026	**0.018168**	0.012104	35.768	6.720	1.321	0.198	0.043	0.000
periodic			***0.002587***	*0.000852*	*29.337*	*13.801*	*2.910*	*0.419*	*0.085*	*0.001*

Tab. 20. *Leveraged expected loss exposure of constituent tranches through time for constant forward probability rates (NID loss function of default losses on a cumulative and periodic basis, see Tab. 14).*

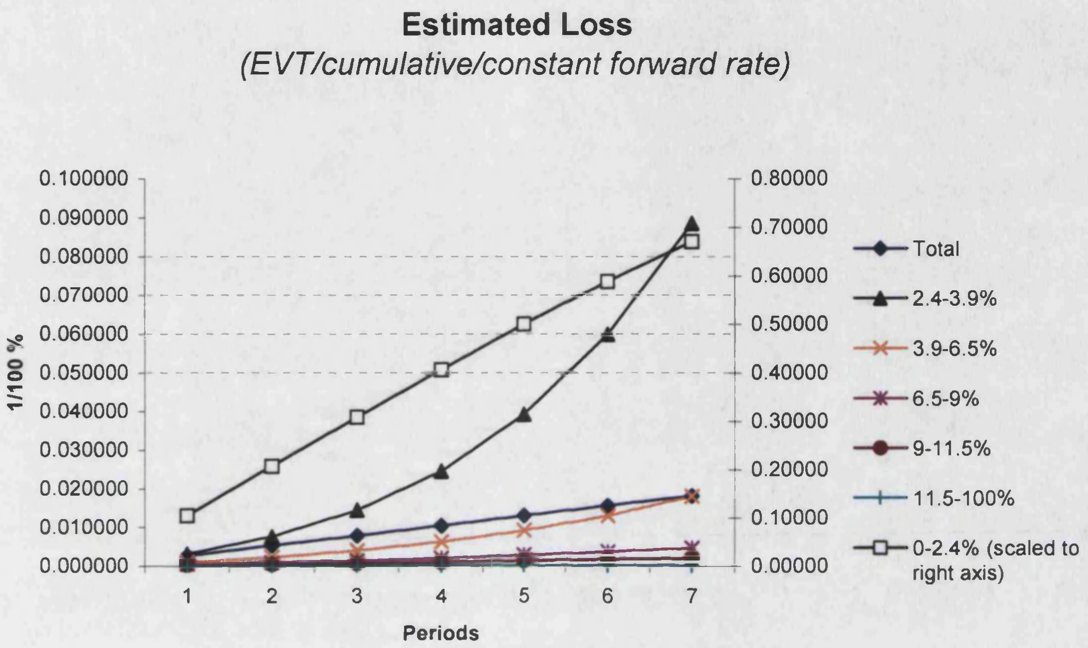
			Expected and unexpected losses		EL leverage: relative tranche loss to relative portfolio $\tilde{L}^k_j/\tilde{L}_j$ multiple					
cum./per.	**Yr**	p	$\tilde{L}_j$	$\sigma_{\tilde{L}_j}$	**0-2.4%**	**2.4-3.9%**	**3.9-6.5%**	**6.5-9.0%**	**9.0-10.5%**	**10.5-100%**
cumulative	1	0.0026	**0.002598**	0.004581	40.250	1.582	0.320	0.057	0.015	0.000
periodic			***0.002598***	*0.004581*	*40.250*	*1.582*	*0.320*	*0.057*	*0.015*	*0.000*
cumulative	2	0.0026	**0.005299**	0.006512	39.154	2.743	0.581	0.111	0.032	0.001
periodic			***0.002701***	*0.001931*	*38.362*	*3.583*	*0.769*	*0.150*	*0.045*	*0.001*
cumulative	3	0.0026	**0.007799**	0.007978	37.649	4.324	0.962	0.184	0.049	0.001
periodic			***0.002500***	*0.001466*	*35.473*	*6.610*	*1.513*	*0.291*	*0.074*	*0.001*
cumulative	4	0.0026	**0.010397**	0.009228	35.649	6.316	1.516	0.297	0.078	0.001
periodic			***0.002598***	*0.001250*	*31.254*	*10.694*	*2.732*	*0.545*	*0.140*	*0.002*
cumulative	5	0.0026	**0.012990**	0.010317	33.300	8.513	2.221	0.446	0.115	0.001
periodic			***0.002593***	*0.001089*	*26.200*	*15.152*	*4.353*	*0.897*	*0.227*	*0.003*
cumulative	6	0.0026	**0.015581**	0.011252	30.706	10.678	3.094	0.655	0.167	0.002
periodic			***0.002591***	*0.000935*	*20.585*	*19.127*	*6.499*	*1.469*	*0.371*	*0.005*
cumulative	7	0.0026	**0.018168**	0.012104	28.046	12.592	4.080	0.930	0.240	0.003
periodic			***0.002587***	*0.000852*	*15.175*	*21.852*	*8.849*	*2.261*	*0.593*	*0.008*

Tab. 21. *Leveraged expected loss exposure of constituent tranches through time for increasing forward probability rates (NID loss function of default losses on a cumulative and periodic basis, see Tab. 15).*

			Expected and unexpected losses		EL leverage: relative tranche loss to relative portfolio $\tilde{L}_j^k / \tilde{L}_j$ multiple					
cum./per.	**Yr**	p	$\bar{L}_j$	$\sigma_{\bar{L}_j}$	**0-2.4%**	**2.4-3.9%**	**3.9-6.5%**	**6.5-9.0%**	**9.0-10.5%**	**10.5-100%**
cumulative	1	0.0026	**0.002598**	0.004581	40.324	1.704	0.230	0.024	0.004	0.000
periodic			***0.002598***	*0.004581*	*40.324*	*1.704*	*0.230*	*0.024*	*0.004*	*0.000*
cumulative	2	0.0026	**0.005299**	0.006512	39.376	2.942	0.378	0.035	0.006	0.000
periodic			***0.002701***	*0.001931*	*38.232*	*4.436*	*0.556*	*0.049*	*0.007*	*0.000*
cumulative	3	0.0026	**0.007799**	0.007978	38.160	4.514	0.580	0.047	0.006	0.000
periodic			***0.002500***	*0.001466*	*35.028*	*8.563*	*1.102*	*0.078*	*0.009*	*0.000*
cumulative	4	0.0026	**0.010397**	0.009228	36.668	6.392	0.854	0.065	0.008	0.000
periodic			***0.002598***	*0.001250*	*30.765*	*13.822*	*1.939*	*0.137*	*0.013*	*0.000*
cumulative	5	0.0026	**0.012990**	0.010317	34.977	8.439	1.210	0.089	0.010	0.000
periodic			***0.002593***	*0.001089*	*25.860*	*19.477*	*3.127*	*0.219*	*0.022*	*0.000*
cumulative	6	0.0026	**0.015581**	0.011252	33.211	10.463	1.640	0.120	0.013	0.000
periodic			***0.002591***	*0.000935*	*20.835*	*24.645*	*4.651*	*0.337*	*0.030*	*0.000*
cumulative	7	0.0026	**0.018168**	0.012104	31.350	12.440	2.172	0.162	0.016	0.000
periodic			***0.002587***	*0.000852*	*15.936*	*28.818*	*6.584*	*0.508*	*0.042*	*0.000*

Tab. 22. *Leveraged expected loss exposure of constituent tranches through time for decreasing forward probability rates (NID loss function of default losses on a cumulative and periodic basis, see Tab. 16).*

11.2 Appendix 2: Figures



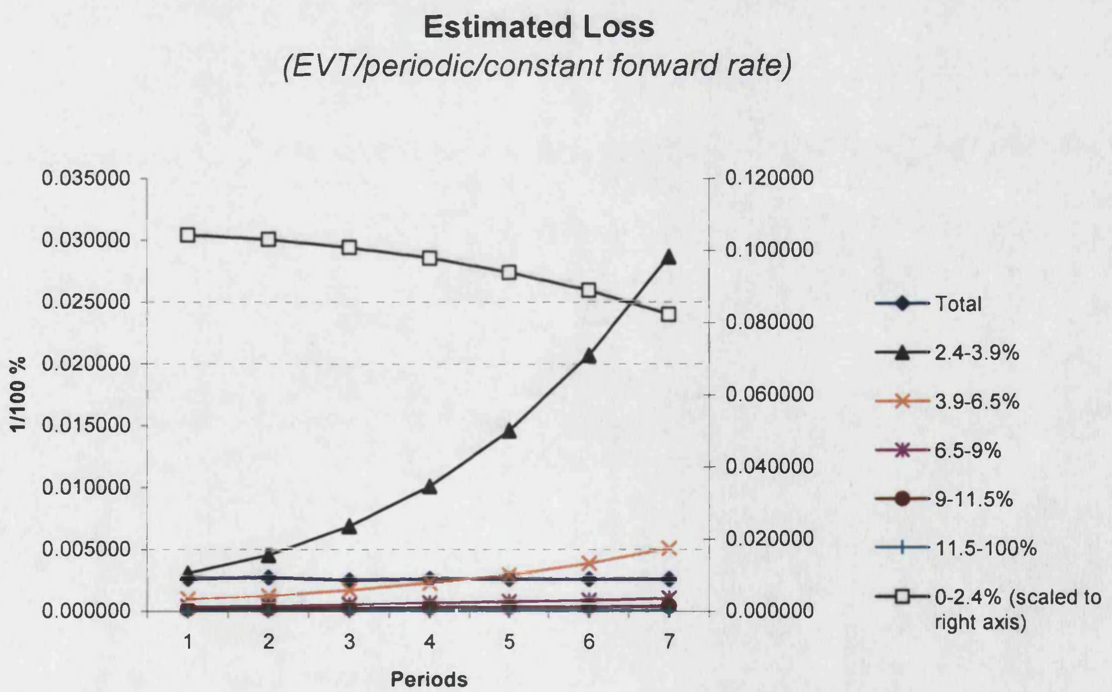
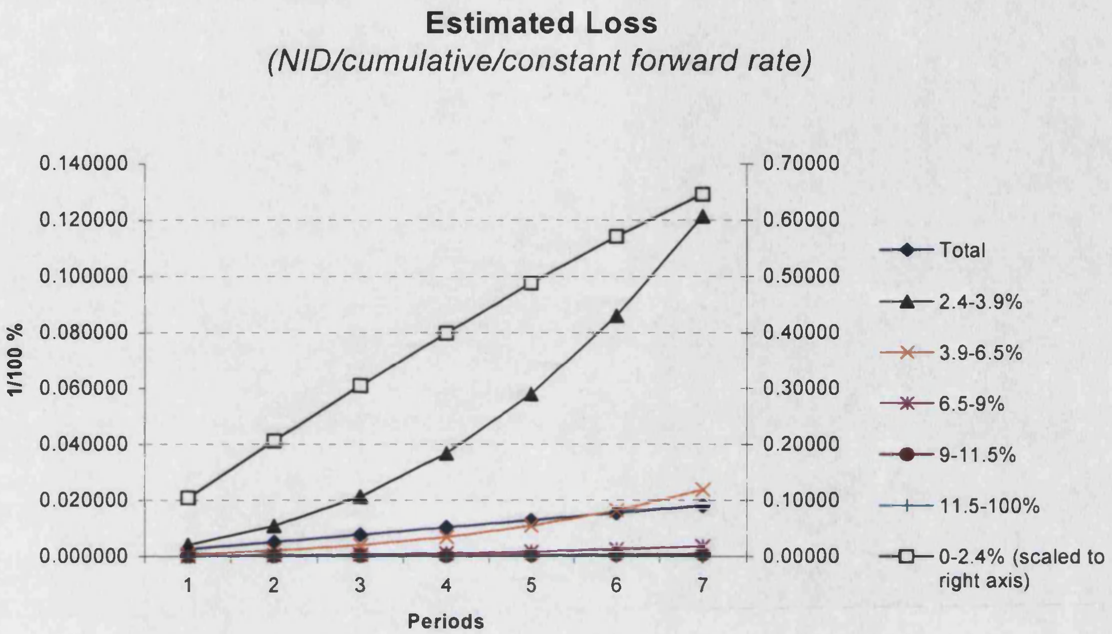


Fig. 5. *Default term structure of cumulative and periodic expected losses of constituent tranches (based on EVT loss function). The first tranche [0-2.4%] scales with the right axis.*



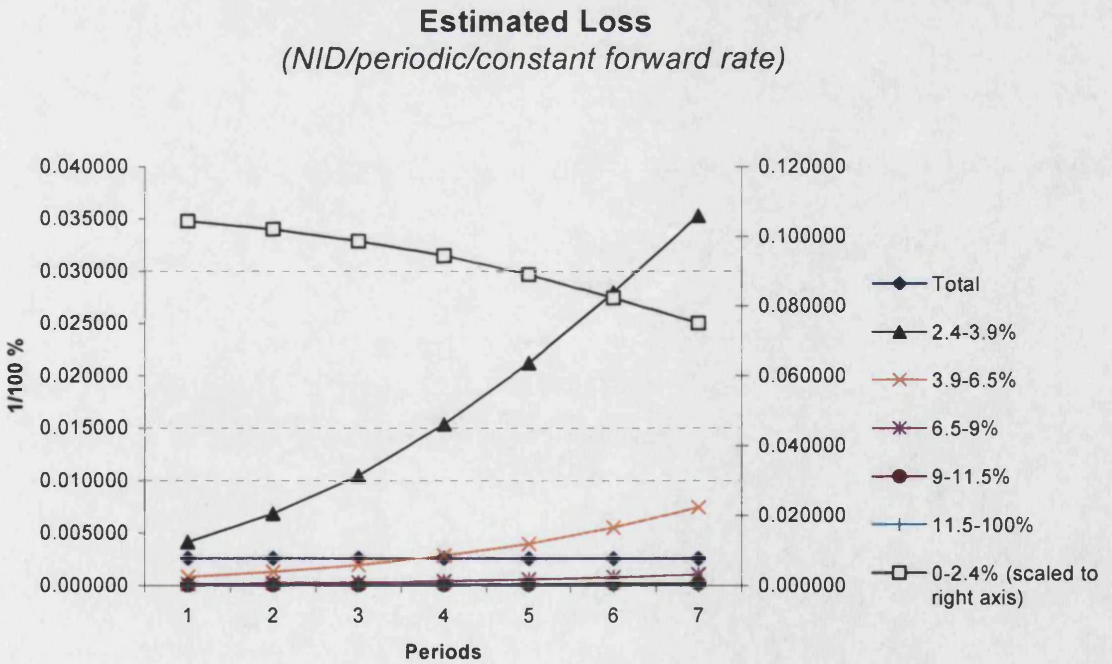
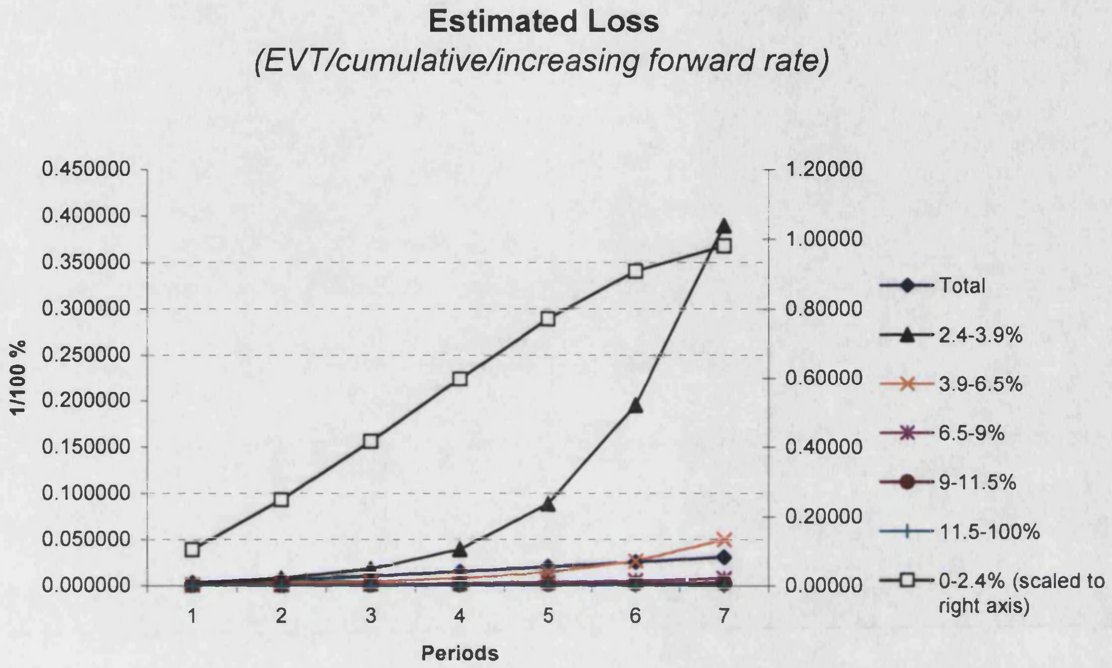


Fig. 6. *Default term structure of cumulative and periodic expected losses of constituent tranches (based on NID loss function). The first tranche [0-2.4%] scales with the right axis. The most senior tranche has been excluded for the logarithmic case due to negative values.*



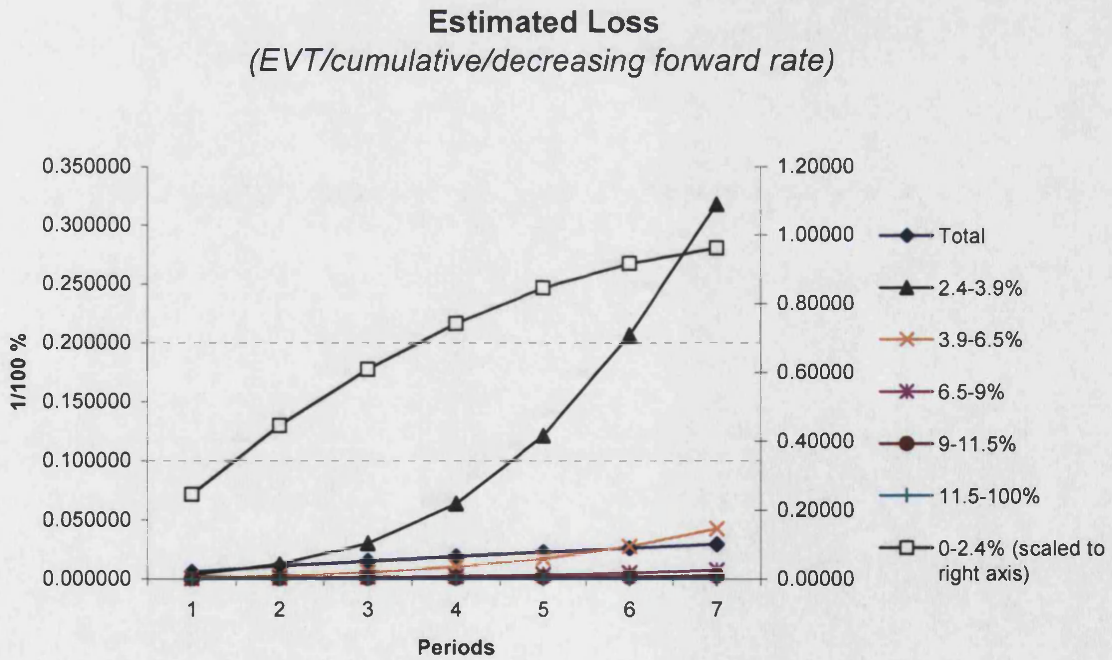


Fig. 7. *Expected loss of constituent tranches for a deteriorating portfolio (i.e. increasing forward rate of default) based on EVT loss function. The most junior tranche [0-2.4%] is scaled to the right axis.*

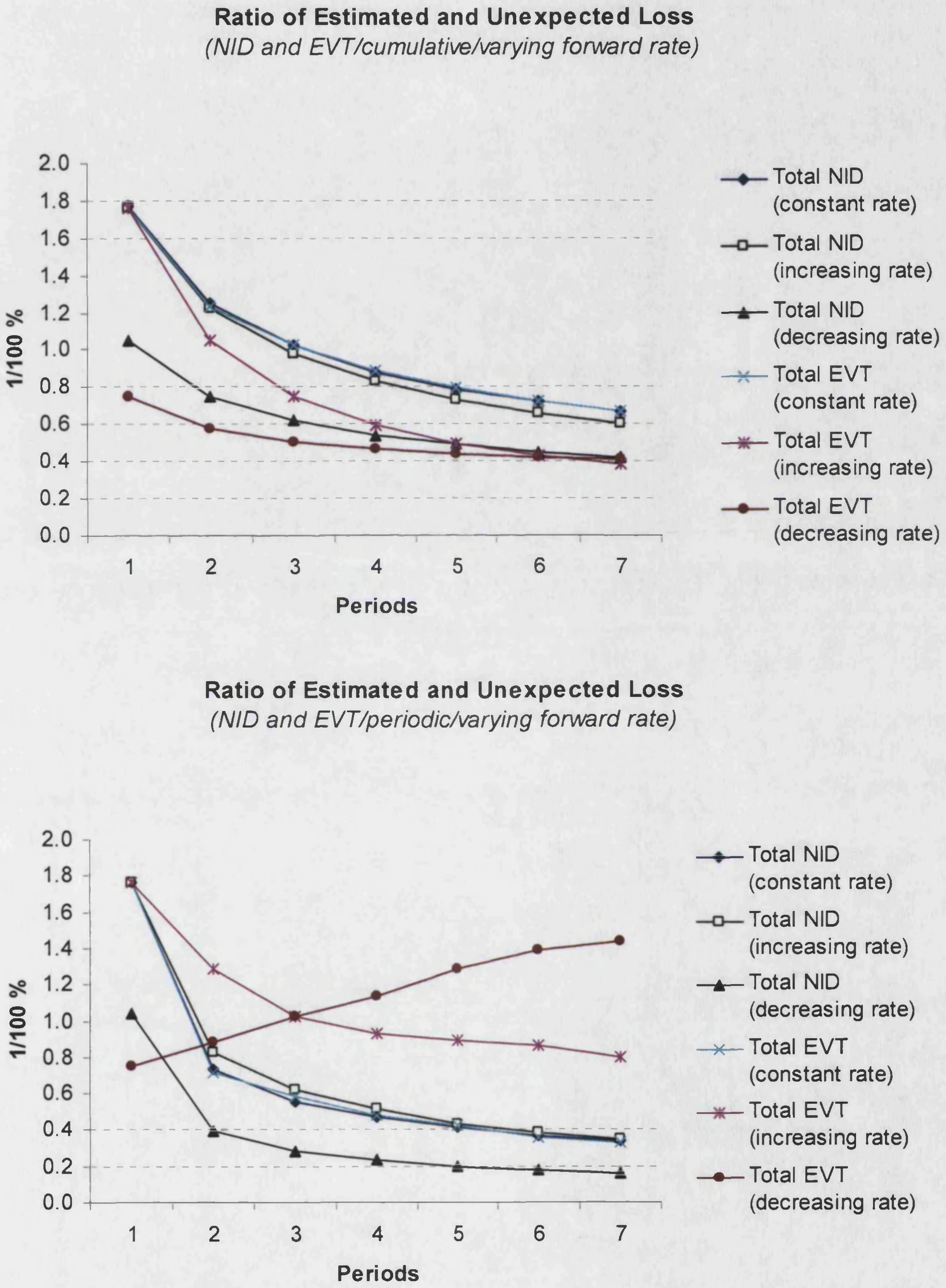
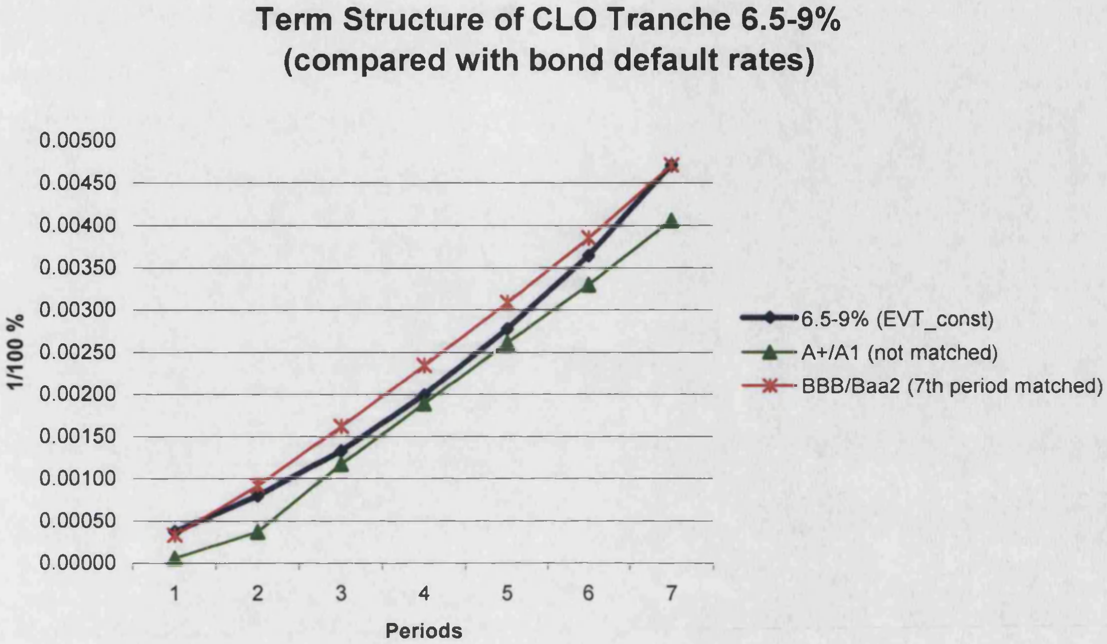


Fig. 8. *Default term structure of the* $\sigma_{\tilde{L}_j^k} / \tilde{L}_j^k$ *ratio for the entire reference portfolio (on the basis of EVT and NID loss functions) for a constant, increasing and decreasing forward rate of default (cumulative and periodic loss).*



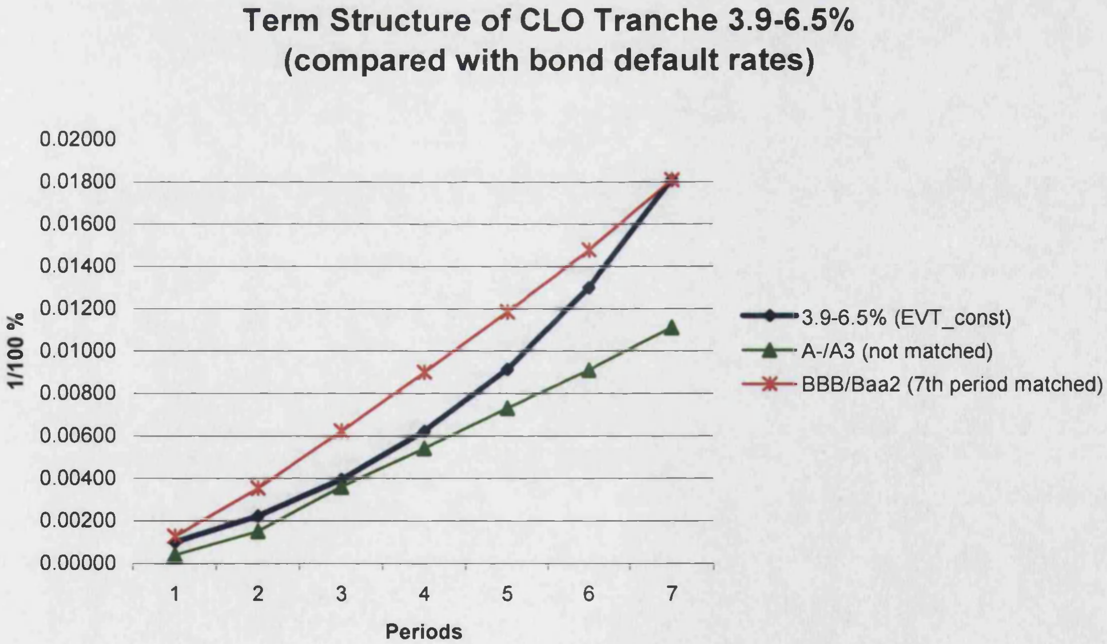
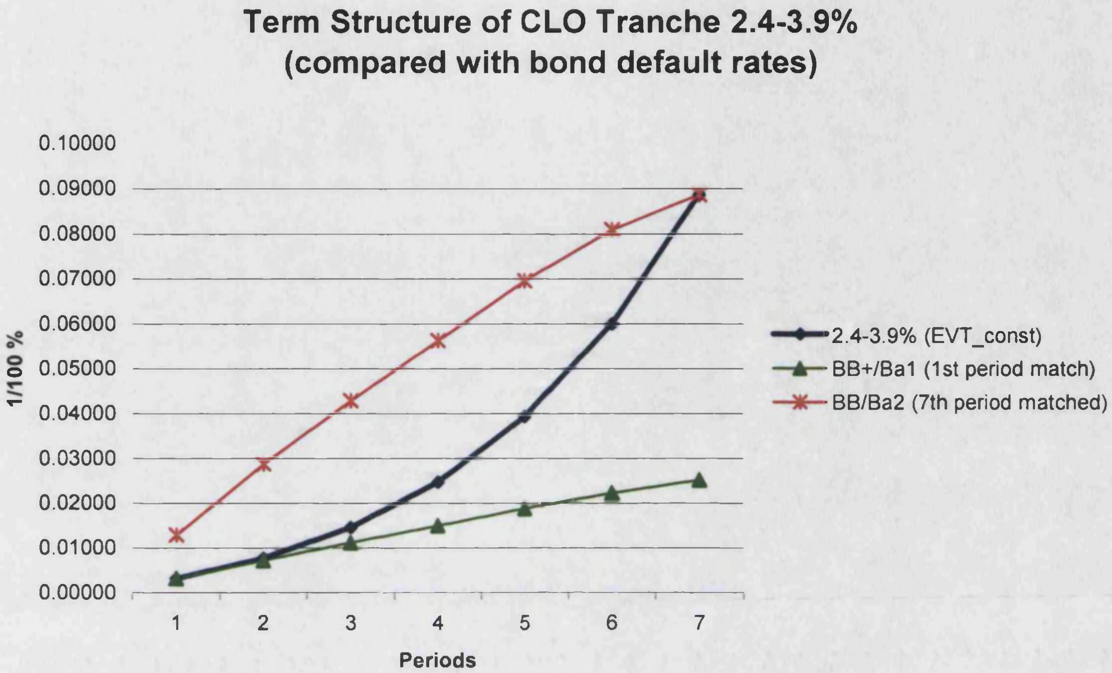


Fig. 9. *Term structure of expected losses in the senior "investor tranches" [3.9-6.5%] and [6.5-9%] at a constant forward rate of default of p=0.0026 on the basis of an EVT loss function compared with corporate zero-coupon bonds.*



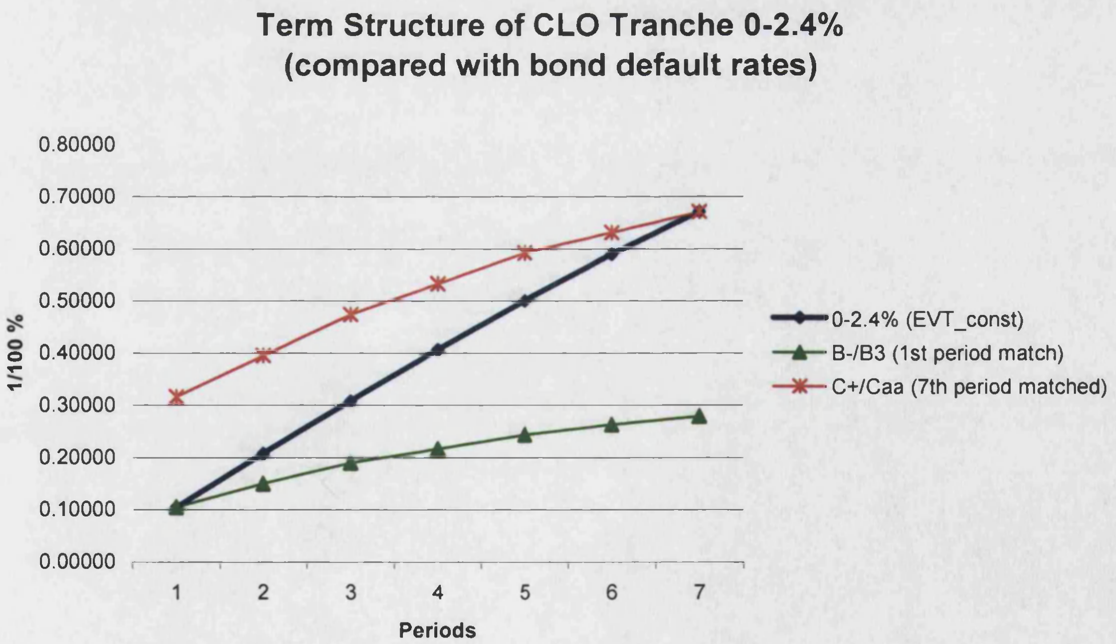


Fig. 10. *Term structure of expected losses in the most junior "investor tranche" [2.4-3.9%] and the first loss position ([0-2.4%] tranche) at a constant forward rate of default of p=0.0026 on the basis of an EVT loss function compared with corporate zero-coupon bonds.*

CHAPTER IV: "EUROPEAN SECURITISATION: A GARCH MODEL OF CDO, MBS AND PFANDBRIEF SPREADS"

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1 ABSTRACT

Asset-backed securitisation (ABS) is a refinancing technique that involves the issuance of state contingent claims on the cash flow performance of a designated pool of asset exposures. Efficient risk management and asset allocation of ABS obligations requires both investors and issuers to thoroughly understand the inherent spread dynamics in this growing segment of fixed income markets. We present a multi-factor GARCH process in order to model the heteroskedasticity of secondary market spreads for valuation and forecasting purposes on the basis of CDO, MBS and Pfandbrief transactions as the most important asset classes of off-balance sheet and on-balance sheet securitisation in Europe. We find that expected spread changes tend to be level stationary with model estimates indicating asymmetric mean reversion depending on the direction of past innovations (errors) and past spread change. Also, conditional spread volatility follows an asymmetric stochastic process contingent on the value of past residuals. This ABS spread behaviour implies negative investor sentiment during cyclical downturns, which is likely to escape stationary approximation in the long run.

Keywords: Securitisation, MBS, CDO, CLO, CBO, ABS, Pfandbrief, GARCH model, structured finance, spread dynamics

JEL: C12, C32, C53, G12, G21

2 INTRODUCTION

2.1 Objective

Securitisation seeks to substitute capital market-based finance for credit finance by sponsoring financial relationships without the lending and deposit-taking capabilities of banks (disintermediation). Generally, securitisation represents a structured finance transaction, where receivables from a designated asset portfolio are sold as contingent claims on cash flows from repayment in the bid to increase the issuer's liquidity position and to support a broadening of lending business (refinancing) without increasing the capital base *(funding motive)*. Aside from being a funding instrument, securitisation also serves (i) to reduce both economic cost of capital and regulatory minimum capital requirements as a balance sheet restructuring tool *(regulatory and economic motive)*, (ii) to diversify asset exposures (especially interest rate risk and currency risk) as issuers repackage receivables into securitisable asset pools (collateral) underlying the so-called *asset-backed securitisation* (ABS) transactions *(hedging motive)*. Also the generation of securitised cash flows from a diversified asset portfolio represents an effective method of redistributing credit risks to investors and broader capital markets. These issuer incentives correspond to certain investment appetites in ABS. As opposed to ordinary creditor claims in lending relationships, the liquidity of a securitised contingent claim on a promised portfolio performance in a structured transaction affords investors at low transaction costs to quickly adjust their investment holdings due to changes in personal risk sensitivity, market sentiment and/or consumption preferences.

Over the last ten years *asset-backed securitisation* (ABS) has established itself as the premier segment of European structured finance. Efficient risk and asset allocation through seasoned trading in this relatively young fixed income market requires both investors and issuers to thoroughly understand the longitudinal properties of ABS spread prices (over some benchmark risk-free market interest rate) of traded securities, which reflect various risk factors of a transaction. Spreads are closely watched by investors and issuers alike, and by doing so, they create efficient primary and secondary markets of informed investment. For loss of any technical study on secondary pricing in structured finance markets outside the U.S., examining the spread development of European structured transactions proves particularly interesting. While recent research has generated a host of models to determine ABS spreads (Goodman and Ho, 1997 and 1998; Arora et al., 2000), the time series properties of ABS transactions have yet been insufficiently addressed. Although research by Koutmos (2001 and 2002) addresses the spread dynamics of U.S. MBS transactions, it falls short of considering other forms of ABS transactions (CDO) and quasi-ABS transactions *(Pfandbriefe)*, a prominent on-balance sheet MBS-type deal structure in Europe, which matches the importance of U.S. MBS by any standard of comparison, be it market volume, trading activity or historical track record.

In the following chapter we conduct an empirical analysis of the spread change behaviour of European ABS transactions in order to assess the robustness of findings in previous studies about certain time series properties of U.S. spread data on securitisation transactions. Moreover, by using secondary market trading data we expand the existing empirical horizon of previous time series analysis of structured finance products. So far no study on the term structure of ABS spreads has been completed on European secondary market trading data. We develop a technical pricing and forecasting approach for the estimation of secondary market spreads of ABS transactions as a discrete approximation of a multi-factor continuous time model. We enlist two multi-factor GARCH processes (GARCH(1,1) and GARCH(2,1)) in order to model the heteroskedasticity of secondary market spreads as a way to examine any volatility-induced future spread movements as well as their degree of symmetry and time variation. In particular, accounting for the variance of errors is instrumental in deriving more accurate estimators of time-varying forecast confidence intervals. We extend earlier approaches by Koutmos (2002) as well as Longstaff and Schwartz (1992) in order to find out (i) whether spread volatility is constant or time-varying and (ii) whether observed spreads are mean reverting or stochastic at level and first differences. Finally, we apply various statistical diagnostics to ensure correct model specification of the presented model for forecasting purposes. Our findings could provide useful insights for adequate secondary market pricing of ABS issues with varying credit quality and an efficient management of ABS portfolios with respect to risk-return considerations.

The rest of the chapter is organised as follows. After a definition of asset securitisation and a brief review of the literature, we present the data set and examine selected statistical diagnostics of linear regression analysis upon the completion of an exhaustive set of descriptive statistics. In the subsequent section, we discuss the effects of data transformation on time series dynamics and the presence of level stationarity as an important requirement for simple inference testing. Then we specify two GARCH processes of the heteroskedasticity for selected spread series of CDO, MBS and *Pfandbrief* transactions. Finally, we present the estimation results and verify the correct model specification by means of residual and coefficient tests. We finally discuss the econometric implications of our findings before we conclude in the last section.

2.2 Securitisation background

The flexible security design of asset-backed securitisation allows for a variety of asset types to be used in securitised reference portfolios. *Mortgage-backed securities* (MBS), *real estate and non-real estate asset-backed securities* (ABS) and *collateralised debt obligations* (CDO) represent the three main strands of asset-backed securitisation in a broader sense. All ABS structures engross different criteria of legal and economic considerations, which all converge upon a basic distinction of security design: *traditional* vs. *synthetic* securitisation.

Traditional (true sale) securitisation involves the legal transfer of assets or obligations to a third party that issues capital market paper on the back of these assets (*"asset-backed securities"*) to investors via private placement or public offering. This transfer of title can take various forms (*novation*, *assignment*, *declaration of trust* or *subparticipation*), which ensures that the securitisation process involves a "clean break" (true sale, bankruptcy remoteness or *credit de-linkage* in loan securitisation) between the sponsoring bank (which originated the securitised assets) and the securitisation transaction itself. In most cases, however, the sponsor retains the servicing function of the securitised assets. Traditional securitisation mitigates regulatory capital requirements by trimming the balance sheet volume. In synthetic securitisation only asset risk (e.g. credit default risk, trading risk, operational risk) is transferred to a third party by means of derivatives without change of legal ownership, i.e. no legal transfer of the designated reference portfolio of assets.[1] Any resulting regulatory capital relief and/or lower cost of economic capital do not stem from the actual transfer of assets off the balance sheet but the acquisition of credit protection against the default of the underlying assets through asset diversification and hedging.[2] Commonly, sponsors of synthetic securitisation issue debt securities supported by credit derivative structures, such as *credit-linked notes* (CLNs),[3] whose default tolerance amounts to total expected loan losses in the underlying reference portfolio. Hence, investors in CLOs are not only exposed to inherent credit risk of the reference portfolio but also operational risk of the issuer.[4] Recently, traditional securitisation transactions also included elements of synthetic securitisation (such as credit derivatives) in order to preserve the credit-linkage of issued securities to the originator and realise on-balance sheet financing to fund assets.[5]

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[1] For instance, sellers of credit default swaps (CDS) receive a premium for their state-contingent obligation of compensating buyers of credit protection for any default losses up to a specified amount. Since the compensation payment through credit default swaps (CDS) is contingent on a certain credit event, derivative components in the security design of synthetic transactions are termed "unfunded", while bonds directly issued to investors as "credit-linked notes" (CLN) are "funded".

[2] This property of synthetic CLOs is attractive to large banks, which tend to have access to on-balance sheet assets at competitive spreads.

[3] "Credit linkage" signifies credit risk transfer without a corresponding change of title (legal ownership) of the underlying asset claims.

[4] The absence of asset transfer to a special purpose vehicle (SPV) as in traditional CLOs aids the cost efficient administration of synthetic securitisation. Synthetic structures also garner issuers with a wider choice of leveraging the underlying reference portfolio, so that on average the nominal total value of issued debt securities of such transactions is significantly outstripped by the nominal tranche volume in conventional securitisation.

[5] The marginal difference in senior risk exposure between partially funded synthetic securitisation and traditional securitisation does not extend to junior noteholders with subordinated security interest. While partial funding structures bear more risk emerging from the sponsor's role, the credit enhancement (first loss provision) and subsequent junior tranches (the second loss position) are no more exposed to credit risk in synthetic deals than they are in traditional CLOs.

In contrast to the U.S., where the market for ABS has had a longstanding tradition since the first half of the 1980s[6] (Klotter, 2000), European ABS has gained popularity only over the last several years – notwithstanding the fact that Pfandbrief structures[7] ("on-balance sheet mortgage-backed securities") have been an established method of securitising homogenous mortgage portfolios for more than two centuries.[8] Actually, the Pfandbrief market has developed into one of the largest fixed income markets in Europe. Recently, the issue volume of both mortgage-backed securities (MBS) and collateralised debt obligations (CDO) has surged at an impressive scale despite depressed expectations from interest-based income and the search for alternative asset funding mechanisms. Both types of ABS transactions have become an important segment of the European bond market as banks, non-bank financial intermediaries (NBFIs) and corporations favour more flexible funding mechanisms. Hence, ABS issues have caught up with Pfandbrief transactions as one of the largest (by outstanding volume) fixed income markets in Europe.

The distinct track record of on-balance sheet securitisation in European structured finance on the basis of the Pfandbrief scheme prohibits a comparison of European and U.S. asset-backed securitisation without consideration of the Pfandbrief market as a control factor. Since a nascent European ABS market falls short of attracting large secondary trading activity, only the Pfandbrief market in Europe seems to match U.S.-based securitisation in liquidity and maturity. Hence, any analysis of ABS markets in Europe also needs to account for the existing investment behaviour of the Pfandbrief market.[9]

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[6] The first asset-backed securitisation issue in its modern form was completed by *Sperry Corporation*, which issued computer lease-backed notes in 1985 (Kendall, 1996).

[7] See also Böhringer et al. (2001).

[8] The first Pfandbrief instrument was created by the executive order of Frederick the Great of Prussia in 1769 (Skarabot, 2002; Anonymous, 1999).

[9] Although MBS transactions and Pfandbrief transactions share the same type of reference assets, upon closer inspection several structural differences between these fixed income investments emerge. While the Pfandbrief is a classical on-balance sheet refinancing tool (with both origination and issuance are completed by one and the same entity), MBS transactions involve at least one more party (besides the mortgage originator), which sells contingent claims on asset cash flows, so that the reference portfolio underlying the securitised assets is removed from the balance sheet and legally segregated (bankruptcy remote). Pfandbrief transactions lack a direct relationship between mortgage cash flows and the promised repayments to investors, who rank *pari passu*, whose claims may be junior to other creditors of the Pfandbrief issuer. In comparison, MBS transactions solely return cash flows generated from the pool performance of the designated reference portfolio. Investor claims rank either *pari passu* to each other in the sense of pass-through (PC) or are prioritised through subordination (but no other parties can declare a moratorium on assets). Hence, Pfandbrief ratings include an implicit financial strength rating of issuers, which are fully liable with their registered capital if the designated asset pools fail to generate sufficient cash flows for repayment of investors. Given this institutional guarantee and (legally defined) *overcollateralisation,* Pfandbrief transactions generally receive high ratings. The downside of this legal arrangement is the fact that investors in Pfandbrief transactions are not insulated from an "originator event" (insolvency and bankruptcy), whereas MBS investors in a dedicated mortgage loan pool are. At the same time, MBS transactions are devoid of any institutional guarantee. So issuers of MBS transactions compensate

2.3 Characteristics of spreads

The pricing of fixed income instruments requires investors to measure the yield-to-maturity (YTM) or even the entire term structure yield curve from the current spot rate, depending on the nature of the obligation, in order to discount future cash flows from holding such assets. Various factors influence the pricing of fixed income securities, such as the interest rate term structure, the current market interest rate ("market spot rate"), the maturity of the obligation, the liquidity of the obligation, the current credit risk, and the credit outlook of the obligation ("rating grade") and its volatility within a risk classification grade, asymmetric information, imbedded options, the notional amount and the tax treatment of the issued security. The market term structure (of key interest rates) enters the calculation of YTM as some benchmark yield curve or spot rate curve (e.g. the LIBOR or EURIBOR rate), which reflects the general maturity dependence of interest rates. The (yield) spread over the benchmark yield captures the (idiosyncratic) risk contribution of other factors ***in addition to the market interest rate***, which have to be taken into account for the mean-variance efficient pricing of fixed income securities. For instance, bonds could be structured so as to include redemption criteria and early amortisation features as options, which benefit issuers and/or investors but at the same time constitute a source of uncertainty. Also, the lack of liquidity contributes to higher market risk from investment. We commonly observe that instruments with imbedded optionality and low verification of trading motives[10] are priced lower and trade at higher spreads than comparable securities without any option components ("option-adjusted spread analysis").

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issuers for the higher asset exposure due to deficient institutional protection by including various kinds of internal and external liquidity and credit support, such as bridge-over facilities, surety bonds, third-party guarantees, yield spreads/excess spreads, overcollateralisation and reserve accounts. Finally, Pfandbrief issues are subject to stringent federal laws (requiring a weighted average loan-to-market or appraised value (LTV) of at least 60% as a statutory benchmark), whilst "private-label" MBS are free from these legal requirements, except in so-called "agency-MBS" in the U.S., where the quasi-government agencies Fannie Mae (FNMA), Freddie Mac (FHLMC) and Ginnie Mae (GNMA) provide institutional guarantees in return for certain restrictions imposed on mortgages eligible for purchase in MBS structures. In general, Pfandbrief transactions represent a very secure and liquid asset class of fixed income instruments with an established track record and cyclical resilience. MBS issues are equally liquid (at least in the U.S. market) and feature an unchallenged degree of flexibility allowing for customised features and investor arrangements, such as variations to amortising repayment (in contrast to bullet repayment structures of Pfandbrief issues). Pfandbriefe serve primarily as funding instruments, whereas MBSs are also employed for credit risk transfer and balance sheet restructuring, with the aim of efficient management of economic and regulatory capital.

[10] Highly liquid, recently issued securities are said to be "on-the-run" in a liquid secondary market, whereas "off-the-run" issues have less of a secondary market low and attract higher liquidity spread.

3 LITERATURE REVIEW

Recent research (Goodman and Ho, 1998; Koutmos, 2002) indicates that the shape of the yield curve plays an important role in the determination of fixed-rate MBS yields in the U.S.[11] In their study on the determinants of MBS spreads on treasury bond yields, Goodman and Ho (1998) also consider the five-year cap volatility and the ten-year swap spreads to identify some LIBOR interest rate effect on MBS spreads. They find that MBS yields are by and large explained by the yield on government securities and the shape of the yield curve, even though the prepayment of principal and interest by mortgagors induces greater variation of duration (compared to government bonds) due to an uncertain timing of cash flows. Arora et al. (2000) propose a five-factor model that explains nearly 60% of mortgage spreads. Koutmos (2002) showed that in an extended version of the term structure model by Longstaff and Schwartz (1992), U.S. MBS spreads over the maturity-matched U.S. treasury rate follow an asymmetric mean-reverting stochastic process, which behaves asymmetrically in response to the direction of past spread changes ("asymmetric mean reversion").

In the following chapter we conduct an empirical analysis of the spread change behaviour of European securitisation transactions in order to ascertain previous studies about certain time series properties of U.S. MBS spread data. We expand the empirical scope of previous studies by using a data set of European secondary market trading quotes of MBS, CDO and Pfandbrief transactions. Our multi-factor specification of time-varying spread variance specifically tests for asymmetric mean reversion and builds on the factor approximation of spread dynamics proposed by Koutmos (2002) as well as Longstaff and Schwartz (1992). In line with Goodman and Ho (1998) we control for LIBOR effects in both the mean and the conditional variance of spread change. Our findings suggest almost all spread series are mean-reverting. In contrast to Koutmos (2002), we find no statistically significant asymmetry of mean reversion during spread increases and decreases. However, the mean-reverting trend following spread decreases is economically stronger than the influence of past spread increases. The conditional variance of spread change behaves largely asymmetric, which increases more after positive past innovations relative to negative past innovations.

[11] Bhasin and Carey (1999) were the first to present an empirical study, which analysed – although in an admittedly rudimentary fashion – the trading behaviour of bank loans. In contrast to conventional wisdom of fixed income securities research, credits with a low rating grade were traded the most. This liquidity effect would of course affect the market price (i.e. the spread over some benchmark yield) *ex ceteris paribus* and its attendant volatility. However, it does not account for the pricing behaviour in ABS markets.

4 DATA DESCRIPTION

The primary data consists of aggregated secondary market spreads (with respect to the 3-month LIBOR rate) of European ABS transactions (Residential Mortgage-Backed Securities (RMBS),[12] Collateralised Debt Obligations (CDO) and Pfandbrief transactions) over almost two years (see Tab. 1). The spread series of RMBS and CDO transactions stems from the structured finance trading desk of a major European commercial bank, which generates an end-of-week indicative secondary spread benchmark from all traded transactions (classified by ABS type, rating and maturity) with the highest market quotes. The time series data of European Pfandbrief spreads are based on the *Merrill Lynch* Pfandbrief database (see Appendix, Tab. 14). In Tab. 13 (Appendix) we spell out the nomenclature of the various time series in our ABS spread data base.

4.1 Further specification

The data set underlying the aggregate secondary spreads (denominated in basis points above LIBOR) includes the majority of European ABS transactions classified as synthetic and traditional (true sale) CDO or RMBS with floating rate tranches of varying rating grades and maturities of 3, 5 and 7 years from 5 January 2001 to 18 October 2002 (93 weekly observations). As opposed to CDO spreads, MBS time series data does not consider synthetic and traditional structures individually but represents the weighted-average, aggregated spreads of both classifications. The dominance of traditional transactions in MBS spreads reflects the observed market preference for true sale structures of this kind of ABS. We chose the *Merrill Lynch (ML) EMU Pfandbrief Index* (via Bloomberg) as a benchmark roughly matched in maturity (1-3 years, 3-5 years and 5-7 years) to the time series data of the selected CDO and RMBS tranches. Originally, daily Pfandbrief spreads were obtained for the time period from 13 April 1998 to 29 March 2002, which were later transformed into weekly spreads and shortened to fit the time period of observed CDO and RMBS spreads in order to ensure a reliable statistical analysis, whose results remain unaffected by disparate sample periods or higher data frequency of observations (see Fig. 1 in the Appendix). We replaced two missing observations on 14 April 2001 and 29 March 2002 (bank holidays) by the spreads of the previous day. The majority of Pfandbrief issues entering each maturity-based index benchmark were originated by German banks. Since the Pfandbrief indices contained different proportions of rating classes at the beginning and the end of the sample periods (see Tab. 14) – on 5 January 2001 all Pfandbrief indices included more than 80% AAA-rated issues compared to 18 October 2002 when roughly 75% of all issues were rated AAA – we computed a mean weighted-average of rating classes for each maturity of Pfandbrief index and derived daily spreads according to this distribution of rating classes for each maturity classification of Pfandbriefe. We discarded the possibility of calculating the index composition for each daily spread observation due to short-term volatility jumps and level effects induced by the accounting scandals surrounding the U.S. corporations Enron and WorldCom.

4.2 Statistical descriptives

The quality of our time series estimation results fundamentally depends on the statistical properties of the ABS spread series in our data set, especially the distribution of the spreads and the degree of autocorrelation, if applicable. We extract preliminary information about the descriptive statistics of the given spreads as a crucial piece of information for modelling the dynamics of spread changes in structured finance transactions (see Tab. 1, and Appendix, Tab. 16-Tab. 20).[13] On first inspection, infrequent changes of spread data on level and first difference bears out strong evidence of distinct illiquidity in European MBS and CDO markets, which are commonly characterised as buy-and-hold markets. Moreover, in some cases the given spread time series of these asset types do not reflect actual transaction data but conflated bid/ask spreads. Pfandbrief spreads reflect reasonable stationarity of periodically mean-reverting cycles. In contrast, sporadically occurring spikes in level spread series of CDO and MBS transactions hint to arguably higher illiquidity of these markets compared to the Pfandbrief market. Although some interspersed idle periods in these spread series might jeopardise the appellation of even weak level stationarity, the frequently occurring volatility peaks in the first differences of spreads (both original and transformed) make a strong case for autoregressive constant heteroskedasticity models (ARCH). Nonetheless, bearing in mind the hazards of "stale time series", we attach great importance to a robust preliminary analysis before we proceed to develop the proposed GARCH approach (see section 6.2 below). Tab. 1 reports several descriptive statistics of logarithmic and Johnson Fit-adjusted spread series (see Appendix, Tab. 16-Tab. 20 for a complete overview of all spread series – actual spread, logarithmic spreads and adjusted spreads). It can be seen that average spreads decrease with higher ratings and maturity. Relative spread volatilities (relative variation) are modest, ranging from 1.6% to 7% for the logarithmic spread series of asset classes in the data set. However, the relative variation of actual spreads in Appendix, Tab. 16-Tab. 20 of up to 25.8% suggests considerable risk in the spread structure across all asset

[12] We will use the generic expression of mortgage-backed securities (MBS) as short-hand for this asset class in the remainder of the chapter.
[13] See also Fig. 1.

classes. The *Jarque-Bera* test statistic (defined in section 4.3 below) shows that most spread series (with the exception of CSAAA3, CSBBB7, PAAA5 and PAAA7) reject the null hypothesis of normal distribution, given their values of skewness and kurtosis. The *Doornik-Hansen* diagnostic (see section 4.3 below) confirms this result about the spread process of observed data. All spread series fail to adhere to normality in their first differences.

According to the *Ljung-Box Q-statistic* (defined in section 4.4 below) significant and high levels of autocorrelation exist in both observed spreads (up to 26 lags) and logspreads (up to 28 lags). The first difference of spreads sheds most of the serial correlation, with only some spread series flagging autocorrelation at up to two lags (e.g. PAAA3 and PAAA5). Nonetheless, autocorrelation remains a pressing issue that needs to be addressed in the course of our preliminary statistical analysis. Even though autocorrelation is close to unity and fails to drop off quickly – hinting at non-stationarity – we will later see that the unit root hypothesis can be rejected for most spreads at level and first difference.

4.3 Test of normality

Aside from time-varying heteroskedasiticity, the proposed GARCH(1,1) and GARCH(2,1) models largely rely on the statistical assumptions of linear multivariate analysis for the coefficient estimates to be valid.[14] Although endogenous variables are not required to fit certain distributional characteristics, robust parametric testing of the statistical significance of coefficients infers normally distributed residuals according for $\varepsilon \sim N\left[0, \sigma^2 \mathbf{I}\right]$ (Greene, 1993), which implicitly applies to dependent variables as well. Otherwise any resulting estimates would not be independent of the residuals and the critical values for parametric tests, such as the t-statistic, would lose their significance (Hair et al., 1998). However, countless empirical studies about investment instruments document that financial time series are hardly normally distributed – a common feature frequently ignored. Various kinds of transformations have been suggested in past research in order to adjust observed data to fit desired distributional assumptions. For instance, Hartung (1987) suggests the logarithmic transformation, $g(x) = \ln(x+c)$, the reciprocal transformation, $g(x) = x^{-1}$, and the square root transformation, which comes in various forms, such as $g(x) = \sqrt{x+c}$. Alternatively, more complex ways of

[14] Assumptions for linear multivariate regression estimation (Greene, 1993) in matrix algebra: (i) linear relationship between exogenous and endogenous variables: $\mathbf{Y} = \mathbf{X}\beta + \varepsilon$, (ii) zero expected residuals: $E(\varepsilon) = 0$, (iii) homoskedasticity: $E(\varepsilon\varepsilon') = \sigma^2 \mathbf{I}$, (iv) independence of residuals: $E(\varepsilon|\mathbf{X}) = 0$, and (v) $\mathbf{X}$ represents a non-stochastic $n \times k$ matrix of rank k.

transformation exist, which promise higher flexibility at the loss of straightforward application, such as the so-called *Johnson Fit* (1949), which allows for transformation of any continuous distribution into a normal distribution. We apply both the logarithmic transformation and a statistical adjustment according to the Johnson algorithm to improve the distributional properties of the time series of our data set for robustness of inference procedures.

First, we conduct the test of normality on non-transformed data. In our preliminary descriptive statistics we first apply the Jarque-Bera (JB) test diagnostic to examine whether the null hypothesis of normally distributed spreads holds. The Jarque-Bera test statistic

$$JB = \frac{N-k}{6}\left(S^2 - \frac{1}{4}(k-3)^2\right) \tag{1}$$

measures the degree to which a time series is normally distributed based on the difference of the skewness S and kurtosis K between the normal distribution and the spread series, where k represents the number of estimated coefficients used to create the series. The probability of the JB test indicates the likelihood of the JB statistic to exceed (in absolute value) the observed value of a normal distribution. Since the JB statistic is particularly suitable for large samples, our limited number of observations suggests an alternative test procedure, which promises greater certainty as regards to the normal distribution assumption. We apply the test procedure of Doornik and Hansen (1994), which was developed for small sample sizes. Similar to the Jarque-Bera test statistic, the Doornik-Hansen diagnostic (E_p) computes the deviations from the normal distribution on the basis of transformed higher moments of skewness z_1 and kurtosis z_2:

$$E_p = z_1^2 + z_1^2 \underset{app}{\sim} \chi^2_{df=2}\,. \tag{2}$$

Doornik and Hansen define the transformation of skewness S and kurtosis K for n number of observations as

$$z_1 = \delta \ln\left(y + \sqrt{y^2 - 1}\right), \tag{3}$$

where $\delta = \frac{1}{\sqrt{\ln(\varpi)}}$, $y = S\sqrt{\frac{\omega^2 - 1}{2}\frac{(n+1)(n+3)}{6(n-2)}}$, $\varpi^2 = -1 + \sqrt{2(\beta - 1)}$,

$$\beta = \frac{3\left(n^2 + 27n - 70\right)(n+1)(n+3)}{(n-2)(n+5)(n+7)(n+9)},$$

and

$$z_2 = \left(\left(\frac{\chi}{2\alpha} \right)^{\frac{1}{3}} - 1 + \frac{1}{9\alpha} \right) \sqrt{9\alpha}\,, \tag{4}$$

where $\chi = 2k\left(K - 1 - S^2\right)$, $\alpha = a + S^2 c$, $k = \dfrac{(n+5)(n+7)\left(n^3 + 37n^2 + 11n - 313\right)}{12\delta}$,

$\delta = (n-3)(n+1)\left(n^2 + 15n - 4\right)$, $a = \dfrac{(n-2)(n+5)(n+7)\left(n^2 + 27n - 70\right)}{6\delta}$,

$c = \dfrac{(n-7)(n+5)(n+7)\left(n^2 + 2n - 5\right)}{6\delta}$.

Based on the Doornik-Hansen test the hypothesis of normally distributed spreads is rejected as the approximate $\chi^2_{df=2}$-distributed test statistic is significantly different from zero (see Tab. 1). Surprisingly, non-normality, which persists even after transformation, does not seem to stem from poor data quality in general and low levels of market liquidity in particular, e.g. if we contrast the spread distribution and the associated *JB* statistic and E_p statistic for PAAA2 and CSBBB7. Despite markedly higher liquidity of Pfandbriefe, the former time series deviates more from the normal distribution assumption than an illiquid, low-rated synthetic CDO tranche.

The normality assumption under both the Jarque-Bera statistic and the Doornik-Hansen approximation is also not satisfied for logarithmically[15] transformed time series, regardless of further adjustment by means of the Johnson Fit (marked by the acronym "AD"). The descriptive statistics show that the suggested transformation is successful in doing little more than improving the JB-statistic for some cases of extreme deviations from the normal distribution only, such as BBB-rated, traditional CDOs with maturity of seven years (CTBBB7_L) and AAA-rated Pfandbriefe with maturity of three years (PAAA3_L). On average the Doornik-Hansen test indicates a worsening of the distributional properties of spreads after logarithmic transformation. Although the logarithmic transformation does not improve the spread distribution across the board of all time series, we find evidence that extreme deviation from the normal distribution can be mitigated, whilst logspreads[16] generally tend to be more dissimilar to normality in the given data set.

[15] These time series are marked by the acronym "L" added to the tranche specification.
[16] Moreover, the additivity of logarithmic returns proves beneficial for our economic analysis.

	Collateralised Debt Obligations (CDO)					
	synthetic			*traditional*		
	CSAAA3_AD_L	CSA5_AD_L	CSBBB7_AD_L	CTAAA3_AD_L	CTA5_AD_L	CTBBB7_AD_L
Mean	3.7314	4.8060	5.5049	3.3846	4.5263	5.2839
Median	3.8192	4.8697	5.5449	3.3769	4.5700	5.2672
Maximum	4.3118	5.3492	6.0047	3.6240	5.0782	5.6205
Minimum	3.2583	4.1993	5.0301	3.0413	4.2178	4.9377
Std. Dev.	0.2617	0.2447	0.2236	0.1313	0.2284	0.1428
Rel. Variation	7.01%	5.09%	4.06%	3.88%	5.05%	2.70%
Skewness	-0.0914	0.0461	0.0972	-0.2280	0.2781	0.0360
Kurtosis	3.2128	3.5767	3.3628	2.7507	2.2272	3.0430
Jarque-Bera	0.3051	1.3359	0.6636	1.0582	3.5511	0.0276
Prob. JB	0.8585	0.5128	0.7176	0.5891	0.1694	0.9863
E_p	1.1243	3.1429	1.8504	1.0287	5.4736	0.4472
Prob. E	0.5700	0.2077	0.3965	0.5979	0.0648	0.7996
LB-Q (lags)*	437.37 (14)	587.16 (26)	609.65 (25)	420.4 (13)	655.46 (16)	739.28 (28)
AC value	0.1990	0.1980	0.1980	0.1790	0.1840	0.1690
Observations	*93*	*93*	*93*	*93*	*93*	*93*

	Mortgage-Backed Securities (MBS)			
	MAAA3_AD_L	MAAA5_AD_L	MA7_AD_L	MBBB7_AD_L
Mean	3.0217	3.1244	4.1751	4.9367
Median	2.9947	3.0854	4.1829	4.9514
Maximum	3.2047	3.3879	4.3678	5.2871
Minimum	2.7988	2.8285	4.0988	4.4829
Std. Dev.	0.1404	0.1446	0.0673	0.1207
Rel. Variation	4.65%	4.63%	1.61%	2.44%
Skewness	-0.1348	0.0701	0.3847	0.1279
Kurtosis	2.0911	3.3462	2.5218	7.3745
Jarque-Bera	3.5201	0.5463	3.2142	75.2062
Prob. JB	0.1720	0.7610	0.2005	0.0000
E_p	4.6662	1.7428	4.9582	49.1697
Prob. E	0.097	0.4184	0.0838	0
LB-Q (lags)*	164.22 (7)	35.073 (3)	645.58 (19)	22.393 (2)
AC value	0.1270	0.1410	0.1760	0.1300
Observations	*93*	*93*	*93*	*93*

	Pfandbriefe		
	PAAA3_AD_L	PAAA5_AD_L	PAAA7_AD_L
Mean	2.9268	3.2045	3.4437
Median	2.9571	3.2111	3.4540
Maximum	3.2652	3.6690	3.9766
Minimum	2.5928	2.8406	2.9558
Std. Dev.	0.1065	0.1691	0.1819
Rel. Variation	3.64%	5.28%	5.28%
Skewness	-0.1098	0.0258	0.0599
Kurtosis	3.6506	2.8617	3.0421
Jarque-Bera	1.8466	0.0854	0.0631
Prob. JB	0.3972	0.9582	0.9689
E_p	3.6514	0.0657	0.469
Prob. E	0.1611	0.9677	0.791
LB-Q (lags)*	226.06 (12)	410.94 (14)	543.62 (17)
AC value	0.1090	0.1950	0.2130
Observations	*93*	*93*	*93*

Tab. 1. *Statistical descriptives of secondary market spreads of CDO, MBS and Pfandbrief transactions (only transformed and Johnson Fit adjusted spreads).*

Besides improved distributional properties, logarithmic transformation also harmonises the spread variation coefficient $V = \sigma_S / \overline{S}$, i.e. the ratio between standard deviation and mean of spreads, for all time series of weekly spreads. The variation coefficient also reveals the level effect of given ABS spreads – the standard deviation of spreads increases in the level of spreads. For non-transformed spreads we compute an average $\overline{S} = 16.67\%$ and a standard deviation $\sigma_S = 5.66\%$, which are highly correlated at $\rho_{\overline{S},\sigma_s} = 0.947$. Logarithmic transformation would mitigate this level effect and stabilise the variance of the entire spread sample for comparative analysis. The correlation of standard deviation and mean of weekly logspreads drops to $\rho_{\overline{S},\sigma_s} = 0.289$. Furthermore, we apply the Johnson Fit adjustment to align the continuous distribution of logspreads closer to normality. This transformation procedure is based on three kinds of distribution functions *(Johnson curves)* – an unbounded (S_U), a bounded (S_B) and a lognormal distribution (S_L) – each associated with transformation function $u = \gamma + \eta k_i(x;\lambda,\xi)$, where u denotes a standard normal target variable and x represents the original variable. One of the three distribution functions

$$S_U: \quad k_1(x;\lambda,\xi) = \sinh^{-1}\left(\frac{x-\xi}{\lambda}\right), \tag{5}$$

$$S_B: \quad k_2(x;\lambda,\xi) = \ln\left(\frac{x-\xi}{\lambda+\xi-x}\right), \text{ and} \tag{6}$$

$$S_L: \quad k_3(x;\lambda,\xi) = \ln(x-\xi), \tag{7}$$

is selected according to its suitability to best transform the original variable to fit a normal distribution, with γ, η, λ and ξ as known parameters. Parameters γ and η define the shape of the fitted curve, the scale factor λ defines the variance and ξ the expected value of the distribution, respectively. Slifer and Shapiro (1980) propose a simplified estimation procedure for all four parameters in each distribution function (S_U, S_B, S_L). First, the original variable data has to be assigned one of the three types of distribution functions. To this end, we pick four values $z > 0$ from a standard normal distribution, where $-3z, -z, z$ and $3z$ constitute three intervals of equivalent distance. Commensurate to the cumulative densities of $-3z, -z, z$ and $3z$, we determine the corresponding values x_{-3z}, x_{-z}, x_z and x_{3z} for the distribution of the original variable x. These values are not equidistant, because they stem from the original, non-normal distribution function to be transformed. Depending on the relationship between the values x_{-3z}, x_{-z}, x_z and x_{3z} we determine the appropriate transformation function according to the following selection criteria: S_U : $mn \times p^{-2} > 1$, S_B : $mn \times p^{-2} < 1$ and S_L : $mn \times p^{-2} = 1$,[17] where $m = x_{3\mathfrak{z}} - x_{\mathfrak{z}}$, $n = x_{-\mathfrak{z}} - x_{-3\mathfrak{z}}$ and $p = x_{\mathfrak{z}} - x_{-\mathfrak{z}}$. Once we have determined the adequate distribution function from the set of S_U, S_B and S_L, we introduce a system of equations for each type of function in order to compute the four parameters γ, η, λ and ξ, with $\mathfrak{z}$ small enough for small sample sizes,[18] so that the value of $x_{\pm 3\mathfrak{z}}$ can easily be calculated:

For S_U : $u = \gamma + \eta \sinh^{-1}\left(\left(x-\xi\right)\lambda^{-1}\right)$ —

$$\gamma = \eta \sinh^{-1}\left(\frac{(n-m)p^{-1}}{2\left(mn \times p^{-2}-1\right)^{0.5}}\right),\ \eta = \frac{2\mathfrak{z}}{\cosh^{-1}\left(0.5(m+n)p^{-1}\right)} \quad \text{for } \eta > 0,$$

$$\lambda = \frac{2p\left(mn \times p^{-2}-1\right)^{0.5}}{\left((m+n)p^{-1}-2\right)\left((m+n)p^{-1}+2\right)^{0.5}} \quad \text{for } \lambda > 0, \text{ and } \xi = \frac{x_{\mathfrak{z}}+x_{-\mathfrak{z}}}{2} + \frac{p\left((n-m)p^{-2}\right)}{2\left((m-n)p^{-1}-2\right)}.$$

For S_B : $u = \gamma + \eta \ln\left(\left(x-\xi\right)\left(\lambda+\xi-x\right)^{-1}\right)$ —

$$\gamma = \eta \sinh^{-1}\left(\left[\left(pn^{-1}-pm^{-1}\right)\left(\left(1+pm^{-1}\right)\left(1+pn^{-1}\right)-4\right)^{0.5}\right]\left(2\left(p^2(mn)^{-1}-1\right)\right)^{-1}\right),$$

$$\eta = \mathfrak{z}\left(\cosh^{-1}\left(0.5\left(\left(1+pm^{-1}\right)\left(1+pn^{-1}\right)\right)^{0.5}\right)\right) \quad \text{for } \eta > 0,$$

$$\lambda = p\left(\left(\left(1+pm^{-1}\right)\left(1+pn^{-1}\right)-2\right)^2-4\right)^{0.5}\left[p^2(mn)^{-1}-1\right]^{-1} \quad \text{for } \lambda > 0, \text{ and}$$

$$\xi = \frac{x_{\mathfrak{z}}+x_{-\mathfrak{z}}}{2} - \frac{\lambda}{2} + p\left(pn^{-1}-pm^{-1}\right)\left[2\left(p(mn)^{-1}-1\right)\right]^{-1}$$

For S_L : $u = \gamma^* + \eta \ln\left(x-\xi\right)$ —

$$\gamma^* = \eta \ln\left(\left(mp^{-1}-1\right)\left[p\left(mp^{-1}\right)^{0.5}\right]^{-1}\right),\ \eta = \frac{2\mathfrak{z}}{\ln\left(mp^{-1}\right)}, \text{ and } \xi = \frac{x_{\mathfrak{z}}+x_{-\mathfrak{z}}}{2} - \frac{p}{2} \times \frac{mp^{-1}+1}{mp^{-1}-1}.$$

[17] Since the probability of $mn/p^2 = 1$ to occur borders to zero, it seems reasonable to use certain tolerance levels around the critical value 1 for this selection process.

[18] Slifker and Shapiro (1980) recommend $\mathfrak{z} = 0.5$.

The application of the Johnson Fit routine on our data set of weekly spread series indicates that the quality of the desired adjustment to normality is highly sensitive to the choice of the z-value. Hence, we resort to an iterative procedure to determine the optimal z-value at six decimals. First, we compute a preliminary z-value (preliminary optimal) for the best approximation of the original distribution to the normal distribution, measured by the Jarque-Bera statistic, as we count from 0 to 2 by staggered increments of 0.02. We refine the preliminary z-value through another cycle of increments of 0.001 within a band of +/-0.02 around its value in order to determine the optimal value of z. This iterative procedure continues until the parameterisation of z is sufficiently accurate for an optimal approximation of the normal distribution measured by the Jarque-Bera statistic of the original distribution after transformation. In our data, set the transformation of the original spread time series via the Johnson Fit merely nears the standard normal. Moreover, the first two moments, μ and σ, of the adjusted spreads – which would describe a standard normal distribution under optimal transformation – deviate significantly from the original spread series across the sample. Consequently, we further adjust the Johnson-fitted spread series by matching mean and standard deviation to the original distribution; at the same time, however, we preserve the approximative normal distribution in the transformed spread series. In order to reinstate the variance of each original spread series we recalibrate the differences between fitted spreads and original spreads by means of multiplication with an adequate scaling factor. We also adjusted the mean of the fitted spread distribution to the original mean value by conditioning the new starting value.[19] The new adjusted spread series (marked by the acronym "_AD_L" in the rest of the chapter) bear great resemblance to the original spread series for all asset classes in our data set. The correlation coefficient between both exceeds 90% in most cases. Only the matched pairs of one issue type of traditional CDOs (CTA5) and three out of four MBS time series (MAAA3, MAAA5 and MBBB7) exhibit weak correlation effects due to distorting effects by the transformation procedure. In Appendix, Tab. 15 we illustrate the chosen z-values, the type of distribution underlying the transformation function, the correlation between the fitted spread series and the original spread series as well as the indicators of the normal distribution assumption, which include the Jarque-Bera statistic and the estimation results for the Doornik-Hansen test. We will consider these results when carrying out the GARCH estimation procedure.[20] We particularly address the violation of the normality assumption as we compute the heteroskedasticity consistent (quasi-maximum likelihood)

[19] Both optimisations were conducted via the "goal seek" function supplied by the Microsoft Excel software package.
[20] Please note that we have not applied the Johnson Fit to LIBOR rates. So the LIBOR rates in later GARCH estimations with adjusted and Johnson Fit-adjusted spread series include logarithmic LIBOR rates only.

covariance matrix according to White (1980),[21] which is also needed for several model diagnostics (coefficient and residual tests) at a later stage of this chapter.

Due to the disparate distributional characteristics and the varying goodness of adjustment through the Johnson Fit, we continue to apply the proposed GARCH models on all spread series, i.e. non-adjusted spreads, logarithmic spreads and Johnson-fitted and adjusted logspreads. We postpone the conscious choice of eliminating certain spread data from our analysis at this stage, as the trade-off between lower levels of normality in all spread series (by retaining non-transformed time series) and sporadic distortions of actual spread change (in some Johnson-fitted spread series, e.g. CSAAA3) is not straightforward to this point.[22]

4.4 Test of autocorrelation

The main statistical diagnostic for autocorrelation in time series is the Llung-Box test. Llung-Box Q-statistic at lag k represents the test statistic for the null hypothesis of i.i.d. variables (i.e. no autocorrelation) up to order k for

$$Q_{LB} = T(T+2)\sum_{j=1}^{k} r_j (T-j)^{-1}, \tag{8}$$

where r_j is the j^{th} autocorrelation and T is the number of observations. The Q-statistic is asymptotically distributed as χ^2 with the degrees of freedom equal to the number of autocorrelations, since the observations are not the result of an ARIMA estimation. We augment this test statistic by the AC-value of autocorrelation (with the null hypothesis of no autocorrelation). The AC-value confirms the Q-statistic of absent serial correlation if it cannot be rejected at the 5% level, i.e. falls within the two standard error bounds of $\pm 2T^{-0.5}$. We assume 36 lags as the default test setting for all test statistics of autocorrelation for the given time series. We estimate the autocorrelation of series y with lag k and sample mean $\bar{y}$ as the correlation coefficient over k periods

[21] The heteroskedasticity consistent covariance matrix proposed by White (1980) estimates coefficient covariances in the presence of heteroskedasticity of unknown form. The White covariance matrix is defined by $\tilde{\Sigma}_W = \frac{T}{T-k}(X'X)^{-1}\left(\sum_{t=1}^{T} u_t^2 x_t x_t'\right)(X'X)$, where T is the total number of observations, k denotes the number of regressors and u_t is the error term.

[22] Solely the MBBB7_AD_L spread series constitutes a strong case for disregarding the Johnson Fit of spreads and subsequent scaling, since this adjustment effects both a significant distortion of spread dynamics <u>and</u> a lower degree of normality.

$$r_k = \frac{\sum_{t=k+1}^{T} (y_t - \bar{y})(y_{t-k} - \bar{y}_{t-k}) / (T-k)}{\sum_{t=1}^{T} (y_t - \bar{y})^2 / T}, \tag{9}$$

where $\bar{y}_{t-k} = \sum_{t=k+1}^{T} \left(y_{t-k} \times (T-k)^{-1} \right)$ relies on the same overall mean $\bar{y}$ as the mean of both y_{t-k} and y_t (which would bias the result towards zero for finite series) for matters of computational simplicity. Hence, $r_k \neq 0$ means that the series is first order serially correlated. A geometric decrease of r_k in an increase of k lags would constitute a low-order autoregressive (AR) process, whereas as rapid decline of r_k to zero flags a low-order moving average (MA).

We determine the degree of autocorrelation at the statistical threshold of significant Q-statistics (*p*-value) and AC values (together with the partial correlation measure PAC) for the null hypothesis of no autocorrelation. This threshold level entails the maximum number of lags until either the associated AC value or the Q-statistic no longer indicate a rejection of the null hypothesis at the 5 % level or higher – whichever occurs first, with the Q-statistic being the primary criterion. For the given spread series the Llung-Box statistics and the AC-values of the correlogram (Tab. 1 and Appendix, Tab. 21-24) indicate high levels of autocorrelation for at least twenty lags, which abate as the spread series are transformed into logspreads with/without the Johnson Fit procedure. The correlogram-generated partial correlation coefficients (PAC) between the current spread levels and past spread levels of up to five lags together with the associated Q-statistics for each period for non-transformed and transformed logspreads confirm this assessment. While partial correlation decreases substantially after one lag for synthetic and traditional CDO and MBS spread series (with the Johnson Fit reducing some of the correlation), in some instances Pfandbrief spreads retain partial correlation values of more than 20% for up to three lags.

We attempt to strip all spread series of any autocorrelation effects by using the residuals of an AR(*p*) estimation of past spreads for up to *p* number of (autocorrelative) lags. In an ordinary least squares regression (OLS) of lagged spreads (in keeping with the computation of abnormal returns in financial research), the residuals should not be correlated if past spreads, as exogenous regressors, absorb all serial correlation effects. We estimate

$$S_t = \alpha + \beta_1 S_{t-1} + \ldots + \beta_p S_{t-p} + \varepsilon_t \tag{10}$$

for observed spreads and transformed spreads S, where we choose $p = 2$ for PAAA3 and PAAA5 series (given high partial correlation coefficients for up to at least lag two for these spread series in original and adjusted form) and $p = 1$ for the spread time series of all other asset types.[23] Since the regression coefficients β_1 to β_p would normally take up all autoregressive effects, the residuals should be independent from each other. They serve as new spread differences of the new spread series, which are conditioned on the starting level of the original spread series in order to establish comparability across the various spread series of asset types. We find that autocorrelation persists in the new spread time series of residuals (see Tab. 21-22), with autocorrelation and partial correlation test diagnostics only marginally different from the original spread series. Hence, we abstain from using new autocorrelation-adjusted spread series of AR estimated residuals. Nonetheless, the later GARCH estimation will include correction terms, which control for autoregressive effects up to lag two (see GARCH(2,1) model in section 6.2.2).

In some cases for CDO and MBS data this result might be primarily attributable to level effects as well as spread dynamics with "stale data" properties, where slight changes over time generate significant autocorrelation, which, at the same time, sustains a mean reverting process. However, in this case, "stale data" would mimic mean reversion, which would normally be a result of level stationarity in very liquid and volatile markets. This observation has important consequences for the later formulation of the multi-factor term structure model of structured spreads, where we control for past changes in LIBOR as the spread reference base (so we could view the spread series as "excess returns" over LIBOR). We particularly take account of autocorrelation in the later GARCH estimation by computing heteroskedasticity consistent (quasi-maximum likelihood) covariance matrices, which are needed for several model diagnostics (coefficient and residual tests).

5 TIME SERIES DYNAMICS

5.1 Stationarity tests

In this section we examine the time series dynamics of the different asset class spreads of our sample as to whether, and if so, at what order of integration, they obey by the stationarity condition of inference procedures. Level stationary series exhibit time-invariant mean and autocovariance. The canonical example of a non-stationary series (with a stationary random disturbance term) is a random

[23] We could have generated even better indications of residual autocorrelation if we had introduced further lags in the OLS estimation. However, in view of the small number of observations in the data set, we disregard this

walk, which can be integrated at first order (difference stationary series). The random walk has a constant forecast value, conditional on time, and associated variance increasing over time. In order to investigate the order of integration, we conduct both a mean reversion regression as well as unit root tests before we specify a multi-factor model to estimate asymmetric spread dynamics with stochastic variance (GARCH specification), while controlling for level effects induced by past spreads and changes in the base rate (LIBOR).

	Collateralised Debt Obligations (CDO)					
	synthetic			*traditional*		
	CSAAA3_AD_L	CSA5_AD_L	CSBBB7_AD_L	CTAAA3_AD_L	CTA5_AD_L	CTBBB7_AD_L
μ	0.0811	0.13182	0.0808	0.2382*	-0.0705	0.2279
(t-stat.)	(0.4613)	(0.7595)	(0.8063)	(1.4590)	-(0.5424)	(0.9830)
γ	-0.0195	-0.0251	-0.0129	-0.0698*	0.0164	-0.0422
(t-stat.)	-(0.4264)	-(0.7021)	-(0.6973)	-(1.4712)	(0.5551)	-(0.9646)
Adj. R^2	-0.0068	0.0003	-0.0067	0.0320	-0.0058	0.0165
F-stat.	0.3813	1.02956	0.3861	4.0454	0.4679	2.5474
(p-value)	(0.5385)	(0.3130)	(0.5359)	(0.0473)	(0.4957)	(0.1139)
θ	4.1497	5.2527	6.2838	3.4144	4.2987	5.3997
η	35.4696	27.6198	53.9246	9.9367	-42.2445	16.4202
θ/μ	51.1718	39.8470	77.7968	14.3357	-60.9459	23.6894

	Mortgage-Backed Securities (MBS)			
	MAAA3_AD_L	MAAA5_AD_L	MA7_AD_L	MBBB7_AD_L
μ	-0.5959**	-1.8904***	0.2182*	2.6557**
(t-stat.)	-(2.2887)	-(3.5561)	(1.4033)	(2.0783)
γ	0.1977**	0.6049***	-0.0526*	-0.5377**
(t-stat.)	(2.3133)	(3.5717)	-(1.4011)	-(2.0810)
Adj. R^2	0.0824	0.2948	0.0151	0.2635
F-stat.	9.2631	39.4681	2.4147	33.9136
(p-value)	(0.0031)	(0.0000)	(0.1237)	(0.0000)
θ	3.0135	3.1248	4.1458	4.9392
η	-3.5053	-1.1458	13.1704	1.2892
θ/μ	-5.0571	-1.6530	19.0009	1.8599

	Pfandbriefe		
	PAAA3_AD_L	PAAA5_AD_L	PAAA7_AD_L
μ	1.16206***	0.5525***	0.4476***
(t-stat.)	(4.8191)	(3.5922)	(2.6783)
γ	-0.3975***	-0.1734***	-0.1316***
(t-stat.)	-(4.8838)	-(3.6002)	-(2.7277)
Adj. R^2	0.1949	0.0933	0.0920
F-stat.	23.2714	10.4697	10.3186
(p-value)	(0.0000)	(0.0017)	(0.0018)
θ	2.9238	3.1870	3.4018
η	1.7440	3.9982	5.2678
θ/μ	2.5160	5.7682	7.5998

We define the level of mean reversion as $\theta=-\gamma/\mu$ and the speed of mean reversion as $\eta=\ln(0.5)/\gamma$.

Tab. 2. *Test of mean reversion – OLS regression of secondary market spreads of CDO, MBS and Pfandbrief transactions (only transformed and Johnson Fit adjusted spreads).*

option.

Various financial studies (such as Goodman and Ho, 1997 and 1998) have shown that interest rates follow a random walk and, hence, do not succumb to a mean-reverting process of level stationarity (Nelson and Plosser, 1982). According to Koutmos (2001), U.S. MBS price quotes and government bond yields each have unit roots, while U.S. MBS spreads and U.S. Treasury spreads appear co-integrated, i.e. both share a long-term relationship.[24] Koutmos (2002), however, finds that the unit root tests confirm stationarity of MBS spreads on a sample of weekly spreads of U.S. MBS transactions with maturities of five, seven and ten years over a time period of more than 30 years. Furthermore, his analysis concludes that spread changes exhibit asymmetric mean reversion, i.e. the first difference of spreads is strongly mean-reverting following spread decreases, but non-stationary following spread increases. Two conventional approaches for the investigation of mean reversion in stochastic processes with drift and time trend are the correlogram and the unit root test. Since the correlogram testing procedure is imprecise in cases when autocorrelation of a data generating process converges to zero for k elements in a finite sample series, even under non-stationary, we choose the classical unit root testing procedures by Dickey-Fuller (1979 and 1981) and Phillips-Perron (1987) – the *Augmented Dickey-Fuller* (ADF) and the *Phillips-Perron* (PP) test statistics (Greene, 1993) to determine the presence of mean reversion in all CDO, MBS and Pfandbrief spread series (actual, adjusted and with/without Johnson Fit).[25]

Since unit root tests examine the existence of a random walk based on a linear AR(p) model with p number of lags with shift and deterministic time trends, we first examine the degree of mean reversion in a *simplified* fashion by starting from principles on the basis of inference procedures through ordinary least squares regression (OLS) with heteroskedasticity-consistent standard errors and covariance (White, 1980).[26] This analysis indicates the level and the speed of mean reversion, as well as their consistency across the spread series of various asset classifications that are examined. The level of mean reversion represents the long-term mean, which stationary spreads ought to converge upon to match the sample mean value of the respective spread series. The speed of mean

[24] If observed variables grow together, spurious correlation might be measured erroneously. However, in the presence of co-integration they might share a fundamental economic driver that gives rise to a long-term relationship.

[25] In a finite data sample the correlogram testing procedure is imprecise, because sample autocorrelation will converge to zero for k elements (and indicate mean reversion) even if the time series is non-stationary. In practice it is difficult to tell whether a time series is non-stationary or slowly converging stationary. If values for autocorrelation drop to zero after some periods we can reject the random walk hypothesis (unit root).

[26] We use heteroskedasticity consistent covariance estimators for all OLS regressions, so that the estimated standard errors are robust even if the assumption of homoskedastic residuals in linear OLS-estimations is not satisfied for equation $Y_t = \mathbf{X}_i\boldsymbol{\gamma} + \varepsilon$ for $i = 1,\dots,n$, where $\mathbf{X}_i$ and $\boldsymbol{\gamma}$ are $k \times 1$-vectors. Y_i and ε_i are scale variables. White (1980) proposes the following estimator for a heteroskedasticity consistent covariance matrix: $(\mathbf{X}'\mathbf{X}/n)^{-1}\left(\left(\sum_{i=1}^{n}\hat{\varepsilon}_{in}^{2}\right)/n\right)(\mathbf{X}'\mathbf{X}/n)^{-1}$, where $\hat{\varepsilon}_{in} = Y_i - \mathbf{X}_i\hat{\boldsymbol{\gamma}}$.

reversion is defined as the average time (in number of cycles, i.e. weekly observations in our case) needed for spreads to reverse an upward or downward spread change by half its amplitude.

We complete a hypothesis test for $H_0 : \gamma < 0$ for mean reversion of logarithmic spreads of asset class tranches in the estimation equation

$$\Delta \ln(S_t) = \mu + \gamma \ln(S_{t-1}) + \varepsilon_t \quad \text{where} \quad \varepsilon_t \sim N(0, \sigma), \operatorname{cov}(\varepsilon_t, \varepsilon_{t-1}) = 0 . \tag{11}$$

Tab. 2 shows the OLS estimation results of the regression parameters for all spread series and the values for the level of mean reversion, $\theta = -\mu/\gamma$, and the speed of mean reversion, $\eta = \ln 0.5/\gamma$, as well as the correlation of the sample mean $\overline{S}$ and the level of mean reversion.

We find that all the estimated coefficients for MBS and Pfandbrief spread series are highly significant, especially highly liquid Pfandbrief transactions with a positive constant and a negative mean reversion coefficient. No CDO classification yields estimated coefficients at common levels of statistical significance. The OLS estimation output of each spread series substantiates our initial prediction about stationary series with the level of mean reversion θ closely associated with sample mean $\overline{S}$ for almost all types of spread data (actual, transformed, Johnson Fit-adjusted). Hence, we would expect the subsequent unit root test (which also considers a shift and time trend) to be negative. The positive correlation coefficient between θ and $\overline{S}$ across all types of spread series (see Tab. 3) implies that the level of mean reversion varies by rating grade, maturity and asset classification and increases with the sample mean of the time series in question. The absolute difference between θ and $\overline{S}$, however, is slightly higher for CDO tranches than for MBS and Pfandbrief tranches, where we also observe low correlation coefficients of these values for synthetic and traditional CDOs. This could hint at a weaker degree of mean reversion over the sample period (e.g. the time series of low frequency observations has not fully traversed an entire stationary cycle). To the contrary, in the case of Pfandbrief spread series, the level of mean reversion squares up with the sample means at a very high correlation in all cases, which ascertains almost complete mean-reversion over the given sample time period. The deviation of θ from $\overline{S}$ in the case of traditional and synthetic CDOs, but also for MBS transactions, clearly points to high illiquidity of those ABS transactions relative to Pfandbrief deals. Closer inspection of the relationship between the level of mean reversion and the sample mean of all spread series offers one possible explanation for the low correlation coefficients of CDO – and to some extent MBS transactions. Low-rated CDO transactions (CSBBB7 and CSA5) display a sustained upward trend over the sample period that the linear specification of the OLS regression estimation fails to capture.

We also compare the level of mean reversion θ to the constant μ of each spread series. If the constant, rather than the degree of mean reversion, influences the heteroskedasticity of spread levels ("level effect"), high correlation between both values should exist. Tab. 3 shows that the degree of mean reversion indeed increases with a higher estimated intercept. However, the CDO spread series lose the level effect once adjusted by the Johnson Fit procedure.

The estimation results for the speed of mean reversion defy a reliable general interpretation due to the inconsistent coefficient values for mean reversion of one CDO and two MBS spread series (CTA5, MAAA3, MAAA5). We find that MBS and Pfandbrief transactions show short mean-reverting cycles from slightly less than two weeks to almost eight weeks, while CDO spreads take from almost 10 to 78 weeks to recover previous upward or downward movements by half. Moreover, we find a clear relationship between the speed of mean reversion and the maturity of a certain tranche type only for Pfandbrief and CDO spreads – the longer the maturity of a certain transaction, the slower any mean-reverting adjustment through stationarity. We explain the slow speed of mean reversion for CDO transactions of up to 53 weeks on the grounds of low data frequency and insufficient market illiquidity, mainly because most of these transactions feature above-sample average maturities and, hence, entail a long reaction time to underlying spot rate changes. For more liquid Pfandbrief transactions the speed of mean reversion is far higher, ranging from 2.5 weeks (PAAA3_AD_L) to 7.6 weeks (PAAA7_AD_L).

	Correlation Coefficient ($\rho_{S_{avg.},\theta}$)			*Correlation Coefficient* ($\rho_{\mu,\theta}$)		
Asset Class	"AD_L" (fitted logspreads)	"L" (logspreads)	actual spreads	"AD_L" (fitted logspreads)	"L" (logspreads)	actual spreads
CDO, synthetic	0.3732	0.6196	-0.9989	0.0140	-0.3805	0.8570
CDO, traditional	0.4531	0.4983	0.6359	0.0337	-0.1183	0.9603
MBS	0.5229	0.4208	0.8197	0.9255	0.4655	0.8238
Pfandbriefe	0.9999	0.9998	0.9995	-0.9465	-0.9379	-0.9242

Tab. 3. *Correlation of sample mean and level of mean reversion as well as correlation of estimated constant and level of mean reversion of all secondary market spreads of CDO, MBS and Pfandbrief transactions.*

5.2 Test of unit root

We need to augment the inference procedure of simple OLS hypothesis testing by alternative cases to determine the order of integration for stochastic processes for all combinations of price sensitivity γ to past mean prices and the significance of some resilient price level as drift μ (intercept term): We consider all combinations of spread sensitivity γ (time trend) to past mean spreads and the significance of some resilient level of spreads as drift μ (intercept term): (i) I(1) process <u>without</u> drift $\gamma=0,\mu=0$, (ii) I(1) process <u>with</u> drift $\gamma=0,\mu\neq 0$, (iii) stationarity I(0) <u>with</u> mean $\gamma<0,\mu\neq 0$, (iv) stationarity I(0) <u>without</u> mean $\gamma<0,\mu=0$. In a mean reversion test based on OLS in section 5.1 we would be able to reject H_0 for case (iii) only. So prior to the estimation of a factor model to draw statistical inferences from the time series dynamics for forecasting purposes, we need to consider a shift and time trend in the given spread series at level and first differences to examine whether estimated residuals testify to serial correlation as a unit root in violation of stationarity by means of the *Augmented Dickey-Fuller (ADF)* and the *Phillips-Perron (PP)* unit root tests. In this way we can explore the degree of mean reversion in weekly spreads and their first differences over the given sample time period. In our case the autoregressive ADF test (with deterministic time trend) is defined as

$$\ln(S_t)=\mu+\beta t+\gamma\ln(S_{t-1})+\sum_{j=1}^{p-1}\phi_j\ln(\Delta S_{t-j})+\varepsilon_t \quad \text{with } H_0:\rho=1\ vs.\ H_1:\rho<1, \tag{12}$$

with the one-sided hypothesis test $H_0:\gamma=0\ vs.\ H_1:\gamma<0$ (since the differences from the null hypothesis are unidirectional *ex ante*), where Δ is the difference operator, μ (i.e. the long run mean) and γ are the test parameters and i.i.d. residuals as white noise error term $\varepsilon\sim N(0,\sigma^2)$. If $\gamma=0$, $\ln(S_t)$ follows a random walk with drift (non-stationarity), i.e. the variance of the spread process increases steadily with time and goes to infinity, else for $\gamma>0$, $\ln(S_t)$ is an explosive series. The PP test for the specification $\Delta\ln(S_t)=\mu+\beta(t-T/2)+\gamma\ln(S_{t-1})+\varepsilon_t$ with $H_0:\gamma=1\ vs.\ H_1:\gamma<1$ in our case also corrects the t-statistic of the γ coefficient of the AR(1) process by the serial correlation of residuals ε_t. This non-parametrical correction computes the spectrum of ε_t at frequency zero under the Newey-West (1987) heteroskedastic and autocorrelation consistent estimator to

$$t_{PP}=\frac{\sqrt{\gamma_0}t_b}{\omega}-\frac{(\omega^2-\gamma_0)Ts_b}{2\omega\hat{\sigma}}, \tag{13}$$

where $\omega^2 = \gamma_0 + 2\sum_{j=1}^{q}\left(1 - j/(q+1)\right)\gamma_j$, $\gamma_j = T^{-1}\sum_{t=j+1}^{T}\tilde{\varepsilon}_t\tilde{\varepsilon}_{t-j}$, truncation lag q, test regression standard error $\hat{\sigma}$, and t_b and s_b as t-statistic and standard error of β. We run the ADF test with a constant and a linear trend on level and first differences of spreads of up to two lags in order to control for serial correlation. We also complete the PP test diagnostic, corrected by the Newey-West autocorrelation consistent variance estimator, which accounts for the number of periods of serial correlation through three truncation lags. For both tests we employ MacKinnon (1996) critical values for (one-sided) rejection of the unit root null hypothesis.

Similar to earlier studies with respect to U.S. MBS spreads (Koutmos, 2002) we reject the unit root in most weekly spread time series for level data (Tab. 4 and Appendix, Tab. 25). Merely PAAA5 and PAAA7 spreads seem to be non-stationary (according to the ADF test statistic), while MAAA5 spreads yield inconclusive results. Autocorrelation effects can be almost entirely eliminated at a test specification of up to four lags. For the first difference of spreads both ADF and PP test diagnostics strongly reject the null hypothesis of a unit root in all cases. Hence, all spread series are at least integrated at the order of one. Generally, we find that LIBOR rates and CDO, MBS and Pfandbrief spreads share unique co-integration vectors, indicating difference stationarity of most individual spread series.

We identify two possible causes for divergent stochastic properties across level spread series: liquidity and data frequency. First, our results are less homogenous compared to Koutmos (2002), which could be attributed to the poor data quality.[27] Whereas Koutmos (2002) used time series data of more than 30 years to substantiate his findings on the level stationary of U.S. MBS spreads, our limited number of observations over a time period of barely two years does not invite the same degree of measurability for long range cycles of mean-reversion.

[27] Higher ADF and PP test statistics of daily Pfandbrief spreads over the originally generated time period from September 1998 to October 2002 (not reported) indicate that better data quality, with respect to data frequency and time period of observations, support the rejection of a unit root. Moreover, the spread series of Pfandbrief spreads over a four-year period include spread quotations of summer 2000, when some German Pfandbrief issues – for the first time in recent history – were downgraded amid the massive liquidity crises in global financial markets. While almost all German Pfandbrief transactions were AAA-rated and regarded as safe an investment as government bonds, a re-assessment of credit risk in Pfandbrief transactions sent spreads markedly higher during the second half of 2000. Also the shorter series of weekly Pfandbrief spreads used in this analysis might still suffer from lagged effects on spread volatility from January 2001 onwards.

Asset Class Spread Series	Augmented Dickey-Fuller (ADF)				Phillips-Perron (PP)			
	level		*on first difference*		*level*		*on first difference*	
	test stat.#	F-stat.	test stat.	F-stat.	test stat.	F-stat.	test stat.	F-stat.
Collateralised Debt Obligations (CDO), synthetic								
CSA5_AD_L	-3.367652***	2.8945	-6.253208***	23.6575	-2.727887***	3.5594	-9.919613***	49.1234
CSAAA3_AD_L	-2.115569**	1.3658	-5.439055***	21.9381	-2.104623**	2.4597	-9.574888***	45.8374
CSBBB7_AD_L	-2.152063**	1.2455	-5.886175***	23.3047	-2.338996**	2.5349	-9.590928***	45.9627
Collateralised Debt Obligations (CDO), traditional								
CTA5_AD_L	-1.4271	1.0235	-4.934276***	17.2697	-1.3810	1.1353	-8.614782***	36.8747
CTAAA3_AD_L	-1.807324*	1.0596	-7.036044***	26.7650	-1.85988*	2.0212	-8.925047***	39.9795
CTBBB7_AD_L	-3.868666***	3.8989	-7.199525***	28.3019	-3.507903***	5.2950	-8.927302***	39.9059
Mortgage-Backed Securities (MBS)								
MA7_AD_L	-2.293844**	4.1190	-6.616401***	21.2514	-2.71831***	3.6791	-8.431175***	35.9602
MAAA3_AD_L	-2.669565***	2.3823	-5.624701***	27.9576	-4.066767***	7.6201	-11.7885***	68.7735
MAAA5_AD_L	-3.9070	13.6306	-7.060149***	70.6754	-6.408603***	19.6483	-18.23404***	144.1522
MBBB7_AD_L	-6.035035***	10.9508	-7.239436***	35.9587	-5.76176***	16.8164	-12.14478***	68.2325
Pfandbriefe								
PAAA3_AD_L	-2.526267**	10.6802	-7.223362***	66.8306	-5.418308***	14.5363	-18.02513***	127.5861
PAAA5_AD_L	-1.5908	3.8489	-7.114721***	43.7777	-2.82416***	5.4351	-13.8917***	85.7927
PAAA7_AD_L	-1.5950	2.0476	-6.467876***	32.5846	-2.995738***	5.5289	-11.63695***	63.6673

Sample (adjusted): 21/01/2001-18/10/2002; 92 weekly observations; constant and linear time trend (shift) included in the text as exogenous variables. # MacKinnon (1996) critical values for rejection of hypothesis of a unit root based on one-sided p-values. Significance: * significant at 10% level, ** significant at 5% level, *** significant at 1% level. PP test completed with three-lag truncation for Bartlett (1981) kernel given Newey-West (1987) test.

Augmented Dickey-Fuller (ADF) test is based on: $\Delta y_t=\mu+\gamma_1 t+\gamma_2 y_{t-1}+\delta_1\Delta y_{t-1}+\delta_2\Delta y_{t-2}+\varepsilon_t$ with $H_0{:}\gamma_2=0$ vs. $H_1{:}\gamma_2<0$

Phillips-Perron (PP) test is based on: $\Delta y_t=\mu+\beta_1(t-T/2)+\beta_2 y_{t-1}+\varepsilon_t$ with $H_0{:}\beta_2=1$ vs. $H_1{:}\beta_2<1$

Tab. 4. *Test of unit root – adjusted OLS regression of secondary market spreads of CDO, MBS and Pfandbrief transactions (only transformed and Johnson Fit adjusted spreads).*

Moreover, we need to view cases of level stationary spreads with great caution, given the quality of the data series. MBS and CDO markets differ from the Pfandbrief market in investment liquidity. We also recognise that persistent stochastic processes over long spans of time with a small autoregressive component (due to low liquidity and infrequent trading activity) could bias the ADF and PP tests towards rejecting the unit root, in the absence of strong statistical power against the alternative of level stationarity (Papell and Prodan, 2003a and 2003b).[28] The "stale" nature of spread movements of

[28] The danger of type II error misspecification, which also operates in the presence of a nonlinear data generating process, has critical implications on the interpretation of ADF results: the linear specification biases

MBS and CDO spreads, together with a persistent autoregressive effect in spread residuals for up to at least 20 lags (see Tab. 1) might fit this caveat. However, strong autocorrelation does not apply for first differences of spreads, so at least first order integration (as suggested in the later model measuring spread dynamics on the basis of spread changes) yields satisfactory characteristics of mean reversion. If spreads are stationary, standard statistical hypothesis testing is appropriate.

6 MODEL

6.1 Model specification

The following model aims to describe the distribution and volatility of ABS spreads (CDO, MBS) and Pfandbrief spreads in Europe. Like the equilibrium models of the term structure of interest rates, with a stochastic process followed by a small number of state variables,[29] ABS spreads S_t follow a standard geometric Brownian motion (GBM),

$$S_t = S_0 \exp\left\{\left(\mu - \sigma^2/2\right)t + \sigma\sqrt{t}z_t\right\}, \tag{14}$$

where the volatility process $\sigma\sqrt{t}z_t$ – which could also be written in a discrete sense as $\sqrt{t}z_t \equiv W_t - W_0$ – contains a Wiener process with zero mean change and variance proportional to *t*, so that $\Delta z \sim \left(0, \Delta t\right)$. The dynamics of S_t, i.e. the instantaneous value, are identified by the stochastic differential equation

$$dS_t / S_t = \mu dt + \sigma dW_t, \tag{15}$$

of the Ito process $dS_t = \mu\left(S_t, t\right)dt + \sigma\left(S_t, t\right)dW_t$ (generalised Wiener process), whose trend and volatility depend on the current spread level S_t and time *t*.[30] This approach assumes that normalised spread changes dS_t/S_t follow a standard normal distribution $N(0,1)$. We measure the spread dynamics of $dS_{i,t}/S_{i,t} = \mu dt + \sigma dW_t$ on the basis of a GARCH multi-factor term structure model as

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the unit root test into failing to reject the unit root hypothesis (Taylor, 2001, Taylor et al., 2001; Taylor and Peel, 2000).

[29] These models are represented by Ito equations, as in Hull (1995 and 1993) and others.

[30] In the case of the GBM, the drift μ and the volatility σ are proportional to the current value of S_t. W_t is a standard Brownian motion, whose infinitesimal increment is denoted by a standard Wiener process $dz_{x,t} = \varepsilon_j\sqrt{dt}$ and ε_j as a standard normal random variable.

a discrete approximation of spread change, provided that the spread change follows a stationary process (see section 5). For this purpose, we modify the approximative GARCH(1,1) model of U.S. MBS yields (over government bonds) by Koutmos (2002),[31] and we describe the dynamics of spread change, on the basis of additional endogenous factors, in a refined GARCH model.

Generally, a GARCH(*p*,*q*) process models the heteroskedasticity of a given time series x_T, whose distribution – conditionally on past observations of x_{t-q} – is specified by $F(x_t/\sigma_t) \sim (0,1)$. The conditional variance of the mean value follows a GARCH process defined by the volatility from the previous period(s), measured as the q lag(s) of the squared residual(s) from the mean equation (ARCH term(s)), and the forecast variance(s) of the last p periods (GARCH term(s)). Hence, this specification of conditional variance in a GARCH model, if applied to spread movements over time, can be easily interpreted in a practical context, where an agent predicts the periodic variance based on a weighted average of a long term mean (the constant), the forecasted variance from the last period (GARCH term(s)) and the information about the volatility observed in the previous period(s) (ARCH term(s)). An adapted version of the original two-factor GARCH(1,1) model by Longstaff and Schwartz (1992) as discrete approximation of continuous spread change would read

$$S_t - S_{t-1} \equiv \Delta S_t = \alpha_0 + \alpha_1 S_{t-1} + \alpha_2 \sigma_t^2 + \varepsilon_t \tag{16}$$

$$\sigma_t^2 = \beta_0 + \beta_1 \varepsilon_{t-1}^2 + \beta_2 S_{t-1} + \beta_3 \sigma_{t-1}^2, \tag{17}$$

for $F(\Delta S_t/\sigma_t) \sim (0,1)$. The equations of the mean and the conditional variance of spreads above capture any past influence on both spread change ΔS_t (mean equation) and conditional variance σ_t^2. If the mean reversion parameter $\alpha_1 < 0$, the spread series is considered level stationary. The conditional mean of the spread change is dependent on the past spread level S_{t-1} and the level of the conditional variance, with error term ε_t. The conditional variance follows a GARCH(1,1) process, which is defined by one lag squared errors ε_{t-1}^2 in the mean equation, the autocorrelation term (forecast variance of the previous period) σ_{t-1}^2 and the past spread level (as extension to the standard GARCH(1,1) model).

[31] Building on the two-factor model by Longstaff and Schwartz (1992) and the work by Bali (2000), Koutmos (2002) considers frequently observed volatility clusters of yield curves (GARCH effect) in the context of asymmetric mean reversion. He finds that spreads commonly behave non-stationary if a positive spread change in the past had preceded an external shock, whilst mean reversion is statistically significant after a negative spread change.

Since both equations do not recognise asymmetric spread dynamics, Koutmos (2002) proposes a two-factor model, which accommodates mean reversion in U.S. MBS yields after positive and negative past spread changes in line with Bali (2000). We break down the mean reversion term α_1 (mean equation) into $\alpha_{1,p} I_t S_{t-1} + \alpha_{1,n}(1 - I_t) S_{t-1}$ by imposing the indicator function $I_t = \begin{cases} 1 & \text{if } S_t - S_{t-1} \geq 0 \\ 0 & \text{if } S_t - S_{t-1} < 0 \end{cases}$ on the first difference of spreads. Moreover, we also introduce asymmetry in to the conditional variance equation by discriminating between the coefficient value of the positive and negative squared residuals of the previous period, by means of an extended ARCH term $\beta_1 \varepsilon_{t-1}^2 + \beta_2 u_{t-1}^2$ for $u_{t-1} = \min(0, \varepsilon_{t-1})$ instead of using only $\beta_1 \varepsilon_{t-1}^2$ (ordinary ARCH term). Here, β_1 measures any general sensitivity of the conditional variance σ_t^2 to past squared residuals, while the coefficient value of β_2 is limited to the contribution of negative past errors $\varepsilon_{t-1} < 0$ to the variance and, hence, reflects any degree of potential asymmetries. This approach differs only formally from the so-called "threshold ARCH" (TARCH) process developed independently by Glosten et al. (1993) and Zakoian (1990), which allows asymmetric shocks to volatility through the ARCH term $\beta_1 \varepsilon_{t-1}^2 + \gamma \varepsilon_{t-1}^2 d_{t-1}$ for $d = \begin{cases} 0 & \text{if } \varepsilon_{t-1}^2 \geq 0 \\ 1 & \text{if } \varepsilon_{t-1}^2 < 0 \end{cases}$. In the original TARCH setting introduced by Engle and Ng (1993) in their research on the impact of news on volatility (asymmetric News Impact Curve), good news $\varepsilon_{t-1} < 0$ and bad news $\varepsilon_{t-1} > 0$ have different effects on the conditional variance. Good news has an impact of β_1, while bad news has an impact of $\beta_1 + \gamma$. If $\gamma \neq 0$ the news impact is asymmetric, where $\gamma > 0$ signifies a "leverage effect".

6.2 GARCH specification

In this chapter we explain the heteroskedasticity spread change behaviour (term structure of spreads) by a multi-factor asymmetric GARCH process on the basis of two equations for the mean and conditional variance. In extension to Koutmos' (2002) adaptation of Longstaff and Schwartz (1992), the conditional mean of spread changes is influenced by past spread levels, the past LIBOR rate and the conditional variance. The latter follows a GARCH process defined by past variance (GARCH term), past squared residuals of the mean equation (ARCH term) as well as the LIBOR rate and past spreads as variance regressors. We find both the level and the first differences of LIBOR rates as an appropriate reference base for the given spread series.[32] In contrast to Koutmos, however, our sample size is limited to 93 weekly observations of actual secondary market spread data for traded tranches of these asset types. In order to improve the statistical properties of the analysis, we adjusted the spread series and transformed them, so that the subsequent examination could be completed on "raw" data, logarithmic spreads and spreads adjusted by the Johnson Fit. We abstained from the Johnson Fit procedure for LIBOR rates, i.e. the spread series of LIBOR enters the estimation only as observed spot rates and logarithmic spot rates without the Johnson Fit.

We propose two GARCH specifications, GARCH(1,1) and GARCH(2,1), with one variation each. In the GARCH(1,1) model we incorporate (i) first differences of LIBOR (with indicator function) in the mean equation and (ii) the past LIBOR rate as variance regressors. As a variation to this specification we include past LIBOR rates as either level data or first differences. In the alternative GARCH(2,1) process, we refine the GARCH(1,1) model as we (i) introduce a new set of mean reversion coefficients of lag two for the positive and negative past spread levels mean equation (with a corresponding indicator function) and (ii) extend the past forecast variance to two lags in the estimation of conditional variance. Overall, we consider asymmetric effects of explanatory factors through (i) indicator functions for past spreads and past LIBOR rates in the mean equation as well as (ii) two coefficients for positive and negative errors in the expression for conditional variance.

6.2.1 GARCH(1,1) model specification

We specify the GARCH(1,1) model by the following mean equation and conditional variance equation:

$$\begin{aligned} S_t - S_{t-1} \equiv \Delta S_t = \alpha_0 + I_t \alpha_{1,1} S_{t-1} + \left(1 - I_t\right) \alpha_{1,2} S_{t-1} + \\ K_t \alpha_{2,1} L_{t-1} + \left(1 - K_t\right) \alpha_{2,2} L_{t-1} + \alpha_3 \sigma_t^2 + \varepsilon_t \end{aligned}, \tag{18}$$

and

$$\sigma_t^2 = \beta_0 + \beta_1 \varepsilon_{t-1}^2 + \beta_2 u_{t-1}^2 + \beta_3 S_{t-1} + \beta_4 L_{t-1} + \beta_5 \sigma_{t-1}^2, \tag{19}$$

which transform to

$$\begin{aligned} \Delta \ln S_t = \alpha_0 + I_t \alpha_{1,1} \ln S_{t-1} + \left(1 - I_t\right) \alpha_{1,2} \ln S_{t-1} + \\ K_t \alpha_{2,1} \ln L_{t-1} + \left(1 - K_t\right) \alpha_{2,2} \ln L_{t-1} + \alpha_3 \sigma_t^2 + \varepsilon_t \end{aligned} \tag{20}$$

and

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[32] See also Goodman and Ho (1998).

$$\sigma_t^2 = \beta_0 + \beta_1 \varepsilon_{t-1}^2 + \beta_2 u_{t-1}^2 + \beta_3 \ln S_{t-1} + \beta_4 \ln L_{t-1} + \beta_5 \sigma_{t-1}^2, \qquad (21)$$

for LIBOR sport rates as well as

$$\begin{aligned} \Delta \ln S_t &= \alpha_0 + I_t \alpha_{1,1} \ln S_{t-1} + (1 - I_t) \alpha_{1,2} \ln S_{t-1} + \\ &K_t \alpha_{2,1} \Delta \ln L_t + (1 - K_t) \alpha_{2,2} \Delta \ln L_t + \alpha_3 \sigma_t^2 + \varepsilon_t \end{aligned} \qquad (22)$$

and

$$\sigma_t^2 = \beta_0 + \beta_1 \varepsilon_{t-1}^2 + \beta_2 u_{t-1}^2 + \beta_3 \ln S_{t-1} + \beta_4 \Delta \ln L_t + \beta_5 \sigma_{t-1}^2 \qquad (23)$$

for the first differences of LIBOR. S_t denotes the secondary market spreads of a certain asset class – either CDO, MBS or Pfandbrief – and L_t is the 3-month-LIBOR rate, both at time t. The indicator function of past innovations (negative and positive) is expressed as $u_{t-1} = \min(0, \varepsilon_{t-1})$. The indicator functions for the first difference of spreads S_t and LIBOR rates L_t are $I_t = \begin{cases} 1 & \text{if } S_t - S_{t-1} \geq 0 \\ 0 & \text{if } S_t - S_{t-1} < 0 \end{cases}$ and $K_t = \begin{cases} 1 & \text{if } L_t - L_{t-1} \geq 0 \\ 0 & \text{if } L_t - L_{t-1} < 0 \end{cases}$ respectively.

In the above GARCH(1,1) expression the first order spread change depends on the spread level of the previous period (conditional on the direction of change), the change of the sport rate (LIBOR) of the previous period as a reference base and the conditional variance with a past volatility forecast (GARCH term) and lagged squared residuals from the mean equation (ARCH term). The use of one lag spreads captures first-order autocorrelation. The inclusion of the LIBOR rate (at level and first difference) as a proxy for the general interest rate level is a crucial control factor of our analysis, because a statistically significant LIBOR effect as the most prominent fixed income benchmark helps specify the nature of spread changes due to idiosyncratic effects in the ABS market. The squared residuals measure the part of spread changes that escape the explanatory power of independent factors in the mean equation. Hence, they measure mainly those parts of changes in the spread over time, which are common to the pricing of structured debt.

Moreover, the model allows the examination of asymmetric effects of past spread levels and squared errors on future spread dynamics. If the conditions $\alpha_{1,1} \neq \alpha_{1,2}$ and $\alpha_{1,1} + \alpha_{1,2} < 0$ for the regression coefficients hold, the given spread series is level stationary with asymmetric mean reversion at lag one. Analogously, the same applies for the relationship between $\alpha_{2,1}$ and $\alpha_{2,2}$ in the context of lag two. Moreover, past errors have different effects on the conditional v $\sigma_t^2 = \beta_0 + \beta_1\varepsilon_{t-1}^2 + \beta_2 u_{t-1}^2 + \beta_3 \ln S_{t-1} + \beta_4 \Delta \ln L_t + \beta_5 \sigma_{t-1}^2 + \beta_6 \sigma_{t-}^2$ general sensitivity of the conditional variance to past errors, whereas β_2 measures the impact of negative past error $\varepsilon_{t-1} < 0$ on the conditional variance, and hence, reflects any degree of potential asymmetries for $\beta_2 \neq 0$. The contribution of an (overall) positive error $\varepsilon_{t-1} > 0$ will be equal to $\beta_1 + \beta_2$. If $\beta_2 > 0$, the conditional variance of spread change is more sensitive to positive past errors (i.e. spread increases) than negative past errors (i.e. spread decreases). However, if $\beta_2 < 0$, negative residuals precipitate a negative reaction

$$\Delta \ln S_t = \alpha_0 + I_t \alpha_{1,1} \ln S_{t-1} + (1 - I_t)\alpha_{1,2} \ln S_{t-1} + J_t \alpha_{2,1} \ln S_{t-2} +$$
$$(1 - J_t)\alpha_{2,2} \ln S_{t-2} + K_t \alpha_{3,1} \Delta \ln L_t + (1 - K_t)\alpha_{3,2} \Delta \ln L_{t-1} + \alpha_3 \sigma_t^2 + \varepsilon_t ,$$

of variance to the spread level and the LIBOR ra or ΔL_t is used in the specification of the GARCH model), while β_5 represents its persistence.

6.2.2 *GARCH(2,1) model specification*

In extension to the GARCH(1,1) model we allow for a greater explanatory power by past volatility in a GARCH(2,1) process, as we expand the forecast variance of the conditional variance (GARCH term) to the last two periods, matched by two lag spreads as additional independent variables in the mean equation to control for second-order autocorrelation. Squared errors in the conditional variance expression are kept at one lag. Hence, building on the GARCH(1,1) specification above, this extension yields

$$\Delta \ln S_t = \alpha_0 + I_t \alpha_{1,1} \ln S_{t-1} + (1 - I_t)\alpha_{1,2} \ln S_{t-1} + J_t \alpha_{2,1} \ln S_{t-2} +$$
$$(1 - J_t)\alpha_{2,2} \ln S_{t-2} + K_t \alpha_{3,1} \ln L_{t-1} + (1 - K_t)\alpha_{3,2} \ln L_{t-1} + \alpha_3 \sigma_t^2 + \varepsilon_t ,$$

$$\begin{aligned}\Delta \ln S_t &= \alpha_0 + I_t \alpha_{1,1} \ln S_{t-1} + (1 - I_t)\alpha_{1,2} \ln S_{t-1} + J_t \alpha_{2,1} \ln S_{t-2} + \\ &(1 - J_t)\alpha_{2,2} \ln S_{t-2} + K_t \alpha_{3,1} \ln L_{t-1} + (1 - K_t)\alpha_{3,2} \ln L_{t-1} + \alpha_3 \sigma_t^2 + \varepsilon_t ,\end{aligned} \tag{24}$$

and

$$\sigma_t^2 = \beta_0 + \beta_1 \varepsilon_{t-1}^2 + \beta_2 u_{t-1}^2 + \beta_3 \ln(S_{t-1}) + \beta_4 \ln(L_{t-1}) + \beta_5 \sigma_{t-1}^2 + \beta_6 \sigma_{t-2}^2 , \tag{25}$$

as well as

$$\begin{aligned}\Delta \ln S_t &= \alpha_0 + I_t \alpha_{1,1} \ln S_{t-1} + (1 - I_t)\alpha_{1,2} \ln S_{t-1} + J_t \alpha_{2,1} \ln S_{t-2} + \\ &(1 - J_t)\alpha_{2,2} \ln S_{t-2} + K_t \alpha_{3,1} \Delta \ln L_t + (1 - K_t)\alpha_{3,2} \Delta \ln L_{t-1} + \alpha_3 \sigma_t^2 + \varepsilon_t ,\end{aligned} \tag{26}$$

and

$$\sigma_t^2 = \beta_0 + \beta_1 \varepsilon_{t-1}^2 + \beta_2 u_{t-1}^2 + \beta_3 \ln S_{t-1} + \beta_4 \Delta \ln L_t + \beta_5 \sigma_{t-1}^2 + \beta_6 \sigma_{t-2}^2 , \tag{27}$$

depending on whether the LIBOR spot rates are considered on level or first differences. The indicator function for second differences of spreads S_t is $J_t = \begin{cases} 1 \text{ if } S_t - S_{t-2} \geq 0 \\ 0 \text{ if } S_t - S_{t-2} < 0 \end{cases}$.

6.2.3 *Estimation procedure*

The estimation of the presented GARCH models requires a non-linear solution algorithm for conditional maximum likelihood (CML). We apply two kinds of maximum likelihood iterative estimation procedures – *Berndt-Hall-Hall-Hausman (BHHH)/Gauss-Newton* (1974)[33] and *Marquardt* (1963).[34] Since the first difference of logarithmic spreads of most time series in our data set does not follow a normal distribution (see Tab. 1), with the exception of some Pfandbrief issue spreads, we use the heteroskedasticity consistent covariance method by Bollerslev and Wooldridge (1992), which is needed for several model diagnostics (coefficient and residual tests). In this way, we derive robust estimators for quasi-maximum likelihood (QML) covariance and standard errors (Bollerslev and Woolridge, 1992), even in the absence of normally distributed spread differences.

Since both the maximum-neighbourhood procedure of the *Marquardt* ML algorithm and the approximation of the negative Hessian by the sum of the gradient vectors of the *Berndt, Hall, Hall, and Hausman (BHHH)* algorithm use random iterative components, the estimation for one and the same spread series could yield different results each time. This holds true especially for short time series, such as in our case of CDO, MBS and Pfandbrief spreads, where disparate local optima misrepresent the overall estimation result. In order to reduce parameter uncertainty and derive estimation results at parameter values that maximise the objective function (global optimum), we devise a specific estimation procedure. After N iterative cycles generate preliminary estimation

[33] The shared underlying approximative estimation algorithm is referred to as *Gauss-Newton* for general nonlinear least squares problems, and *Berndt, Hall, Hall, and Hausman (BHHH)* for maximum likelihood problems. For both types of problems this estimation routine represents the substitution of the negative Hessian by an approximation derived from the summed outer product of the gradient vectors of each observation's contribution to the objective function. It is asymptotically equivalent to the actual Hessian when evaluated at the parameter values that maximise the objective function. Advantages of *Gauss-Newton/BHHH* are that only the first derivatives need to be evaluated and the outer product is necessarily positive. However, this approximation algorithm might provide poor guidance concerning the overall shape of the function, when evaluated at parameter values away from the maximum, so that more iterations may be needed for convergence.

[34] The *Marquardt* ML algorithm is based on a maximum-neighbourhood procedure, which combines the benefits of both Gauss algorithms and gradient procedures. According to Marquardt (Marquardt, 1963) pure Gaussian estimation procedures frequently fail due to the divergence of successive iterative steps, whereas gradient procedures only gradually reach the necessary level of convergence if the approximate optimum solution has been determined already. The *Marquardt* ML estimation procedure does not share these drawbacks. Its algorithm quickly converges to the optimum solution (similar to Gauss algorithms) and pushes the updated parameter values in the direction of the gradient. Like in gradient procedures, the Marquardt estimation aims to find the optimum based on random solution values far removed from the area of convergence of other iterative estimation procedures (Marquardt, 1963). The *Marquardt* algorithm modifies the *Gauss-Newton* algorithm in exactly the same manner as quadratic hill climbing modifies the *Newton-Raphson* method (by adding a correction matrix (or ridge factor) to the Hessian approximation). Note that in the Marquardt estimation we compute asymptotic standard errors from the unmodified *(Gauss-Newton)* Hessian approximation once convergence is achieved.

results, we perpetuate the estimation process until the adjusted R^2-measure and the significance of estimators square up with the best results after the first N number of estimations. The determination of N represents a trade-off between computational time and the consistency of the successive estimations given the length of the time series. We set $N = 1,000$ for the short time series of weekly spreads. The estimation procedure is conducted with starting values different from 1 (i.e. $\times 0.7, \times 0.5, \times 0.3$ or $\times 0$) for the OLS estimation in cases where the estimation algorithm encountered a singular matrix due to multicollinearity of model factors.[35]

Upon estimation of the two specifications of GARCH models, we examine the statistical significance of the degree of level stationarity contingent on past positive and negative spread change (coefficient test). In order to attest overall mean reversion to the given spread dynamics, and possible asymmetric effects on past spread levels, we validate the hypotheses for the coefficient values $\alpha_{1,1} + \alpha_{1,2} < 0$ in GARCH(1,1) and $\alpha_{1,1} + \alpha_{1,2} < 0$ and $\alpha_{2,1} + \alpha_{2,2} < 0$ in GARCH(2,1), respectively. Each hypothesis is comprised of two sub-hypotheses: $H_{0,1} : \alpha_{1,1} + \alpha_{1,2} = 0$ and $H_{0,2} : \alpha_{1,1} + \alpha_{1,2} = \hat{\alpha}_{1,1} + \hat{\alpha}_{1,2}$ for both GARCH models as well as $H_{0,1} : \alpha_{2,1} + \alpha_{2,2} = 0$ and $H_{0,2} : \alpha_{2,1} + \alpha_{2,2} = \hat{\alpha}_{2,1} + \hat{\alpha}_{2,2}$ for GARCH(2,1) in order to account for past spread levels of up to lag two. The time series is stationary overall, if (i) we cannot reject the second null hypothesis, i.e. the sum of the coefficient values is not significantly different from the sum of the calculated test estimators, and (ii) the sum of the coefficients is smaller than zero, so that the first null hypothesis is rejected. Furthermore, in the context of measuring the heteroskedasticity of spreads, we can also assess any asymmetry of spread dynamics. If $H_0 : \alpha_{1,1} = \alpha_{1,2}$ for GARCH(1,1) as well as $H_0 : \alpha_{1,1} = \alpha_{1,2}$ and $H_0 : \alpha_{2,1} = \alpha_{2,2}$ for GARCH(2,1) can be rejected, past spread change influences the sensitivity of future spread change to past spread levels.

Both tests are completed by means of the *Wald coefficient test*, which computes the test statistic by estimating an unrestricted regression without imposing the coefficient restrictions specified by the null hypothesis. The Wald test diagnostic is calculated from

[35] We apply SQR-GARCH estimation in cases when multicollinearity of estimation yields a singular matrix for any starting value of simple OLS-estimators. Alternatively, we could have also omitted the intercept term α_0 (i.e. the constant of spread differences) from the estimation equation. This remedial procedural, however, would only be commendable if the statistical significance of the intercept term is negligible for the interpretation of the estimation results. Particularly in the case of the GARCH(2,1) specification, high levels of significance of the intercept prohibit this approach.

$$W = (\mathbf{R}\beta - r)' \times \left(\sigma^2 \mathbf{R}(\mathbf{X}'\mathbf{X})^{-1}\mathbf{R}'\right)^{-1} (\mathbf{R}\beta - r) \sim \chi^2_{df=m},^{36} \tag{28}$$

where σ^2 is the variance of unrestricted residuals. It tests the validity of linear coefficient restrictions as it measures how close the unrestricted estimates come to satisfying the restrictions under the null hypothesis. In matrix algebra the null hypothesis is generally written as $H_0 : \mathbf{R}\beta = r$, where r denotes the $m \times 1$ vector of the required results of the testable restrictions and m is the number of restrictions. The matrix $\mathbf{R}_{(m \times k)}$ represents the linear combinations of the restrictions, with β as the coefficient vector with k coefficients.[37]

Finally, we impose robustness tests on the simulation results of specific model specifications in order to address contingencies of both estimation risk and state variable uncertainty. We determine the correct specification of both GARCH models on the basis of three standard residual tests (*Ljung-Box (LB) Q-statistic* and *Jarque-Bera statistic*) and three model specific residual tests (sign bias test, negative size bias test and positive size bias test). The *Ljung-Box (LB) Q-statistic* for standardised and squared standardised residuals of the estimation process can detect any remaining serial correlation in the mean equation and any remaining ARCH effect in the conditional variance equation respectively. If the mean equation is correctly specified, all Q-statistics of standardised residuals should be insignificant with no observable autocorrelation. Analogously, the same applies to the LB Q-statistic of squared standardised residuals for a correctly specified conditional variance. Moreover, we resort to the *Jarque-Bera* statistic for standardised residuals as a statistical diagnostic in order to test the null hypothesis of a normal distribution assumption of errors. As standard residual tests fail to address asymmetric mean reversion and heteroskedasticity of spread series, we need to consider possible biased effects of past errors. The sign bias test, the negative size bias test and the positive size bias test generate OLS estimates of squared standardised errors, whose statistical significance help indicate whether the model estimates are influenced by the size and the sign of past errors (ARCH terms) in a systematic way.

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[36] Under the assumption of independent and normally distributed residuals ε, we calculate the F-statistic $F = (\mathbf{R}\beta - r)' \times \left(s^2 \mathbf{R}(\mathbf{X}'\mathbf{X})^{-1}\mathbf{R}'\right)^{-1} \times (\mathbf{R}\beta - r) \times m^{-1}$, where $m = 1$ is equal to the value of W and s^2 poses as estimator of σ^2 (Hamilton, 1994).

[37] For instance, the validity of the joint hypotheses of $\beta_1 + \beta_2 = 1$ and $\beta_3 = \beta_4$ would require the following specification of the Wald test for $m = 2$ and $k = 4$: $H_0 : \begin{bmatrix} 1 & 1 & 0 & 0 \\ 0 & 0 & 1 & -1 \end{bmatrix} \otimes \begin{bmatrix} \beta_1 \\ \beta_2 \\ \beta_3 \\ \beta_4 \end{bmatrix} = \begin{bmatrix} 1 \\ 0 \end{bmatrix}$ (Hamilton, 1994).

7 ESTIMATION RESULTS

Tabs. 5-8 report the Berndt-Hall-Hall-Hausman (BHHH) estimation results for the multi-factor GARCH(1,1) and GARCH(2,1) models with asymmetric mean reversion (at level or first difference of LIBOR spot rates) on the basis of Johnson-Fit-adjusted and logarithmic spreads. Comprehensive estimation results for non-transformed and unadjusted spreads and for both conditional maximum likelihood estimation algorithms – *Marquardt* ("M") and *Berndt-Hall-Hall-Hausman* ("BHHH") – are found in Appendix, Tabs.26-33 for GARCH estimations with LIBOR at level and Appendix, Tabs. 43-49 for GARCH estimations with LIBOR at first differences. Both GARCH models produce heterogeneous ML estimation results rather different from the simple OLS regression model, which only captures symmetric mean reversion (see Tab. 2). Generally, the specified factors have relatively weak influence on the conditional spread differences (mean equation) and conditional variance of low-rated, long maturity CDOs spread series in GARCH(1,1) – for both level or first difference LIBOR spot rates – and on the spread change under the GARCH(2,1) specification for level LIBOR spot rates. We also find low levels of significance for the specified conditional variance equation for high-rated MBS in GARCH(1,1) with LIBOR at first difference and MBS in GARCH(2,1) with LIBOR at level, as well as Pfandbrief spread series in GARCH(2,1) with LIBOR at first difference. The spread series of all other asset classes confirm the high degrees of explanatory power to designated model factors in both the GARCH(1,1) and the GARCH(2,1) specification. Generally, the GARCH(2,1) model yields feature parameter significance more than the GARCH(1,1) specification, especially with regards to GARCH effects, whereas ARCH effects claim stronger explanatory power for conditional variance in the GARCH(1,1) setting – with the use of LIBOR rates at first differences (instead of level data of LIBOR rates) intensifying this observation. In the following discussion of the estimation results, we concentrate on those GARCH model specifications, where the first difference of the LIBOR spot rate is used as regressor in the mean and the conditional variance equations, as these model specifications generally perform better (at least for GARCH(2,1)) than model specifications with LIBOR at level. However, whenever the use of level data of LIBOR spot rates appreciably changes the economic and statistical significance of model parameters, for better or worse, we incorporate these findings in the discussion of the model estimates.

The intercept coefficient is significant for all spread series under the GARCH(2,1) specification, with the exception of all Pfandbrief tranches and MA7. Similar results are found for GARCH (1,1) if we substitute the first difference of LIBOR rates for level spot rates. Only CTAAA3, CTA5, CTBBB7, MA7 and PAAA5 are insignificant. For level LIBOR rates, however, the picture in the GARCH(1,1) model reverses, where the constant is only significant for CSAAA3, MAAA5, PAAA3 and PAAA7. The number of significant values of α_0 is limited to only two series (CSAAA3 and MAAA3) for GARCH(2,1) with the first difference of LIBOR rates as regressor. The influence of past spreads on future spread change at lag one $(\alpha_{1,1},\alpha_{1,2})$ in both GARCH models clearly supports the degree of mean reversion observed in the preceding OLS regression and the unit root test (see section 5.2) for the given coefficient values and the level of statistical significance. In some spread series (CSAAA3, CSBBB7 and CTAAA3 in GARCH(1,1) with LIBOR at first difference, CTAAA3 and MAAA5 in GARCH(2,1) with LIBOR at first difference and CTAAA3 and CTBBB7 in GARCH(2,1) with LIBOR at level) the coefficients for past spreads levels associated with subsequent negative and positive spread change sum up to negative values, indicating level stationarity. Moreover, asymmetric mean reversion is more pronounced for low-rated MBS transactions and all Pfandbrief time series, whose spread development and pricing pattern might be attributable to higher market liquidity and different asset-specific investor sentiment, compared to CDO deals. Considering – where appropriate and statistically significant – the null hypothesis of future spread change, irrespective of whether past spreads increased or declined, we find higher spread sensitivity to past spread levels associated with negative first differences (negative asymmetric mean reversion). All cases in GARCH(1,1) show this pattern of asymmetric mean reversion. The time series of all asset classes in both models (with the exception of the spread series of traditional CDO transactions and one synthetic CDO spread series for GARCH(2,1)) exhibit higher effects of negative spread change at lag one $(\alpha_{1,2})$; yet, the coefficients $\alpha_{1,1}$ and $\alpha_{1,2}$ in both GARCH models share similar significance across the given spreads series, so that first order stationarity follows both negative and positive past spread change. As we extend the influence of past spread levels contingent on the direction of spread change (i.e. second differences) to two lags $(\alpha_{2,1},\alpha_{2,2})$ in GARCH(2,1) the stochastic time series properties alter dramatically. For one, the coefficients $(\alpha_{2,1},\alpha_{2,2})$ are positive for all spread series (with the exception of CTAAA3 and CTBBB7 with LIBOR at first difference and CTBBB7 and MA7 with LIBOR at level), limiting stationarity to first differences of spread change. Furthermore, the asymmetric effect of past spread change reverses for second differences of past spread levels (at lag two), where the spread reaction after positive shocks is more pronounced. In the GARCH(2,1) model we detect exactly the opposite effect of two lag spread change compared to the first difference of spread change – the response to a positive direction of past spread change $(\alpha_{2,1})$ dominates negative changes $(\alpha_{2,2})$. This positive pricing bias (i.e. positive trend) might be attributable to the depressed economic outlook and cautious investor behaviour during the time the sample was taken.

Their statistical significance is the same for each type of spread series. However, two out of three traditional CDO series (and all three spread series for LIBOR at level) and two out of four MBS spread series (and three out of four spread series for LIBOR at level) in GARCH(2,1) do not generate significant $\alpha_{2,1}$ and $\alpha_{2,2}$ coefficients. Level effects in α_0 seem to be confined to synthetic CDOs and MBSs in the GARCH(1,1) model (and also traditional CDOs for GARCH(2,1) if level data for LIBOR spot rates are taken into account), and go hand in hand with first-order mean reversion, so that spread change remains almost unaffected by the LIBOR rate of the previous period (except for some MBS and Pfandbrief spread series in GARCH(1,1) and all CDO spread series in GARCH(2,1) for LIBOR at level spot rates), as documented by coefficients $\alpha_{2,1}$ and $\alpha_{2,2}$ in GARCH(1,1) and $\alpha_{3,1}$ and $\alpha_{3,2}$ in GARCH(2,1).

The coefficients α_3 in GARCH(1,1) and α_4 in GARCH(2,1), which measure the direct influence of the conditional variance on spread change, are significant for all Pfandbrief and some CDO spreads in GARCH(1,1), whilst all other model specifications, i.e. the variation on the properties of LIBOR rates as regressors or the extension of the forecasting power of the GARCH term in GARCH(2,1), do not produce similar parameter significance. Surprisingly, neither the short time series nor the relative illiquid nature of CDO and MBS transactions in our data set induce pseudo-causalities of spread dynamics – a situation that might reasonably explain why the z-statistics of MA7 in GARCH(1,1), all traditional CDO spread series in GARCH(2,1) and generally all CDO spread series with LIBOR rates at first differences are shy of reaching the 10% significance threshold by only a margin. No conclusive assessment can be made with regard to the coefficient values of α_3 and α_4, whose signs do not seem to be associated with either a certain rating quality, maturity or asset class of the tranches (spread series).

We do not obtain homogenous estimation results for the constant β_0 of the conditional variance equation in either GARCH model. While most spread series generate positive intercept values (except for synthetic CDOs and some MBS spread series, especially if level data is used for the LIBOR regressor), significant estimators are found for almost all CDO spreads and the two lowest rated MBS tranche spreads in both GARCH models, with Pfandbrief spreads faintly revealing some level effect.

The coefficients β_1 and β_2 measure the general sensitivity of the conditional variance to past residuals (ARCH effects) of estimated spread change. We reject the null hypothesis that the conditional variance of spread changes is not dependent on past errors β_1 (general ARCH term), as spreads increase only for Pfandbrief spreads and two out of four MBS spreads in the GARCH(1,1) model and CSAAA3 and CTBBB7 in the GARCH(2,1) model. Negative past errors β_2 (ARCH term) for spread decline (negative ARCH effect) are significant in further spread series, e.g. synthetic CDOs for GARCH(1,1) and traditional CDOs, if the LIBOR parameter is kept to level data as well as highly rated MBSs, for GARCH(2,1). Since $\beta_1 + \beta_2$ measures the dependence on positive past errors and β_2 measures the influence of negative past errors only, $\beta_2 \neq 0$ reflects potential asymmetries of how past errors generally affect conditional variance. We find $\beta_2 > 0$ in most spread series (with negative signs only for all Pfandbrief spreads and two out of four MBS spreads in GARCH(1,1) and CTA5, CTBBB7, MBBB7 and PAAA3 in GARCH(2,1), with all of them but one being insignificant), where significant β_2 are always positive (the only exception is PAAA7 in GARCH(1,1)). Since negative effects of past squared residuals dominate the general effect of residuals by absolute value for both GARCH models, the conditional variance σ_t^2 of spread change is more sensitive to negative past errors (i.e. spread declines) (Bali, 2000). The predominantly positive influence (i.e. positive coefficient value β_2) of negative innovations (i.e. spread declines) on the conditional variance in both GARCH specifications documents that volatility is asymmetric, i.e. negative past errors increase spread volatility more than positive innovations (i.e. spread increases) – similar to stock price volatility. Apparently, the asymmetry of spread dynamics for the given time period captured by the sample size is not only limited to the mean equation alone but extends to the conditional variance, too. In our specific case, nearly all spread series exhibit an increase of conditional variance after a spread decrease associated with negative past innovations. Since longer time series of Pfandbrief spreads (from 1998 to 2002) confirm these results to the extent that past errors (i.e. spread changes) have a positive and significant effect or no effect at all on the conditional variance, we can rule out that asymmetric spread volatility reflects a specific pattern of spread dynamics of merely transitory (and spurious) validity.

As we define positive contribution of past errors as $\beta_1 + \beta_2$, the degree of the asymmetric effect of past errors on spread volatility is captured by the metric $(\beta_1 + \beta_2)/\beta_1$ (*asymmetry factor* of conditional variance), which should ideally range between -1 and 1 for a balanced effect of past innovations on conditional volatility. An asymmetry factor of more than two in many spread series of our estimation indicates that negative past errors of spread estimates (negative innovations/spread decline) increase the spread volatility twice as much as positive past errors (spread increase). Across many ARCH terms in both GARCH models, the absolute value of the asymmetry factor is greater than one, with the exception of all (in GARCH(1,1) with LIBOR at first differences) or most (in GARCH(1,1) and GARCH(2,1) with level data of LIBOR) MBS spread series, two out three Pfandbrief spread series in GARCH(2,1) with LIBOR at first differences and CTBBB7 spreads in both GARCH models, which feature acceptable values of $(\beta_1 + \beta_2)/\beta_1$. Overall, asymmetric sensitivity to past innovations seems most pronounced for CDO spreads, but the incorporation of LIBOR at first differences and controlling for second moment GARCH effects in GARCH(2,1) diminishes the degree of asymmetry. It also decreases the longer the maturity and the lower the rating grade of the given spread series (in all but the CDO spread series). Nonetheless, the GARCH(1,1) specification seems to produce a more consistent degree of asymmetry for each asset class (CDO, MBS and Pfandbrief spreads) than the GARCH(2,1) model.

The coefficient β_3 measures the sensitivity of the conditional variance to the spread level of the previous period ("level effect"). We find no coherent results for a significant level effect. β_3 carries a negative sign for the majority of spread series in both GARCH models (especially traditional CDO and Pfandbrief spreads), irrespective of the configuration of the LIBOR regressor. Moreover, the parameter estimates have hardly any economic significance; yet, if they do, their value increases in rating quality and maturity of the asset class of the respective spread series. The level effect is most significant for CDO and Pfandbrief transactions in both GARCH models and MBS in GARCH(2,1). Incorporating LIBOR rates as level data lessens the statistical significance, while leaving the economic significance nearly unchanged. In all but synthetic CDO spreads, negative economic significance and statistical significance of at least 10% coincide.

The coefficient β_4 measures the level effect of the underlying reference spot rate (LIBOR rate) of the previous period on the conditional variance of spreads. Past LIBOR rates seem to play some role only for synthetic CDOs and, to some extent, MBS spreads in both GARCH models, whereas evidence of possible influence on traditional CDO structures and Pfandbrief transactions is inconclusive. As the first differences of LIBOR spot rates are replaced by level data, absolute parameter values generally decrease in either GARCH specification, with most parameter estimates for CDO transactions losing their negative sign. Generally, the statistical significance of the coefficient β_4 rises for the entire dataset. Finally, we estimate the coefficients β_5 for both GARCH specifications and β_6 for GARCH(2,1) in order to control the estimation of the conditional variance for the forecast variance (GARCH effect) at lag one (and lag two for GARCH(2,1)).

	Collateralised Debt Obligations (CDO)						Mortgage-Backed Securities (MBS)				Pfandbriefe		
	Synthetic			*Traditional*									
	CSAAA3[#]	CSA5	CSBBB7	CTAAA3[§,#]	CTA5	CTBBB7	MAAA3[#]	MAAA5	MA7[§,#]	MBBB7	PAAA3	PAAA5[#]	PAAA7[#]
α_0	0.5673**	0.8561	1.0612	0.2943	0.1866	0.4390	0.3424	1.13716***	-0.0068	1.5360**	0.3371*	0.1029	0.8264***
	(2.3169)	(0.6994)	(0.9432)	(1.0250)	(0.7681)	(0.6291)	(1.1870)	(4.2574)	-(0.0403)	(2.2702)	(1.9480)	(0.7087)	(3.5174)
$\alpha_{1,1}$	-0.0861**	-0.1161	-0.1325	-0.0511	-0.0280	-0.0769	-0.18967**	-0.4084***	-0.0047	-0.3043**	-0.1328**	-0.0562	-0.3019***
	-(2.1500)	-(0.8382)	-(1.0774)	-(0.7022)	-(0.7225)	-(0.6902)	-(2.0648)	-(4.1699)	-(0.1170)	-(2.3303)	-(2.1319)	-(1.5046)	-(3.5624)
$\alpha_{1,2}$	-0.1069**	-0.1266	-0.1404	-0.0758	-0.0391	-0.0892	-0.1916**	-0.4302***	-0.0104	-0.3270**	-0.1576**	-0.0936**	-0.3270***
	-(2.4369)	-(0.9098)	-(1.1281)	-(1.0653)	-(0.9835)	-(0.7861)	-(2.0874)	-(4.4030)	-(0.2618)	-(2.4617)	-(2.5466)	-(2.5064)	-(3.8437)
$\alpha_{2,1}$	-0.1686**	-0.1990	-0.2061	-0.0813**	-0.0369	-0.0196	0.1656	0.0951	0.0185	-0.0193	0.0439	0.0787	0.2143
	-(2.2852)	-(0.5777)	-(0.7286)	-(2.3773)	-(0.7351)	-(0.2799)	(1.4387)	(1.4032)	(0.3221)	-(0.2680)	(1.4013)	(0.9720)	(1.5737)
$\alpha_{2,2}$	-0.1554**	-0.1812	-0.1955	-0.0762**	-0.0362	-0.0178	0.1630	0.1006	0.0210	-0.0219	0.0483*	0.0849	0.2277*
	-(2.3193)	-(0.5291)	-(0.6962)	-(2.3188)	-(0.7214)	-(0.2563)	(1.4285)	(1.4829)	(0.3683)	-(0.3031)	(1.6853)	(1.0786)	(1.6733)
α_3	2.4101	-0.5681	-9.0706	11.7871	2.5065	7.9509	-8.5146	-0.1351	-0.0001	1.7645	0.1799	-0.0091	-43.8189**
	(1.3336)	-(0.0374)	-(1.1289)	(1.0322)	(1.0794)	(0.9429)	-(1.3835)	-(0.9746)	(0.0000)	(0.8142)	(0.0838)	-(0.0014)	-(1.8944)
β_0	0.0036	0.0402**	0.0212	0.0012	0.0243**	0.0129	-0.0104*	-0.1489**	-0.0006**	-0.0776**	0.0128*	-0.0001	0.0045***
	(0.0560)	(2.0382)	(0.6551)	(0.1793)	(2.4426)	(0.7765)	-(1.6789)	-(2.3609)	-(1.9298)	-(2.2549)	(7.2262)	-(0.0276)	(3.6997)
β_1	-0.0224	-0.0026	0.0744	-0.0246	0.1741	0.3558*	-0.0013	0.3987*	0.1401	0.2669	0.1103	-0.0367	0.0446
	-(0.6368)	-(0.1131)	(1.1934)	-(1.2860)	(0.9792)	(1.6544)	-(0.0077)	(1.8461)	(0.6356)	(1.2400)	(0.8971)	-(0.2232)	(1.0182)
β_2	0.1569	0.5707	0.0623	0.2851	-0.6778**	-0.1365	0.0494	1.4608*	0.0509	0.4774	2.2513***	-0.0728	0.14646*
	(0.6341)	(0.3310)	(0.1393)	(1.3934)	-(2.5173)	-(0.4364)	(0.2688)	(1.8608)	(0.0550)	(0.5279)	(2.7118)	-(0.5866)	(1.6698)
β_3	-0.0005	-0.0047**	-0.0026	-0.0008	-0.0036**	-0.0020	0.0005	0.0457**	-0.0001***	0.0145**	-0.0020*	0.0000	-0.0020***
	-(0.0424)	-(1.9611)	-(0.7561)	-(0.5056)	-(2.4146)	-(0.7841)	(1.3507)	(2.1344)	-(7.3532)	(2.2189)	-(1.9074)	(0.0526)	-(10.2139)
β_4	0.0001	-0.0110**	-0.0041	0.0013	-0.0046**	-0.0014	0.0006**	0.0061	0.0008***	0.0041***	-0.0038***	0.0001	0.0018**
	(0.0114)	-(2.0897)	-(0.4896)	(0.9064)	-(2.3085)	-(0.7085)	(1.8720)	(0.8620)	(2.8981)	(2.7368)	-(3.2261)	(0.0273)	(2.3578)
β_5	0.5772	0.5468**	0.5387***	0.5115*	0.5237**	0.4624	0.3978***	-0.0122	0.5962***	0.3891**	0.0428	1.0295***	0.6096***
	(0.8391)	(2.0165)	(2.8658)	(1.8500)	(2.2190)	(1.2741)	(2.9750)	-(0.7778)	(4.6666)	(1.8906)	(0.4804)	(3.0848)	(6.5966)
asymmetry effect $(\beta_1 + \beta_2)/\beta_1$													
	-6.0065	-220.1977	1.8377	-10.6029	-2.8923	0.6164	1.3634	4.6639	1.3634	2.7886	21.4040	2.9852	4.2837

Time series are transformed by the Johnson Fit over logarithmic ("AD_L") basis point spreads of ABS tranche indices, where M="Residential Mortgage-Backed Securities (RMBS)", P="Pfandbrief", CS="Synthetic Collateralised Debt Obligation (synthetic CDO)" and CT="Traditional/True Sale Collateralised Debt Obligation (traditional CDO)"; letters "AAA" to "BBB" reflect the Standard&Poor's investment grade rating system. The number associated with each time series reflects the maturity in years. Z-statistics in parentheses; ***=1% significance, **=5% significance, *=10% significance; [§] no Bollerslev-Woolridge robust standard errors and variance. All GARCH (1,1) parameters have been estimated according to the Berndt-Hall-Hall-Hausman algorithm, except in cases marked [#] (Marquardt quasi-maximum likelihood estimation procedure); [§] no Bollerslev-Woolridge robust standard errors and variance.

Tab. 5. *Estimation Results of GARCH(1,1) model (only transformed and Johnson Fit adjusted spreads) – LIBOR at level data.*

	Collateralised Debt Obligations (CDO)						Mortgage-Backed Securities (MBS)				Pfandbriefe		
	Synthetic			*Traditional*									
	CSAAA3	CSA5	CSBBB7	CTAAA3	CTA5	CTBBB7#	MAAA3&	MAAA5	MA7	MBBB7#	PAAA3	PAAA5&	PAAA7#
α_0	-0.3359***	0.1323***	-0.0297***	-0.1968	0.1112	0.0468	0.5348***	2.1303***	0.0515	-0.5993***	0.6466**	0.2456	0.1436*
	-(3.3259)	(205.4196)	-(2.9629)	-(0.6718)	(0.6731)	(0.3555)	(2.5633)	(6.3509)	(0.1996)	-(14.8031)	(2.0686)	(1.5503)	(1.7794)
$\alpha_{1,1}$	0.0891***	-0.0249***	0.0071***	0.0534	-0.0227	-0.0087	-0.1828**	-0.6812***	-0.0122	-0.6014***	-0.1954*	-0.0512	-0.0317
	(2.9162)	-(14207.8800)	(3.8994)	(0.6599)	-(0.6256)	-(0.3519)	-(2.4703)	-(6.2183)	-(0.1973)	-(14.8182)	-(1.8981)	-(1.0806)	-(1.3121)
$\alpha_{1,2}$	0.0598*	-0.0360***	-0.0031***	0.0288	-0.0335	-0.0219	-0.2256***	-0.7325***	-0.0178	-0.2156	-0.2328**	-0.0891*	-0.0632***
	(1.9246)	-(15.7886)	-(2.9980)	(0.3705)	-(0.9477)	-(0.8794)	-(2.6568)	-(6.8095)	-(0.2875)	-(1.2432)	-(2.2827)	-(1.9260)	-(2.6532)
$\alpha_{2,1}$	-1.6439	-1.1522	-0.2637	1.0116	-0.2453	0.0762	1.4318	2.0532	0.7260	-0.1725*	-2.8504*	-0.9247	-2.7918***
	-(1.3817)	-(1.6226)	-(0.7213)	(1.5034)	-(0.1584)	(0.2273)	(0.8512)	(1.2231)	(0.9759)	-(1.8021)	-(1.6531)	-(0.5431)	-(2.6031)
$\alpha_{2,2}$	-1.6393	-0.0550	-0.5683***	-0.3110	-0.0663	-0.2355	-0.6449	-3.4029***	-0.6688**	0.0000	0.2487	-1.6499	-0.6465***
	-(0.9808)	-(0.1485)	-(4.1118)	-(0.6428)	-(0.0546)	-(0.7941)	-(0.6854)	-(3.5324)	-(2.4369)	(0.0000)	(0.1668)	-(0.9689)	-(3.2229)
α_3	2.0765	14.945***	4.2287	17.844*	-6.6773	14.2827**	5.9111	-0.8505	-26.8013	2.9657***	-7.9308*	-9.4603*	6.8546*
	(0.4274)	(5.4122)	(0.6065)	(1.6697)	-(0.6684)	(2.3327)	(0.9384)	-(0.4761)	-(0.9588)	(14.7673)	-(1.8327)	-(1.9187)	(1.9447)
β_0	-0.0120	-0.0056***	-0.0021***	-0.0201	0.0021*	0.0005***	0.0043	-0.0432	0.0009***	0.7880***	0.0295***	0.0145***	0.0052
	-(1.3781)	-(216.9990)	-(21.7155)	-(0.3914)	(1.8218)	(32.6239)	(0.2351)	-(1.0739)	(28.4730)	(5.6708)	(4.8383)	(61.6143)	(1.1709)
β_1	0.0003	-0.0308	-0.0059	0.3203**	0.0167	0.2020	0.2535	0.3087**	0.1363	-0.5056***	0.1006*	0.0518**	0.4051***
	(0.0161)	-(0.5067)	-(0.6064)	(2.0288)	(0.8621)	(1.5809)	(0.8003)	(2.0863)	(0.8727)	-(3.4664)	(1.7348)	(2.1670)	(3.2857)
β_2	0.2444	0.6496***	0.4211**	0.3782***	0.0112	0.0908	-0.3176	0.4484	-0.2383	0.1516***	-0.1881	-0.2147	-0.3755***
	(1.2922)	(2.9599)	(2.2967)	(3.5246)	(0.0342)	(0.3364)	-(0.9157)	(1.1253)	-(0.7476)	(3.2581)	-(0.5438)	-(1.3852)	-(3.1800)
β_3	0.0047*	0.0012***	0.0004***	0.0000	-0.0004*	-0.0001***	-0.0006	0.0145	-0.0002***	0.0000	-0.0098***	-0.0042***	-0.0006
	(1.8499)	(145.1169)	(3.53E+101)	(0.0000)	-(1.7410)	-(5.6946)	-(0.0929)	(1.1208)	-(23.4736)	(0.0000)	-(5.0589)	-(123.9026)	-(0.5019)
β_4	-0.2075**	-0.0043	0.0004***	-0.0018	-0.0226	-0.0130	-0.0003	-0.0720	-0.0033***	-0.0009***	-0.0974**	-0.1010	0.0297***
	-(2.3513)	-(0.1624)	(2.6800)	-(1.3512)	-(1.3443)	-(0.9388)	-(0.0051)	-(0.8909)	-(4.0140)	-(26.6370)	-(2.1245)	-(1.2116)	(3.3916)
β_5	-0.1685	0.4014***	0.8667***	-0.0338***	0.8015***	0.4764***	0.4093	0.2605*	0.7180***	0.0005	0.6548***	0.6171***	-0.4841***
	-(0.7951)	(2.8251)	(9.8654)	-(3.0594)	(5.9026)	(3.6227)	(1.3163)	(1.7464)	(6.8271)	(0.7430)	(6.3602)	(5.7479)	-(3.1267)
asymmetry effect $(\beta_1 + \beta_2)/\beta_1$													
	837.8767	-20.0991	-70.3487	2.1808	2.0020	1.4493	-0.2528	-0.2538	-0.7487	0.7002	-0.8698	-3.1448	0.0731

Time series are transformed by the Johnson Fit over logarithmic ("AD_L") basis point spreads of ABS tranche indices, where M="Residential Mortgage-Backed Securities (RMBS)", P="Pfandbrief", CS="Synthetic Collateralised Debt Obligation (synthetic CDO)" and CT="Traditional/True Sale Collateralised Debt Obligation (traditional CDO)"; letters "AAA" to "BBB" reflect the Standard&Poor's investment grade rating system. The number associated with each time series reflects the maturity in years. Z-statistics in parentheses; ***=1% significance, **=5% significance, *=10% significance. All GARCH (1,1) parameters have been estimated according to the Berndt-Hall-Hall-Hausman algorithm, except in cases marked # (Marquardt quasi-maximum likelihood estimation procedure); & singular covariance coefficients are not unique.

Tab. 6. *Estimation Results of GARCH(1,1) model (only transformed and Johnson Fit adjusted spreads) – LIBOR at first differences.*

	Collateralised Debt Obligations (CDO)						Mortgage-Backed Securities (MBS)				Pfandbriefe		
	Synthetic			*Traditional*									
	CSAAA3	CSA5#	CSBBB7	CTAAA3	CTA5	CTBBB7	MAAA3	MAAA5	MA7#	MBBB7#	PAAA3	PAAA5#	PAAA7
α_0	0.4512*	0.9770**	1.1291**	-1.3025***	0.4565***	0.9452*	0.3194***	1.2504***	-0.0001	0.7650**	-0.1462	-0.0888	0.0688
	(1.7998)	(2.0314)	(2.0673)	-(2.5877)	(3.2101)	(1.7063)	(2.8108)	(2.8365)	(0.0000)	(2.0976)	-(0.4601)	-(0.8203)	(0.7261)
$\alpha_{1,1}$	-0.5265***	-0.1521***	-0.3345***	0.2034*	-0.1127	0.1230	-0.1772***	-0.6625***	-0.0052	-0.2182*	-0.4316***	-0.1856***	-0.2950***
	-(3.3951)	-(2.6568)	-(3.2618)	(1.7791)	-(1.0673)	(0.4810)	-(2.8007)	-(6.1594)	-(0.0389)	-(1.7698)	-(5.4273)	-(2.7298)	-(4.0992)
$\alpha_{1,2}$	-0.5232***	-0.1541***	-0.3362***	0.1891*	-0.1256	0.1139	-0.2051***	-0.6949***	-0.0018	-0.2313*	-0.4636***	-0.2155***	-0.3139***
	-(3.4540)	-(2.7158)	-(3.2779)	(1.6724)	-(1.2021)	(0.4452)	-(3.3320)	-(6.6998)	-(0.0108)	-(1.9069)	-(6.0432)	-(3.2446)	-(4.4373)
$\alpha_{2,1}$	0.4876***	0.0398**	0.2047***	0.1029	0.0494	-0.2595	0.0630	0.2645**	-0.0067	0.0429	0.4935***	0.2231***	0.2860***
	(2.8917)	(2.5641)	(3.7188)	(1.1419)	(0.5199)	-(1.1244)	(0.9134)	(2.2946)	-(0.0413)	(0.6068)	(5.6383)	(2.8094)	(3.8173)
$\alpha_{2,2}$	0.4675***	0.0364**	0.1979***	0.0957	0.0435	-0.2601	0.0400	0.2355**	-0.0039	0.0376	0.4677***	0.2084***	0.2669***
	(2.8508)	(2.4113)	(3.5631)	(1.0706)	(0.4661)	-(1.1316)	(0.6480)	(2.0586)	-(0.0253)	(0.5317)	(5.4355)	(2.7004)	(3.6558)
$\alpha_{3,1}$	-0.2089***	-0.2695**	-0.2557**	0.1374*	-0.0991***	-0.1412**	0.0223	0.0292	-0.0052	0.0710	0.0206	0.0112	-0.0023
	-(2.6787)	-(2.0732)	-(2.2377)	(1.8453)	-(3.1577)	-(2.2327)	(0.6670)	(0.3767)	-(0.0338)	(1.2623)	(0.5280)	(0.1851)	-(0.0449)
$\alpha_{3,2}$	-0.1718***	-0.2629**	-0.2506**	0.1479**	-0.0957***	-0.1340**	0.0390	0.0370	0.0211	0.0728	0.0219	0.0266	0.0090
	-(2.2718)	-(2.0562)	-(2.2008)	(1.9641)	-(3.1995)	-(2.2001)	(1.2150)	(0.4998)	(0.4219)	(1.3155)	(0.5753)	(0.4511)	(0.1774)
α_4	0.2385	-10.6189	-8.8101	32.3039***	-1.6554	-10.3923	-0.7260	-1.2715	0.0000	3.5558**	-2.3015	-0.1315	7.1095
	(0.1367)	-(1.5540)	-(1.5093)	(2.7027)	-(0.4600)	-(1.1939)	-(0.3230)	-(0.5421)	(0.0000)	(2.3450)	-(0.2789)	-(0.0680)	(0.9129)
β_0	0.0918**	0.0032	0.0067	0.0222***	0.0237***	0.0171	-0.0181	-0.0458	-0.0004	0.0026	0.0062	-0.0097	0.0070*
	(2.1182)	(0.5237)	(0.7215)	(140.1111)	(2.5758)	(1.2880)	-(0.6834)	-(1.3632)	-(0.7429)	(0.2307)	(1.1436)	-(0.7166)	(1.8599)
β_1	0.4130	-0.0319	0.0611	-0.0285	0.1772	0.2941*	0.1647**	0.0841	0.1268	0.2877***	-0.0030	0.0785	0.0441
	(1.2536)	-(1.4870)	(0.6275)	-(1.4088)	(1.3784)	(1.6461)	(2.4651)	(1.1114)	(0.6495)	(5.8947)	-(0.0499)	(1.2205)	(1.0463)
β_2	-0.4774	0.3497	0.1205	0.2067***	0.9762	-0.2284	-0.0970	0.4669*	0.0472	0.0589	0.4379	0.2777*	0.0408
	-(1.4226)	(0.7898)	(0.3837)	(2.5649)	(1.2649)	-(0.7793)	-(1.0344)	(1.8585)	(0.0452)	(0.5145)	(1.5409)	(1.8896)	(0.9146)
β_3	-0.0133**	-0.0003	-0.0007	-0.0051***	-0.0037**	-0.0026	0.0033	0.0135	-0.0001**	-0.0006	-0.0030	-0.0006	-0.0032***
	-(2.0757)	-(0.8885)	-(0.6463)	(-1468.42)	-(2.5371)	-(1.2705)	(0.4810)	(1.1257)	-(2.3959)	-(0.2911)	-(1.4466)	-(0.5880)	-(3.5052)
β_4	-0.0254**	-0.0010	-0.0017	-0.0028***	-0.0047**	-0.0020	0.0100	0.0040	0.0006	0.0006	0.0018**	0.0092	0.0037***
	-(2.1487)	-(0.4001)	-(0.8310)	-(28.4047)	-(2.5382)	-(1.3047)	(1.0364)	(0.8448)	1.1075	(0.4473)	(1.8611)	(1.1068)	(3.0172)
β_5	-0.0053	0.7662***	0.6896	0.5079**	0.11379***	0.5414	-0.9052***	0.8476***	0.5337	0.4136***	0.2033	0.6453***	0.8942***
	-(0.0209)	(3.7768)	(0.4944)	(2.0074)	(3.7852)	(0.8417)	-(4.8651)	(5.0418)	(0.5510)	(3.5039)	(0.8088)	(2.7110)	(11.1602)
β_6	0.1209	0.2048**	0.1188	0.0224	0.6477***	-0.0211	0.0736	-0.3504***	0.0423	-0.1178***	0.5787**	-0.4895***	-0.7964***
	(0.9002)	(2.0187)	(0.0953)	(0.1435)	(6.2909)	-(0.0464)	(0.3962)	-(2.7044)	(0.0691)	-(3.6302)	(2.5586)	-(2.6539)	-(10.2685)
asymmetry effect $(\beta_1+\beta_2)/\beta_1$													
	-0.1558	-9.9508	2.9744	-6.2412	6.5096	0.2233	0.4114	6.5542	1.3722	1.2049	-145.5082	4.5299	1.9249

Time series are transformed by the Johnson Fit over logarithmic ("AD_L") basis point spreads of ABS tranche indices, where M="Residential Mortgage-Backed Securities (RMBS)", P="Pfandbrief", CS="Synthetic Collateralised Debt Obligation (synthetic CDO)" and CT="Traditional/True Sale Collateralised Debt Obligation (traditional CDO)"; letters "AAA" to "BBB" reflect the Standard&Poor's investment grade rating system. The number associated with each time series reflects the maturity in years. Z-statistics in parentheses; ***=1% significance, **=5% significance, *=10% significance. All GARCH (2,1) parameters have been estimated according to the Berndt-Hall-Hall-Hausman algorithm, except in cases marked # (Marquardt quasi-maximum likelihood estimation procedure); § no Bollerslev-Woolridge robust standard errors and variance.

Tab. 7. *Estimation Results of GARCH(2,1) model (only transformed and Johnson Fit adjusted spreads) – LIBOR at level data.*

	Collateralised Debt Obligations (CDO)						Mortgage-Backed Securities (MBS)				Pfandbriefe		
	Synthetic			*Traditional*									
	CSAAA3	CSA5	CSBBB7	CTAAA3	CTA5	CTBBB7#	MAAA3&	MAAA5	MA7	MBBB7#	PAAA3	PAAA5&	PAAA7#
α_0	-0.3359***	0.1323***	-0.0297***	-0.1968	0.1112	0.0468	0.5348***	2.1303***	0.0515	-0.5993***	0.6466**	0.2456	0.1436*
	-(3.3259)	(205.4196)	-(2.9629)	-(0.6718)	(0.6731)	(0.3555)	(2.5633)	(6.3509)	(0.1996)	-(14.8031)	(2.0686)	(1.5503)	(1.7794)
$\alpha_{1,1}$	0.0891***	-0.0249***	0.0071***	0.0534	-0.0227	-0.0087	-0.1828**	-0.6812***	-0.0122	-0.6014***	-0.1954*	-0.0512	-0.0317
	(2.9162)	-(14207.8800)	(3.8994)	(0.6599)	-(0.6256)	-(0.3519)	-(2.4703)	-(6.2183)	-(0.1973)	-(14.8182)	-(1.8981)	-(1.0806)	-(1.3121)
$\alpha_{1,2}$	0.0598*	-0.0360***	-0.0031***	0.0288	-0.0335	-0.0219	-0.2256***	-0.7325***	-0.0178	-0.2156	-0.2328**	-0.0891*	-0.0632***
	(1.9246)	-(15.7886)	-(2.9980)	(0.3705)	-(0.9477)	-(0.8794)	-(2.6568)	-(6.8095)	-(0.2875)	-(1.2432)	-(2.2827)	-(1.9260)	-(2.6532)
$\alpha_{2,1}$	-1.6439	-1.1522	-0.2637	1.0116	-0.2453	0.0762	1.4318	2.0532	0.7260	-0.1725*	-2.8504*	-0.9247	-2.7918***
	-(1.3817)	-(1.6226)	-(0.7213)	(1.5034)	-(0.1584)	(0.2273)	(0.8512)	(1.2231)	(0.9759)	-(1.8021)	-(1.6531)	-(0.5431)	-(2.6031)
$\alpha_{2,2}$	-1.6393	-0.0550	-0.5683***	-0.3110	-0.0663	-0.2355	-0.6449	-3.4029***	-0.6688**	0.0000	0.2487	-1.6499	-0.6465***
	-(0.9808)	-(0.1485)	-(4.1118)	-(0.6428)	-(0.0546)	-(0.7941)	-(0.6854)	-(3.5324)	-(2.4369)	(0.0000)	(0.1668)	-(0.9689)	-(3.2229)
α_3	2.0765	14.945***	4.2287	17.844*	-6.6773	14.2827**	5.9111	-0.8505	-26.8013	2.9657***	-7.9308*	-9.4603*	6.8546*
	(0.4274)	(5.4122)	(0.6065)	(1.6697)	-(0.6684)	(2.3327)	(0.9384)	-(0.4761)	-(0.9588)	(14.7673)	-(1.8327)	-(1.9187)	(1.9447)
β_0	-0.0120	-0.0056***	-0.0021***	-0.0201	0.0021*	0.0005***	0.0043	-0.0432	0.0009***	0.7880***	0.0295***	0.0145***	0.0052
	-(1.3781)	-(216.9990)	-(21.7155)	-(0.3914)	(1.8218)	(32.6239)	(0.2351)	-(1.0739)	(28.4730)	(5.6708)	(4.8383)	(61.6143)	(1.1709)
β_1	0.0003	-0.0308	-0.0059	0.3203**	0.0167	0.2020	0.2535	0.3087**	0.1363	-0.5056***	0.1006*	0.0518**	0.4051***
	(0.0161)	-(0.5067)	-(0.6064)	(2.0288)	(0.8621)	(1.5809)	(0.8003)	(2.0863)	(0.8727)	-(3.4664)	(1.7348)	(2.1670)	(3.2857)
β_2	0.2444	0.6496***	0.4211**	0.3782***	0.0112	0.0908	-0.3176	0.4484	-0.2383	0.1516***	-0.1881	-0.2147	-0.3755***
	(1.2922)	(2.9599)	(2.2967)	(3.5246)	(0.0342)	(0.3364)	-(0.9157)	(1.1253)	-(0.7476)	(3.2581)	-(0.5438)	-(1.3852)	-(3.1800)
β_3	0.0047*	0.0012***	0.0004***	0.0000	-0.0004*	-0.0001***	-0.0006	0.0145	-0.0002***	0.0000	-0.0098***	-0.0042***	-0.0006
	(1.8499)	(145.1169)	(3.53E+101)	(0.0000)	-(1.7410)	-(5.6946)	-(0.0929)	(1.1208)	-(23.4736)	(0.0000)	-(5.0589)	-(123.9026)	-(0.5019)
β_4	-0.2075**	-0.0043	0.0004***	-0.0018	-0.0226	-0.0130	-0.0003	-0.0720	-0.0033***	-0.0009***	-0.0974**	-0.1010	0.0297***
	-(2.3513)	-(0.1624)	(2.6800)	-(1.3512)	-(1.3443)	-(0.9388)	-(0.0051)	-(0.8909)	-(4.0140)	-(26.6370)	-(2.1245)	-(1.2116)	(3.3916)
β_5	-0.1685	0.4014***	0.8667***	-0.0338***	0.8015***	0.4764***	0.4093	0.2605*	0.7180***	0.0005	0.6548***	0.6171***	-0.4841***
	-(0.7951)	(2.8251)	(9.8654)	-(3.0594)	(5.9026)	(3.6227)	(1.3163)	(1.7464)	(6.8271)	(0.7430)	(6.3602)	(5.7479)	-(3.1267)
asymmetry effect $(\beta_1 + \beta_2)/\beta_1$													
	837.8767	-20.0991	-70.3487	2.1808	2.0020	1.4493	-0.2528	-0.2538	-0.7487	0.7002	-0.8698	-3.1448	0.0731

Time series are transformed by the Johnson Fit over logarithmic ("AD_L") basis point spreads of ABS tranche indices, where M="Residential Mortgage-Backed Securities (RMBS)", P="Pfandbrief", CS="Synthetic Collateralised Debt Obligation (synthetic CDO)" and CT="Traditional/True Sale Collateralised Debt Obligation (traditional CDO)"; letters "AAA" to "BBB" reflect the Standard&Poor's investment grade rating system. The number associated with each time series reflects the maturity in years. Z-statistics in parentheses; ***=1% significance, **=5% significance, *=10% significance. All GARCH (1,1) parameters have been estimated according to the Berndt-Hall-Hall-Hausman algorithm, except in cases marked # (Marquardt quasi-maximum likelihood estimation procedure); & singular covariance coefficients are not unique.

Tab. 8. *Estimation Results of GARCH(2,1) model (only transformed and Johnson Fit adjusted spreads) – LIBOR at first differences.*

Past variance levels at lag one $\left(\sigma_{t-1}^2\right)$ are almost always positive (with the exception of the spread series for CSAAA3, CTAAA3 and PAAA7 in GARCH(1,1) and CSAAA3 and MAAA3 in GARCH(2,1)) and highly significant for almost all time series in both GARCH models, especially for CDO and Pfandbrief transactions. The economic significance of β_5 improves as we (i) extend the GARCH effect two lags in GARCH(2,1) and (ii) specify the influence of LIBOR based on first differences. The latter modification, however, improves the statistical significance of the parameter estimates in the context of GARCH(1,1) only. The coefficient values of β_6 document that most of the explanatory power of the GARCH term carries over even into the second lag variance forecast in GARCH(2,1). Our estimation fails to reject the null hypothesis at the 10% significance level that β_6 has no effect on the conditional variance for only two Pfandbrief and two MBS spread series (PAAA3, PAAA7, MA7 and MBBB7) as well as one CDO spread series (CSAAA3). In contrast to σ_{t-1}^2, evidence of how past forecast variance σ_{t-2}^2 at lag two influences the conditional variance in GARCH(2,1) is mixed.

Most Pfandbrief and CDO spreads exhibit negative GARCH effects for β_6, whereas positive GARCH effects dominate for MBS transactions. Hence, both β_5 and β_6 point to the fact that the direction and the significance of any GARCH effect might depend on the liquidity of the transaction type (with Pfandbrief transactions being the most liquid and CDO tranches the most illiquid) and, to some extent, data frequency – the degree of significance and coefficient values of β_5 and β_6 increase for an extended series of Pfandbrief spreads (results are not reported in this chapter; see also section 4). Generally, the ARCH and GARCH effects of the conditional variance seem to have greatest statistical significance for Pfandbrief and high-rated CDO transactions (low-rated CDO traditional transactions for LIBOR spot rates at level), while the mean equation with asymmetric effects of past spreads and LIBOR levels generates the closest estimation for the time series of synthetic CDOs, Pfandbriefe and some MBS spread series.

We further need to verify the statistical classification of spread dynamics (in the mean equation). We examine (i) the specification of level stationarity as well as (ii) the statistical validity of asymmetric mean reversion for the coefficients $\alpha_{1,1}, \alpha_{1,2}$ (ARCH terms) in GARCH(1,1) as well as $\alpha_{1,1}, \alpha_{1,2}$ and $\alpha_{2,1}, \alpha_{2,2}$ in the GARCH(2,1) model. To this end, we resort to the Wald coefficient test to first examine the null hypothesis $\mathrm{H}_0: \alpha_{1,1} + \alpha_{1,2} = 0$ ($\mathrm{H}_0: \alpha_{2,1} + \alpha_{2,2} = 0$ for GARCH(2,1) only) for overall mean reversion of the GARCH models. If $\alpha_{1,1} + \alpha_{1,2} = 0$ the trend has a unit root (random walk) and if $\alpha_{1,1}+\alpha_{1,2}>0$ the spread development would be explosive. So spread change is level stationary if we can reject H_0. We validate the assumption of $\alpha_{1,1}+\alpha_{1,2}<0$ on the basis of two separate sub-hypotheses $H_{0,1}:\alpha_{1,1}+\alpha_{1,2}=0$ and $H_{0,2}:\alpha_{1,1}+\alpha_{1,2}=\hat{\alpha}_{1,1}+\hat{\alpha}_{1,2}$ (for both GARCH models) as well as $H_{0,1}:\alpha_{2,1}+\alpha_{2,2}=0$ and $H_{0,2}:\alpha_{2,1}+\alpha_{2,2}=\hat{\alpha}_{2,1}+\hat{\alpha}_{2,2}$ (for GARCH(2,1) only). For coefficients $\alpha_{1,1},\alpha_{1,2}$ almost all spread series in GARCH(1,1) (see Tabs. 5-6) and most Pfandbrief and MBS spread series (but only two CDO spread series (CSAAA3 and CSBBB7)) in GARCH(2,1) (see Tabs. 7-8) generate Wald test statistics of at least 10% statistical significance. The rejection of the null hypothesis $H_{0,1}:\alpha_{1,1}+\alpha_{1,2}=0$ at high levels of significance means that the sum of the coefficients $\alpha_{1,1},\alpha_{1,2}$ equals the sum of their estimators $\left(H_{0,2}:\alpha_{1,1}+\alpha_{1,2}=\hat{\alpha}_{1,1}+\hat{\alpha}_{1,2}\right)$ at a 90% confidence level and differs (statistically significant) from zero. Moreover, the trend of each spread series can be determined based on the sign of $\hat{\alpha}_{1,1}+\hat{\alpha}_{1,2}$. Since the sum of estimators $\hat{\alpha}_{1,1}+\hat{\alpha}_{1,2}$ is negative for all spread series but CTAAA3, CSBBB7 and CSAAA3 in GARCH(1,1) and CTAAA3 and MAAA5 in GARCH(2,1) (Appendix, Tabs. 7-8), they clearly exhibit negative (and statistically viable) mean reversion coefficients at lag one.[38] The modification of the GARCH models by using LIBOR level data as a reference base compromises the well-specified parameter values of the mean reversion coefficients. Hence, the Wald test for mean reversion for both GARCH models at lag one confirms our results obtained from the unit root test and least squares regression (see Tab. 2 and Tab. 4)[39], which generate the most robust results for Pfandbrief and MBS spreads. The degree of statistically valid mean reversion weakens for the coefficients $\alpha_{2,1},\alpha_{2,2}$ at lag two of past spread levels as reported in the results of the Wald-testing procedure of $\alpha_{2,1},\alpha_{2,2}$ for the GARCH(2,1) model (see Tabs. 9-12). In comparison to the coefficient values $\alpha_{1,1},\alpha_{1,2}$, the significance of mean reversion at lag two proves to be robust in the unrestricted regression procedure of the Wald coefficient test only for one CDO, one Pfandbrief, and two MBS spread series (CSAAA3, PAAA3, MAAA5 and MA7)., where $H_{0,1}:\alpha_{2,1}+\alpha_{2,2}=0$ can still be rejected. Moreover, the sum of estimators $\hat{\alpha}_{2,1}+\hat{\alpha}_{2,2}$ is positive for most spread series (Appendix, Tabs. 9-12). Hence, the Wald coefficient tests for both GARCH models indicate that CDO spreads fail to unequivocally support the statistical significance of mean reversion coefficients obtained in the estimation procedure, i.e. mean reversion at lag one and non-stationarity at lag two (only in GARCH(2,1) by definition) for first and second spread differences. In contrast, MBS and Pfandbrief spread series show significant

[38] For the Wald test statistics of unadjusted spread series please refer to Appendix, Tabs. 34-42 and Tabs. 50-57.

[39] See also Appendix, Tabs. 23-25 for a detailed overview.

and valid level stationarity in $\alpha_{1,1}+\alpha_{1,2}<0$ and, to a lesser degree, for $\alpha_{2,1}+\alpha_{2,2}<0$ (with the first differences of LIBOR rates as regressor in GARCH(2,1) generating Wald test statistics indicating slightly better (worse) results for Pfandbrief (MBS) spreads).

We also assess the degree of asymmetry of spread dynamics in context of measuring the heteroskedasticity of spreads. We test the null hypothesis of no asymmetry for the spread differences at lag one $\left(\mathrm{H}_0:\alpha_{1,1}=\alpha_{1,2}\right)$ for both GARCH models and at lag two $\left(\mathrm{H}_0:\alpha_{2,1}=\alpha_{2,2}\right)$ for GARCH(2,1) only. The results of both tests are reported in Tabs. 9-12 (and more detailed in Appendix, Tabs. 34-42 for LIBOR at level data and Appendix, Tabs. 50-57 for LIBOR at first differences). The null hypothesis of no statistically valid asymmetry at lag one $\left(\mathrm{H}_0:\alpha_{1,1}=\alpha_{1,2}\right)$, i.e. future spreads are equally sensitive to positive $\left(\alpha_{1,1}\right)$ or negative $\left(\alpha_{1,2}\right)$ first differences of past spreads (spread declines/spread increases), can be rejected in the unrestricted Wald testing procedure at high confidence intervals for all asset classes in GARCH(1,1) and all but three asset classes (CSA5, CSBBB7 and MA7) in GARCH(2,1), which generate sufficiently low probability values of H_0 as coefficient restriction.[40] These results hold by and large regardless of the configuration of LIBOR in each GARCH model. The valid significance of asymmetric effects of previous spread change also persists for past spread levels at lag two in GARCH(2,1) – although at an admittedly lower degree of significance, especially for traditional CDO and MBS spread series, compared to the case of spread differences at lag one $\left(\mathrm{H}_0:\alpha_{1,1}=\alpha_{1,2}\right)$.

Our estimation results for the mean equation are in general agreement with the findings by Koutmos (2002) on U.S. MBS spreads. Future spreads show varying sensitivity to the direction of past spread change, be it for first or second differences; yet, spreads exhibit mean reversion in almost every case. However, in contrast to Koutmos (2002), we find that all spread time series (with the exception of CSAAA3, CSBBB7 and CTAAA3 in GARCH(1,1) and CTAAA3 and MAAA5 in GARCH(2,1)) generate negative $\alpha_{1,1}$ and $\alpha_{1,2}$ coefficients of past spread levels (one lag) of different explanatory power (with greater effects of negative past spread changes compared to positive changes). Consequently, overall mean reversion for both $\alpha_{1,1}$ and $\alpha_{1,2}$ is maintained in line with our estimation results of least squares regressions in Tab. 3 (see also Appendix, Tabs. 23-24). Interestingly, each time series exhibits the same direction of asymmetric spread response to first differences of past spreads in both GARCH models. This observation also holds true for two lags (with second differences as direction) in GARCH(2,1). However, whilst the absolute coefficient values for negative past spread change $(\alpha_{1,2})$ are consistently higher than for positive past spread change $(\alpha_{1,1})$ in both GARCH models (except for two CDO spread series), the asymmetric direction of spread change at two lags indicates significant positive bias if we compare the absolute values of $\alpha_{2,1}$ and $\alpha_{2,2}$ in GARCH(2,1). We also observe a complete sign reversal – the $\alpha_{2,1}$ and $\alpha_{2,2}$ coefficients carry positive signs in all cases (excluding the CTAAA3 and MBBB7 spread series), which defies the appellation of mean reversion. Considering the high speed of mean reversion at lag one (see Tab. 2), this result seems plausible. The estimation results of the Wald coefficient test for asymmetric mean reversion of Pfandbrief spreads are contradictory, given the strong evidence of mean reversion in the estimation of the GARCH model, while the ADF test (see Tab. 4 and Appendix, Tab. 25) indicates the existence of a unit root in level data, limiting co-integration to the order of one (I(1) process). If we abandon the first difference of LIBOR rates as model regressors in favour of LIBOR at level data, evidence of asymmetric spread dynamics is indistinct. The estimation results in both GARCH models also affirm the high significance of the previous period's variance forecast (GARCH term) for the conditional variance (β_5). The extended approach of GARCH(2,1) hints to an even stronger historical effect of past volatility, where two lag past variance (β_6) exerts a durable influence on future spread change. Judging by the estimation results for Pfandbriefe, market liquidity apparently facilitates this effect, although less liquid CDO transactions also feature strong GARCH effects of up to at least lag two.

By and large our estimation results of the conditional variance of selected European ABS spread series corroborate the findings in Koutmos (2002) about comparable U.S. structured finance products. Although we find that negative past errors (β_2) at lag one increase the volatility of spread series more than positive past errors (β_1), in contrast to Koutmos (2002) asymmetric squared residuals from the mean equation (ARCH terms) – as an indication of the goodness of fit of the mean equation – are mostly significant for negative past errors (β_2) only, such as in the GARCH(2,1) specification (with LIBOR rates at first differences) and the GARCH (1,1) model (with LIBOR rates at level). Only in the GARCH(1,1) model for Pfandbrief spreads do we actually observe a tendency towards significant positive ARCH effects at lag one. In the remaining GARCH models the statistical significance of past errors, contingent on the direction of past spread change, divides

[40] The *p*-value indicates the probability of the tested restriction to be significant for the estimation. In this case, the χ^2-distributed Wald-statistic would not deviate from zero at a commonly accepted level of significance.

equally into statistically positive and negative coefficient values of the ARCH terms $(\beta_1 \text{ and } \beta_2)$. The statistical irrelevance of past positive errors (as spreads increase) – particularly for CDO spreads in GARCH(1,1) and Pfandbrief spreads in GARCH(2,1) – is striking, and leads to reservations regarding preliminary statistical interpretation of these asset classes that have particularly low t-statistics of coefficient estimates (also with respect to the specification of the mean equation). The model specification in the following section will address this issue in detail. If we take into account all estimation results, only coefficient values β_1 and β_2 for synthetic CDOs in both GARCH models, highly-rated traditional CDOs in GARCH(1,1) as well as highly-rated MBS in GARCH(2,1) deliver clear support for asymmetric effects of past errors. Also, for Pfandbrief spread series in both GARCH specifications with LIBOR rates at level, the effect of negative past errors (in cases of spread decline) is more prevalent than any positive past errors. Moreover, despite their strong significance for CDO spreads in both GARCH models (with LIBOR at level), MBS spreads in GARCH(1,1) and traditional CDO spreads (in both GARCH models with LIBOR at first differences), the coefficient values of spread levels and LIBOR rates of the previous period play a modest economic role in explaining conditional variance as variance regressors. Only in the GARCH(1,1) model do our estimation results for MBS transactions tally with the findings by Koutmos (2002).

8 MODEL SPECIFICATION

The correct (model) specification of the mean and conditional variance of spread dynamics shows in the time series characteristics of standardised residuals, i.e. the volatility not explained by the model. Due to its vital importance for forecasting purposes and the management of spread risk, we apply residual-based model diagnostics to both GARCH specifications. Hence, by doing so, we aim (i) to detect any remaining non-linear structure/autocorrelation (Llung-Box (LB) Q-statistic) of estimated standardised errors $E(\varepsilon_t/\sigma_t)$ and squared standardised errors $E(\varepsilon_t/\sigma_t)^2$, and (ii) to test the normality (Jarque-Bera statistic) of standardised residuals (with first and second moments equal to zero and unity respectively).

We start with the examination of any non-linear effects in the standardised residuals. Both *LB(x)* and *LB²(x)* denote the Llung-Box Q-statistics for standardised errors and for squared standardised errors up to x lags, at which the Q-statistic no longer indicates statistically significant observations of autocorrelation in the given time series, leading to the rejection of the null hypothesis of no autocorrelation. High LB Q-statistics of low statistical significance with a small number of lags in

Tabs. 9-12 testify to an almost complete absence of higher order serial correlation in the time series of both standardised residuals of the mean equation (i.e. specification of mean equation) and squared standardised residuals of conditional variance (i.e. specification of conditional variance equation). In fact, all spread series – except MBBB7 (in all GARCH specifications) and MAAA3 (only in GARCH(2,1) for squared standardised errors with LIBOR rates at first differences), which retain statistically significant serial correlation – do not exhibit any autocorrelation beyond one lag. Since the LB Q-statistics for standardised residuals indicate no significant autocorrelation, the inclusion of one lag spread levels in the in the mean equation of the GARCH(1,1) model and spreads up to two lags as regressors in the mean equation of GARCH(2,1) model prove sufficient for the correct specification of the mean equation. No further inclusion of appropriate lagged endogenous variables in the equation, at the cost of losing degrees of freedom, is warranted. Also in the specification of conditional variance, we can rule out ARCH effects (significant Q-statistics) in squared standardised residuals for all asset types. With regard to the Jarque-Bera statistic, we find that the null hypothesis of normally distributed standardised residuals is rejected for the estimation results of all time series, with the exception of PAAA7 in all GARCH specifications (see Tabs. 9-12). This observation complies with the descriptive statistics of non-transformed spread time series (see Appendix, Tabs. 34-42 and Tabs. 50-57), where the majority of all cases do not uphold a normal distribution of spreads over time.

Although the Llung-Box (LB) and Jarque-Bera (JB) statistics are commonly accepted and well established model diagnostics to examine the degree of autocorrelation and normality of standardised residuals,[41] they fail to test how well the proposed GARCH models capture the asymmetric effects on spread volatility, i.e. the contribution of positive and negative past estimation errors/innovations to changes in conditional variance (Koutmos, 2002). Since the GARCH processes explain the heteroskedasticity of observed spread behaviour, the correct specification of the conditional variance equation and any patterns of asymmetric change is imperative. In the spirit of the diagnostics developed by Engle and Ng (1993) to test asymmetric effects in the news impact curve implied by the model estimates of conditional variance, we examine the correct specification of asymmetric spread heteroskedasticity, i.e. the volatility process of spread dynamics, by means of three different testing procedures: (i) the (negative) sign bias test, (ii) the negative size bias test and (iii) the positive sign bias test. All three tests assume that the conditional variance is correctly specified only if the squared standardised residuals escape any predictability through observed variables, i.e. positive and

[41] The Llung-Box Q-statistic of standardised residuals is deemed sufficient for the correct specification of the mean equation at this point, as it merely confirms the estimation results obtained from the OLS regression and the Wald coefficient statistics. However, the correct specification of conditional variance requires a further refinement of autocorrelation tests.

negative past errors (null hypothesis). Hence, if the t-statistics of these tests are statistically insignificant, the estimated volatilities from the GARCH models fully incorporate past information (at one lag). Conversely, any residual values generated by the conditional variance equation would not follow a stochastic pattern. Like in the estimation of the GARCH models, the three bias tests are based on heteroskedasticity consistent covariance according to White (1980). The negative sign bias test $(\varepsilon_t/\sigma_t)^2 = \mu + \gamma K + e_t$ measures any statistically significant influence of negative past errors ε_{t-1} (at one lag) on squared standardised residuals $(\varepsilon_t/\sigma_t)^2$, which is the volatility that is not predicted by conditional variance of the model estimation. Since we define the dummy variable $K = 1$ for $\varepsilon_{t-1} < 0$ else $K = 0$ to capture asymmetric influences of past errors, a significant t-statistic of the regression coefficient of K signifies that the impact of positive and negative past errors on spread volatility is not fully specified in the asymmetric ARCH terms of the conditional variance equation, i.e. unexplained spread volatility would still contain some positive/negative effect by past errors. The negative size bias test extends this sensitivity analysis to negative past errors to include the size of past estimation errors. This means that we regress the squared standardised residuals on past residuals conditioned by the dummy variable K. Significant t-values for the regression coefficient γ mean that the specification of the conditional variance does not account for the asymmetric effect of small or large negative errors. The same logic applies analogously to the positive size bias test $(\varepsilon_t/\sigma_t)^2 = \mu + \gamma(1-K)\varepsilon_{t-1} + e_t$. In all three residual tests we find strong evidence that the number of explanatory variables generating the GARCH model estimates for spread heteroskedasticity correctly specify asymmetric influence on conditional variance. We cannot reject the null hypothesis that past errors do not influence the spread volatility (squared standardised residuals) not predicted by the GARCH models. Nonetheless, one or more residual tests of CTBBB7 and MAAA5 in both GARCH models, CTAAA3 and MBBB7 in GARCH(1,1) as well as PAAA3, MAAA3 and MA7 in GARCH(2,1) indicate that some explanatory power of past errors is not captured by the conditional variance equation and, hence, contributes to the coefficient values of standardised squared residuals. All of the aforementioned spread series (except MAAA3 spreads) confirm statistically significant negative size bias of past errors on squared standardised residuals. Most of them also show significant sign bias and/or positive size bias. While standardised residuals of CTBBB7 and MAAA5 spreads in GARCH(1,1) flag significant sign bias and positive size bias of past innovations, the specification of conditional variance seems to be particularly insufficient for the spread volatility of MBBB7 spreads in GARCH(1,1) and CTBBB7, PAAA3 and MA7 in GARCH(2,1), where all residual bias tests of estimation errors reveal significant t-statistics.

	Collateralised Debt Obligations (CDO)					
	synthetic			*traditional*		
	CSAAA3#	CSA5	CSBBB7	CTAAA3$,#	CTA5	CTBBB7
Wald-test H_0: $\alpha_{1,1}=\alpha_{1,2}$ (t-stat.)	4.4406**	12.7732***	13.3682***	83.3839***	15.2958***	15.7247***
Wald-test H_0: $\alpha_{1,1}+\alpha_{1,2}=0$ (t-stat.)	5.3525**	0.7641	1.2165	0.7777	0.7311	0.5455
LB-Q Statistic (lags)	0.0055 (1)	0.0226 (1)	NA	2.009 (1)	0.0994 (1)	NA
LB^2-Q Statistic (lags)	0.0411 (1)	0.0202 (1)	NA	0.2317 (1)	0.0209 (1)	NA
Jarque-Bera	2759.87***	2346.54***	NA	660.55***	5902.84***	NA
Sign Bias Test	0.4877	0.9000	1.3179	-0.7553	0.3191	0.5642
H_0: $(\varepsilon_t/\sigma_t)^2=\mu+\gamma K+e_t$ (t-stat.)	(0.5726)	(1.3202)	(1.0990)	-(0.7636)	(0.5286)	(0.9857)
Negative Size Bias Test	-0.8180	-0.4823	-0.6458	1.1579	-0.0844	-0.3431
H_0: $(\varepsilon_t/\sigma_t)^2=\mu+\gamma K\varepsilon_{t-1}+e_t$ (t-stat.)	-(0.5443)	-(0.4299)	-(1.1442)	(2.5419)	-(0.2548)	-(0.7493)
Positive Size Bias Test	-0.1375	-0.1162	-0.1833	0.1769	-0.0966	-0.2733
H_0: $(\varepsilon_t/\sigma_t)^2=\mu+\gamma(1-K)\varepsilon_{t-1}+e_t$ (t-stat.)	-(0.7542)	-(0.5758)	-(0.6505)	(0.5453)	-(0.5688)	-(1.5163)

	Pfandbriefe			*Mortgage-Backed Securities (MBS)*			
	PAAA3	PAAA5#	PAAA7#	MAAA3#	MAAA5	MA7$,#	MBBB7
Wald-test H_0: $\alpha_{1,1}=\alpha_{1,2}$ (t-stat.)	109.4263***	164.5061***	101.6267	1.4256	11.6254***	22.3917***	8.4351***
Wald-test H_0: $\alpha_{1,1}+\alpha_{1,2}=0$ (t-stat.)	5.4711**	4.0279**	13.7176	4.3106***	18.3921***	0.0356	5.7481**
LB-Q Statistic (lags)	8.8087 (1)	0.3085 (1)	NA	0.0378 (1)	0.1214 (1)	0.0036 (1)	1.4258 (1)
LB^2-Q Statistic (lags)	0.7654 (1)	0.0016 (1)	NA	0.4199 (1)	0.0753 (1)	0.0163 (1)	7.2609 (3)
Jarque-Bera	145.98***	3635.51***	NA	329.03***	93.28***	18763.83***	78.90***
Sign Bias Test	-0.2359	-0.1875	0.3252	-0.7118	-0.3354	0.7185	-0.7211**
H_0: $(\varepsilon_t/\sigma_t)^2=\mu+\gamma K+e_t$ (t-stat.)	-(0.5517)	-(0.4716)	(0.9111)	-(0.4282)	-(0.4370)	(0.9667)	-(2.0195)
Negative Size Bias Test	0.0401	-0.1123	-0.0787	-0.1684	0.1982	-2.7148	-0.7957**
H_0: $(\varepsilon_t/\sigma_t)^2=\mu+\gamma K\varepsilon_{t-1}+e_t$ (t-stat.)	(0.0734)	-(0.2738)	-(0.2175)	-(0.0855)	(0.6784)	-(0.8831)	-(2.2343)
Positive Size Bias Test	0.0266	0.3220	0.1145	0.6560	0.2845	-0.1416	0.4474
H_0: $(\varepsilon_t/\sigma_t)^2=\mu+\gamma(1-K)\varepsilon_{t-1}+e_t$ (t-stat.)	(0.1353)	(1.7332)	(0.4593)	(1.0222)	(0.8404)	-(1.0055)	(1.5544)

All GARCH (1,1) parameters have been estimated from the time series - transformed by the Johnson Fit and the natural logarithm ("AD_L") - according to the Berndt-Hall-Hall-Hausman algorithm, except in cases marked # (Marquardt quasi-maximum likelihood estimation procedure); $ no Bollerslev-Woolridge robust standard errors and variance; ***=1% significance, **=5% significance, *=10% significance. *NA* indicates that no results could be generated by the statistics software due to data overflow. The estimated values (ε_t/σ_t) and $(\varepsilon_t/\sigma_t)^2$ are the mean and the conditional variance of standardised residuals obtained from the GARCH (1,1) model. *LB(x)* denotes the Llung-Box Q-statistic (autocorrelation) for standardised errors up to x lags and $LB^2(x)$ denotes the Llung-Box Q-statistic for squared standardised errors up to x lags at which the Q-statistic does no longer indicate statistically significant observations of autocorrelation in the given time series different from the null hypothesis of no autocorrelation. The computation of the three bias tests was completed at heteroskedasticity consistent covariance according to White (1980). Number of observations: 93. In the sign bias and size bias tests we included 91 observations (instead of 93) after adjusting for endpoints.

Tab. 9. *Coefficient and residual tests of GARCH(1,1) model (only transformed and Johnson Fit adjusted spreads) – LIBOR at level data.*

	Collateralised Debt Obligations (CDO)					
	synthetic			*traditional*		
	CSAAA3	CSA5	CSBBB7	CTAAA3	CTA5	CTBBB7#
Wald-test H_0: $\alpha_{1,1}=\alpha_{1,2}$ (t-stat.)	7.5655***	23.8282***	49.3522***	38.1184***	24.9706***	2.9836***
Wald-test H_0: $\alpha_{1,1}+\alpha_{1,2}=0$ (t-stat.)	6.0161**	712.6768***	2.3971	19.2352***	0.1244	0.3817
LB-Q Statistic (lags)	0.0494 (1)	0.3783 (1)	0.1617 (1)	0.1069 (1)	7.1395 (3)	0.3129 (1)
LB^2-Q Statistic (lags)	0.0909 (1)	0.0692 (1)	0.0352 (1)	0.0128 (1)	0.1359 (1)	0.0014 (1)
Jarque-Bera	2206.44***	3449.73***	6709.17***	234.93***	5771.945***	149.09***
Sign Bias Test	-0.6351	1.3575	1.257	-0.3306**	-0.611	0.314
H_0: $(\varepsilon_t/\sigma_t)^2=\mu+\gamma K+e_t$ (t-stat.)	-(0.5143)	(1.5682)	(1.0607)	-(2.1300)	-(1.0143)	(1.4513)
Negative Size Bias Test	0.2629	-4.5647	-1.777	4.4133**	-0.033	-0.4986**
H_0: $(\varepsilon_t/\sigma_t)^2=\mu+\gamma K\varepsilon_{t-1}+e_t$ (t-stat.)	(0.1543)	-(1.2439)	-(1.0671)	(2.1300)	-(0.1324)	-(2.1544)
Positive Size Bias Test	-0.2542	-0.2637	-0.314	0.209	0.031	-0.2067*
H_0: $(\varepsilon_t/\sigma_t)^2=\mu+\gamma(1-K)\varepsilon_{t-1}+e_t$ (t-stat.)	-(0.3707)	-(0.4137)	-(1.0077)	(1.0298)	(0.2195)	-(1.6609)

	Pfandbriefe			*Mortgage-Backed Securities (MBS)*			
	PAAA3	PAAA5[&]	PAAA7[#]	MAAA3[#]	MAAA5	MA7	MBBB7[#]
Wald-test H_0: $\alpha_{1,1}=\alpha_{1,2}$ (t-stat.)	79.7204***	180.2684***	72.2650***	114.4901***	16.0829***	19.4155***	20.5709***
Wald-test H_0: $\alpha_{1,1}+\alpha_{1,2}=0$ (t-stat.)	4.3676**	1.0605	3.1330*	4.5068**	42.5402***	0.0587	219.3632***
LB-Q Statistic (lags)	0.0100 (1)	0.6945 (1)	0.2286 (1)	0.0029 (1)	0.0015 (1)	0.9923 (1)	31.0600 (20)
LB^2-Q Statistic (lags)	0.0341 (1)	0.0007 (1)	0.2203 (1)	0.0105 (1)	145.5700 (1)	0.0311 (1)	24.2910 (15)
Jarque-Bera	139.52***	1263.37***	1.8746	365.36***	10.9757***	5119.85***	121.25***
Sign Bias Test	0.754	-0.236	0.118	-0.352	-0.339	0.883	-3.1102*
H_0: $(\varepsilon_t/\sigma_t)^2=\mu+\gamma K+e_t$ (t-stat.)	(1.2033)	-(0.8684)	(0.5305)	-(0.7644)	-(0.8901)	(0.6674)	-(1.7690)
Negative Size Bias Test	-1.006	0.336	-0.430	0.138	-1.6038***	-1.432	-0.6751*
H_0: $(\varepsilon_t/\sigma_t)^2=\mu+\gamma K\varepsilon_{t-1}+e_t$ (t-stat.)	-(1.0768)	(0.5956)	-(1.0065)	(0.8021)	-(2.8301)	-(0.9214)	-(1.7838)
Positive Size Bias Test	-0.292	0.108	0.001	0.029	0.7295***	0.064	2.1154*
H_0: $(\varepsilon_t/\sigma_t)^2=\mu+\gamma(1-K)\varepsilon_{t-1}+e_t$ (t-stat.)	-(1.0799)	(0.8157)	(0.0092)	(0.1797)	(3.4061)	(0.2479)	(1.8194)

All GARCH (1,1) parameters have been estimated from the time series - transformed by the Johnson Fit and the natural logarithm ("AD_L") - according to the Berndt-Hall-Hall-Hausman algorithm, except in cases marked [#] (Marquardt quasi-maximum likelihood estimation procedure); [&] singular covariance coefficients are not unique. ***=1% significance, **=5% significance, *=10% significance. *NA* indicates that no results could be generated by the statistics software due to data overflow. The estimated values (ε_t/σ_t) and $(\varepsilon_t/\sigma_t)^2$ are the mean and the conditional variance of standardised residuals obtained from the GARCH (1,1) model. *LB(x)* denotes the Llung-Box Q-statistic (autocorrelation) for standardised errors up to x lags and $LB^2(x)$ denotes the Llung-Box Q-statistic for squared standardised errors up to x lags at which the Q-statistic does no longer indicate statistically significant observations of autocorrelation in the given time series different from the null hypothesis of no autocorrelation. The computation of the three bias tests was completed at heteroskedasticity consistent covariance according to White (1980). Number of observations: 93. In the sign bias and size bias tests we included 91 observations (instead of 93) after adjusting for endpoints.

Tab. 10. *Coefficient and residual tests of GARCH(1,1) model (only transformed and Johnson Fit adjusted spreads) – LIBOR at first differences.*

	Collateralised Debt Obligations (CDO)					
	synthetic			*traditional*		
	CSAAA3	CSA5#	CSBBB7	CTAAA3	CTA5	CTBBB7
Wald-test H_0: $\alpha_{1,1}=\alpha_{1,2}$ (t-stat.)	0.1271	6.8480**	0.0491	5.4014**	39.6823***	7.1080***
Wald-test H_0: $\alpha_{1,1}+\alpha_{1,2}=0$ (t-stat.)	11.7339***	7.2158***	2.6887	2.981473*	1.2868	0.2144
Wald-test H_0: $\alpha_{2,1}=\alpha_{2,2}$ (t-stat.)	4.2960**	3.6399*	0.9576	2.2902	7.8005***	0.0748
Wald-test H_0: $\alpha_{2,1}+\alpha_{2,2}=0$ (t-stat.)	8.2510***	6.2133**	0.6819	1.2250	0.2433	1.2723
LB-Q Statistic (lags)	0.5394 (1)	1.4055 (1)	NA	NA	100.8400 (6)	NA
LB^2-Q Statistic (lags)	0.0067 (1)	1.3667 (1)	NA	NA	11.9350 (2)	NA
Jarque-Bera	1712.16***	1339.42***	NA	NA	808.52***	NA
Sign Bias Test	0.0194	0.5735	1.4148	-0.4545	-0.2699	0.4362
H_0: $(\varepsilon_t/\sigma_t)^2=\mu+\gamma K+e_t$ (t-stat.)	(0.0259)	(0.5362)	(1.3862)	-(0.8517)	-(0.3664)	(0.7818)
Negative Size Bias Test	-0.0647	-0.8217	-2.4588	-0.0181	0.0869	-0.6148
H_0: $(\varepsilon_t/\sigma_t)^2=\mu+\gamma K\varepsilon_{t-1}+e_t$ (t-stat.)	-(0.1715)	-(0.7401)	-(1.5519)	-(0.0747)	(0.2050)	-(1.3185)
Positive Size Bias Test	0.1299	-0.0501	-0.1188	-0.0801	0.0376	-0.1937
H_0: $(\varepsilon_t/\sigma_t)^2=\mu+\gamma(1-K)\varepsilon_{t-1}+e_t$ (t-stat.)	(0.3714)	-(0.2870)	-(0.4077)	-(0.6775)	(0.1489)	-(0.8053)

	Pfandbriefe			*Mortgage-Backed Securities (MBS)*			
	PAAA3	PAAA5#	PAAA7	MAAA3	MAAA5	MA7#	MBBB7#
Wald-test H_0: $\alpha_{1,1}=\alpha_{1,2}$ (t-stat.)	72.0880***	60.2948***	82.7466***	10.8572***	5.1387**	14.7772***	11.7910***
Wald-test H_0: $\alpha_{1,1}+\alpha_{1,2}=0$ (t-stat.)	32.8384***	8.9119***	18.2086***	6.0724**	41.4529***	0.0007	3.3781*
Wald-test H_0: $\alpha_{2,1}=\alpha_{2,2}$ (t-stat.)	65.6099***	18.6160***	52.9039***	0.0965	22.7569***	0.4792	4.8648**
Wald-test H_0: $\alpha_{2,1}+\alpha_{2,2}=0$ (t-stat.)	30.6751***	7.5959***	13.9719***	0.0000	4.7428**	0.0009	0.3241
LB-Q Statistic (lags)	0.4320 (1)	0.8496 (1)	0.3850 (1)	12.7390 (1)	2.0220(1)	0.0004 (1)	0.4099(1)
LB^2-Q Statistic (lags)	0.0292 (1)	1.1775 (1)	1.2235 (1)	13.0250 (1)	0.1321(1)	0.0139 (1)	11.2830(6)
Jarque-Bera	603.62***	1557.34***	4.25	72.17***	20.32***	21186.81***	92.30***
Sign Bias Test	0.5495	0.0120	-0.0768	0.0809	0.0080	1.1401	0.0875
H_0: $(\varepsilon_t/\sigma_t)^2=\mu+\gamma K+e_t$ (t-stat.)	(1.0683)	(0.7392)	-(0.6710)	(0.2427)	(0.0197)	(0.9996)	(0.1188)
Negative Size Bias Test	0.1477	-3.6352***	-0.1000	0.0369	-0.3294	-2.7874	-0.9478
H_0: $(\varepsilon_t/\sigma_t)^2=\mu+\gamma K\varepsilon_{t-1}+e_t$ (t-stat.)	(0.4088)	-(11.5813)	-(0.5797)	(0.1673)	-(0.7366)	-(0.8883)	-(1.3440)
Positive Size Bias Test	-0.2574	-0.1133	0.0922	0.0927	0.2827	-0.1565	1.1591
H_0: $(\varepsilon_t/\sigma_t)^2=\mu+\gamma(1-K)\varepsilon_{t-1}+e_t$ (t-stat.)	-(1.1594)	-(0.6068)	(0.2397)	(0.4533)	(0.9361)	-(1.0206)	(1.4578)

All GARCH (2,1) parameters have been estimated from the time series - transformed by the Johnson Fit and the natural logarithm ("AD_L") - according to the Berndt-Hall-Hall-Hausman algorithm, except in cases marked # (Marquardt quasi-maximum likelihood estimation procedure); ***=1% significance, **=5% significance, *=10% significance. *NA* indicates that no results could be generated by the statistics software due to data overflow. The estimated values (ε_t/σ_t) and $(\varepsilon_t/\sigma_t)^2$ are the mean and the conditional variance of standardised residuals obtained from the GARCH (2,1) model. *LB(x)* denotes the Ljung-Box Q-statistic (autocorrelation) for standardised errors up to *x* lags and $LB^2(x)$ denotes the Ljung-Box Q-statistic for squared standardised errors up to *x* lags at which the Q-statistic does no longer indicate statistically significant observations of autocorrelation in the given time series different from the null hypothesis of no autocorrelation. The computation of the three bias tests was completed at heteroskedasticity consistent covariance according to White (1980). Number of observations: 93. In the sign bias and size bias tests we included 91 observations (instead of 93) after adjusting for endpoints.

Tab. 11. *Coefficient and residual tests of GARCH(2,1) model for all spread series (only transformed and Johnson Fit adjusted spreads) – LIBOR at level data.*

	Collateralised Debt Obligations (CDO)					
	synthetic			*traditional*		
	CSAAA3	CSA5[#]	CSBBB7	CTAAA3[#]	CTA5	CTBBB7
Wald-test H_0: $\alpha_{1,1}=\alpha_{1,2}$ (t-stat.)	2.7887*	0.0081	0.0338	11.9642***	24.9096***	16.2930***
Wald-test H_0: $\alpha_{1,1}+\alpha_{1,2}=0$ (t-stat.)	3.4511*	0.0708	17.2446***	0.0500	0.2732	0.4454
Wald-test H_0: $\alpha_{2,1}=\alpha_{2,2}$ (t-stat.)	10.0836***	0.0031	0.8336	0.2597	0.0658	1.7833
Wald-test H_0: $\alpha_{2,1}+\alpha_{2,2}=0$ (t-stat.)	4.4756*	0.0125	0.0620	0.2925	0.2196	0.4849
LB-Q Statistic (lags)	0.8522 (1)	0.0011 (1)	5.6452 (2)	0.2555 (1)	0.0728 (1)	24.6870 (15)
LB^2-Q Statistic (lags)	0.0411 (1)	0.0365 (1)	0.4504 (1)	0.0021 (1)	0.0870 (1)	5.1869 (2)
Jarque-Bera	444.50***	4101.14***	7155.60***	696.64***	8004.54***	156.61***
Sign Bias Test	0.059	-0.354	1.289	0.115	-0.147	-0.5264***
H_0: $(\varepsilon_t/\sigma_t)^2=\mu+\gamma K+e_t$ (t-stat.)	(0.0715)	-(0.2857)	(1.0082)	(0.3073)	-(0.5864)	-(5.7286)
Negative Size Bias Test	0.053	-2.622	-1.484	-0.510	-0.058	0.3447***
H_0: $(\varepsilon_t/\sigma_t)^2=\mu+\gamma K\varepsilon_{t-1}+e_t$ (t-stat.)	(0.1319)	-(0.6303)	-(0.9179)	-(1.1867)	-(0.2865)	(5.7286)
Positive Size Bias Test	-0.142	-0.223	0.325	-0.062	-0.039	0.3974**
H_0: $(\varepsilon_t/\sigma_t)^2=\mu+\gamma(1-K)\varepsilon_{t-1}+e_t$ (t-stat.)	-(0.7323)	-(1.2217)	(0.9464)	-(0.5693)	-(0.4909)	(2.0832)

	Pfandbriefe			*Mortgage-Backed Securities (MBS)*			
	PAAA3[&]	PAAA5[&]	PAAA7	MAAA3	MAAA5	MA7	MBBB7[&]
Wald-test H_0: $\alpha_{1,1}=\alpha_{1,2}$ (t-stat.)	40.9130***	95.7934***	52.2577***	13.0022***	6.2115**	2.6785	3.3301*
Wald-test H_0: $\alpha_{1,1}+\alpha_{1,2}=0$ (t-stat.)	10.9676***	0.5399	11.7751***	2.4650	65.6843***	115.8702***	0.0757
Wald-test H_0: $\alpha_{2,1}=\alpha_{2,2}$ (t-stat.)	44.1682***	14.0902***	35.8244***	1.0149	18.9879***	0.0047	0.188452
Wald-test H_0: $\alpha_{2,1}+\alpha_{2,2}=0$ (t-stat.)	34.0455***	0.652934	12.3520***	0.7886	6.3620**	124.1782***	0.1426
LB-Q Statistic (lags)	11.4420 (1)	0.2058 (1)	0.1635 (1)	0.6578 (1)	0.2708 (1)	1.6291 (1)	7.1643 (3)
LB^2-Q Statistic (lags)	25.6920 (1)	0.0301 (1)	0.1961 (1)	0.1050 (1)	98.7080 (8)	0.2007 (1)	1.1795 (1)
Jarque-Bera	667.74***	1799.2100***	0.91	112.1410***	18.8417***	14168.17***	382.03***
Sign Bias Test	-0.2694**	-1.651	-0.294	-1.5201**	0.273	-0.6340***	-1.024
H_0: $(\varepsilon_t/\sigma_t)^2=\mu+\gamma K+e_t$ (t-stat.)	-(2.3049)	-(0.9761)	-(0.8689)	-(2.0417)	(0.5912)	-(3.1092)	-(1.3543)
Negative Size Bias Test	1.1131***	-0.204	0.118	9.301	-1.8095***	16.0479***	-0.949
H_0: $(\varepsilon_t/\sigma_t)^2=\mu+\gamma K\varepsilon_{t-1}+e_t$ (t-stat.)	(4.7225)	-(0.8534)	(0.5305)	(1.1671)	-(3.0014)	(3.1092)	-(0.7905)
Positive Size Bias Test	0.1792*	0.368	0.160	0.726	0.282	0.2547***	0.698
H_0: $(\varepsilon_t/\sigma_t)^2=\mu+\gamma(1-K)\varepsilon_{t-1}+e_t$ (t-stat.)	(1.8682)	(0.5612)	(0.5978)	(1.3255)	(0.9228)	(3.3344)	(0.9915)

All GARCH (2,1) parameters have been estimated from the time series - transformed by the Johnson Fit and the natural logarithm ("AD_L") - according to the Berndt Hall-Hall-Hausman algorithm, except in cases marked [#] (Marquardt quasi-maximum likelihood estimation procedure); [&] singular covariance coefficients are not unique. ***=1% significance, **=5% significance, *=10% significance. *NA* indicates that no results could be generated by the statistics software due to data overflow. The estimated values (ε_t/σ_t) and $(\varepsilon_t/\sigma_t)^2$ are the mean and the conditional variance of standardised residuals obtained from the GARCH (2,1) model. *LB(x)* denotes the Llung-Box Q-statistic (autocorrelation) for standardised errors up to x lags and $LB^2(x)$ denotes the Llung-Box Q-statistic for squared standardised errors up to x lags at which the Q-statistic does no longer indicate statistically significant observations of autocorrelation in the given time series different from the null hypothesis of no autocorrelation. The computation of the three bias tests was completed at heteroskedasticity consistent covariance according to White (1980). Number of observations: 93. In the sign bias and size bias tests we included 91 observations (instead of 93) after adjusting for endpoints.

Tab. 12. *Coefficient and residual tests of GARCH(2,1) model for all spread series (only transformed and Johnson Fit adjusted spreads) – LIBOR at first differences.*

Note that the GARCH model specification of spread heteroskedasticity seems to improve as we replace the first difference of LIBOR spot rates by level data as regressor of both the mean and conditional variance equations of the GARCH models.

Overall, the model diagnostics based on common coefficient and residual tests as well as sign bias and size bias testing procedures for asymmetric conditional variance suggest that the specification of spread volatility in either a GARCH(1,1) or GARCH(2,1) process generates adequate results of relatively high statistical validity, which could be relied upon for forecasting purposes. The maximum likelihood estimated, multi-factor model approximation of the given spread series describe the spread dynamics particularly well for Pfandbriefe and, to a lesser extent, for CDOs. However, while asymmetric mean reversion and the asymmetric impact of past errors on conditional variance are statistically and economically significant in most cases, the model specification under GARCH(2,1) seems to leave doubts as to its appropriateness for mortgage-backed securities (MBS).

9 DISCUSSION

After logarithmic transformation in combination with the Johnson Fit procedure, all CDO, MBS and Pfandbrief spread series in the data set exhibit strong mean reversion in both the simple OLS regression analysis and unit root tests (Augmented Dickey-Fuller (ADF) and Phillips-Perron (PP)) – except for CTA5, MAAA5 and two out of three Pfandbrief spread series (PAAA5 and PAAA7).[42] Hence, hypothesis testing is statistically viable. We also found a level effect in the degree of mean reversion, where higher mean spreads of a certain asset time series would entail higher levels of mean reversion than for spread series with lower sample means. Although the unit root tests explain any serial correlation in spread dynamics on the basis of only some shift and time trend without recognition of level effects, the model diagnostic of general level stationarity is consistent with later estimation results of the multi-factor GARCH models.

Although the significance of the estimated maximum-likelihood parameters varies among the series of asset types, we can clearly identify a strong statistical influence of endogenous factors on the mean and conditional variance specifications of all spread series, especially for synthetic CDO and Pfandbrief spreads in GARCH(1,1), as well as all CDO and MBS spreads in GARCH(2,1). In both GARCH processes, model diagnostics indicate asymmetric spread change behaviour, i.e. divergent

[42] The non-stationary of the latter two spread series can only be eliminated by using daily observations over the original time period of four years (with the exclusion of all observations during the second half of 2000 in order to control for exogenous distortions to any mean-reverting trend due to the financial crises in summer 2000).

effects of past spreads on future spread change, with MBS spread series generating economically stronger results (i.e. level of mean reversion) than CDOs in spite of lower average mean spreads. All spread series exhibit asymmetric mean reversion at lag one to the extent that spread changes are mostly level stationary irrespective of the direction of first differences of spreads. However, the effect of negative first differences of spreads is economically and statistically stronger. We find no statistically significant asymmetry of mean reversion during spread increases and decreases. This observation runs counter to findings about non-stationary behaviour of MBS spreads by Koutmos (2002), who breaks down overall asymmetric mean reversion into stationary spread change after spread decreases and random spread change after spread increases, with the former effect dominating the latter. However, we find that the mean-reverting trend following spread decreases is economically stronger than the influence of past spread increases. Our model estimates also consider asymmetries of expected future spread change for more than one period. If we extend the asymmetric effects of past spread levels to two lags (in GARCH(2,1)), we find that the observation of varying degrees of mean reversion completely reverses and spread change – regardless of whether the direction of second spread differences is positive or negative – follows a random walk. The statistical diagnostics (Wald test) of estimated coefficients in both the GARCH(1,1) and GARCH(2,1) processes confirm mean reversion. Hence, the mean equation seems to be correctly specified and hypothesis testing can be justifiably applied. The spread volatility is time-varying, depending on past variance forecasts, past squared errors of the mean equation (innovations) as well as past levels of spreads and the reference sport rate (LIBOR). We observe significant asymmetric effects of past errors on spread volatility. Past negative innovations (associated with spread decline) seem to have a greater effect on the conditional variance than positive past errors.

Standard residual tests for normality (Jarque-Bera statistic) and autocorrelation (Lung-Box Q-statistic) confirm reliable model specification of the mean and the conditional variance of standardised residuals of most spread series. However, theses tests fail to measure how well the proposed GARCH models capture the asymmetric nature of spread volatility. We examine the contribution of variation of past innovations to squared standardised residuals by means of sign bias and size bias test statistics. In almost all cases, past innovations fail to have an effect on estimation errors, i.e. spread volatility not explained by the specification of the model. Hence, the specification of conditional variance in both GARCH model estimations incorporates all explanatory power of past innovations.

Although we do not entertain the idea of a "horse-race" of GARCH model specifications, judging by the derived model estimates, the GARCH(2,1) process seems superior to the GARCH(1,1) specification. Not only do we find economically and statistically stronger asymmetric contributions of past changes in spreads and LIBOR rates to the mean equation of GARCH(2,1), but also more profound and consistent asymmetric effects of past errors on spread volatility (conditional variance). Despite the attendant loss of degrees of freedom, the inclusion of more explanatory factors in GARCH(2,1) estimation promotes higher levels of significance for almost all spread series of CDO and MBS transactions. In contrast, the GARCH(1,1) model only succeeds in generating significant estimation results for most mean equations of synthetic CDO and Pfandbrief spread series. The modification of both GARCH models by a different specification of the LIBOR rate yields an even greater difference of overall parameter significance.

The proof of the pudding of whether such different levels of statistical significance actually matter lies in the correct model specification. Standard residual diagnostics for the detection of any remaining non-linear structure and non-normality in estimation errors (normalised residual spreads) indicate that the GARCH(2,1) model offers more reliable model estimates for the mean and the conditional variance of spread dynamics. The estimation errors in GARCH(2,1) exhibit little or no serial correlation (and do not follow a normal distribution). Also, statistical tests of a correct specification of asymmetries in the volatility process – asymmetries in conditional variance (sign bias test) and the influence of varying degrees of positive and negative past errors on spread volatility (size bias test) – attest lower influence of past errors on standardised residuals in the GARCH(2,1) compared to the GARCH(1,1) process, with all but one CDO spread series showing no bias of past errors (i.e. sign or size effects). Again, the use of level data of LIBOR spot rates improves overall model specification for both GARCH processes. Hence, the inclusion of an asymmetric GARCH term with lag two is a statistically preferable extension to the GARCH(1,1) specification.

However, we need to interpret the estimated results of both GARCH models with caution due to the low data frequency and short time period of our data set, compared to more than 30 years of U.S. MBS trading data used as spread history in Koutmos (2002). Since the European ABS market has seen active secondary trading for only a little more than three years, the data history of this study is limited by systemic constraints. The results of the unit root test and GARCH models are certainly influenced by the data quality of the sample. Additionally, the relative illiquidity of CDO and MBS transaction tranches in Europe exacerbates any distorting effect induced by data limitations. Nonetheless, the presented GARCH models yield estimation results with fairly robust model estimators. The quality of the data sample and the authenticity of the spread series in the data set could also be compromised by the rating volatility and asset liquidity included in the composition of the secondary spread benchmarks. Some GARCH effects of spreads might be induced by varying rating volatility between spread series, e.g. AAA ratings show less volatility than BBB ratings. Furthermore, our data set of secondary market prices does not control for liquidity, because only the transactions with the "tightest" spreads are routinely selected to make up the benchmark for the secondary market prices for each asset class.[43] Hence, the combination of rating volatility and liquidity considerations distort actual spread dynamics.

10 CONCLUSION

In this chapter we explained the spread dynamics of European ABS transaction classes by augmenting the mean specification of stationary spreads by stochastic conditional variance in a multi-factor GARCH process for valuation and forecasting purposes. In particular, accounting for the variance of errors is instrumental in deriving more accurate estimators of time-varying forecast confidence intervals in inference tests of parametric specifications. We estimated the asset and volatility processes (heteroskedasticity) of secondary market spreads by means of modified GARCH multi-factor models (GARCH(1,1) and GARCH(2,1)) on four different asset types of structured finance transactions (synthetic and traditional CDO, MBS and Pfandbrief transactions). Our model specification assumes that spread change behaviour over time represents a weighted measure of the observed long-run average, past estimation errors and the volatility forecast from the previous period(s).

We found that expected spread changes tend to be level stationary with model estimates indicating asymmetric mean reversion with a positive trend depending on the direction of past innovations and spread changes. We observed asymmetric mean reversion for past spread changes at one lag, with the contribution of negative first moments of past spreads being economically and statistically stronger than of positive first moments. We found no evidence of non-stationary spread dynamics specific to either negative or positive first moments (Koutmos, 2002). Although economic asymmetry still remained once we extended spread sensitivity to two lags of past spread changes, the stationarity of spreads, however, did not. We observed significant asymmetric effects of past errors on spread volatility. Also, conditional spread variance followed an asymmetric stochastic process biased towards negative past residuals associated with spread declines, which inflated time-varying heteroskedasticity.

[43] The creation of secondary spread benchmarks also smoothes out price variations across different transactions in the same rating category. Ideally, one would wish to control for liquidity by setting the trading volume of transactions entering the secondary market spread benchmark each week in relation to the total volume of outstanding transactions in the same asset class, which have not been traded. We also do not control for jumps/level effects in the spread series beyond the inclusion of the LIBOR rate as regressor in the conditional variance equation.

These spread dynamics of ABS imply that negative investor sentiment during persistent spread increases causes spreads to escape stationary approximation in the long run, especially for unexpected downward price corrections. Standard residual model diagnostics testified to a correct specification of the mean and the conditional variance of spread change. The autoregressive examination of past errors through sign and size bias tests confirmed that the model specification of conditional spread volatility captured almost all explanatory power of past innovations, leaving no influence of the latter on standardised (squared) residuals in any statistically meaningful way.

Our findings on the heteroskedasticity of European ABS spreads largely corroborates previous findings about the spread behaviour of U.S. MBS transactions. In our case, spread changes behave asymmetrically in response to negative spread changes and innovations in the past. Moreover, the consideration of (i) level effects induced by changes in the LIBOR interest rate (at level and first differences), and (ii) a longer history of past variance forecasts (GARCH effect) of conditional spread volatility yields more reliable approach forecasts of spread dynamics of the analysed asset classes. The presented analysis presented results of the first empirical investigation of market pricing for ABS transactions in Europe on the basis of actual trading data. However, a longer sample period and a higher data frequency of deal-based secondary market trading data would be desirable avenues of extension in an effort to further refine the presented model estimates to control for cyclical effects in spread dynamics in the long run.

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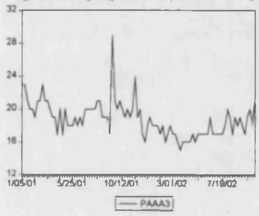
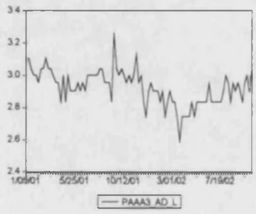
12 APPENDIX

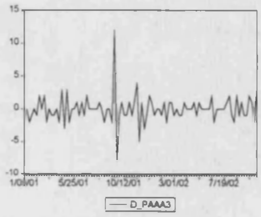
Level Data | **First Differences**

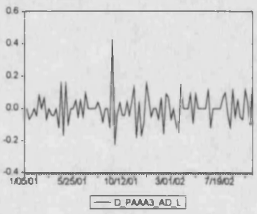
Original Series | *Transformed Series (log. & Johnson Fit)* | *Original Series* | *Transformed Series (log. & Johnson Fit)*

<u>*Pfandbrief Spreads (AAA, 3 years)*</u>

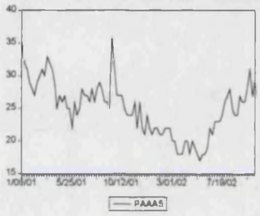


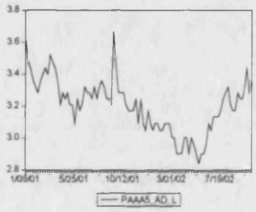


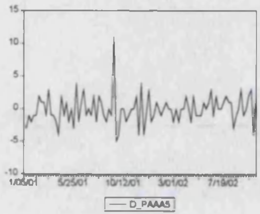


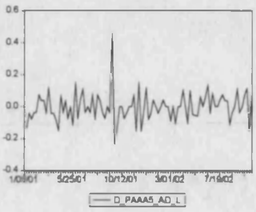


<u>*Pfandbrief Spreads (AAA, 5 years)*</u>





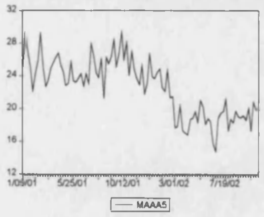


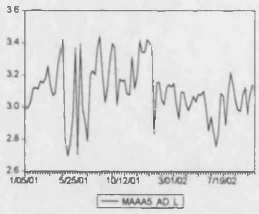


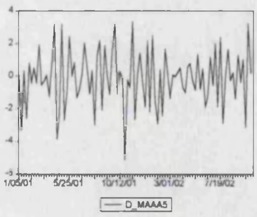
Level Data | **First Differences**

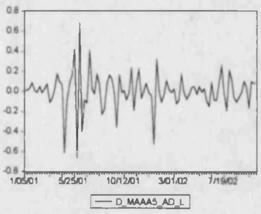
Original Series | *Transformed Series (log. & Johnson Fit)* | *Original Series* | *Transformed Series (log. & Johnson Fit)*

<u>*RMBS Spreads (AAA, 5 years)*</u>



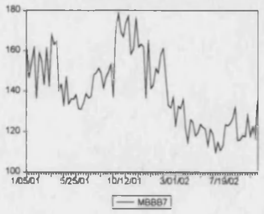


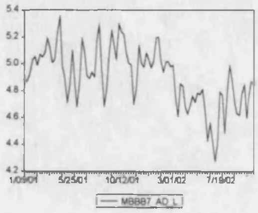


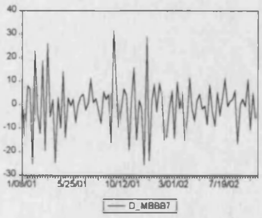


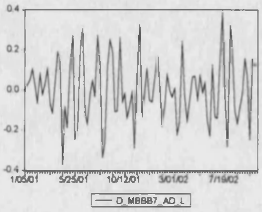
1st differences indicate volatility effects ...

<u>*RMBS Spreads (BBB, 7 years)*</u>









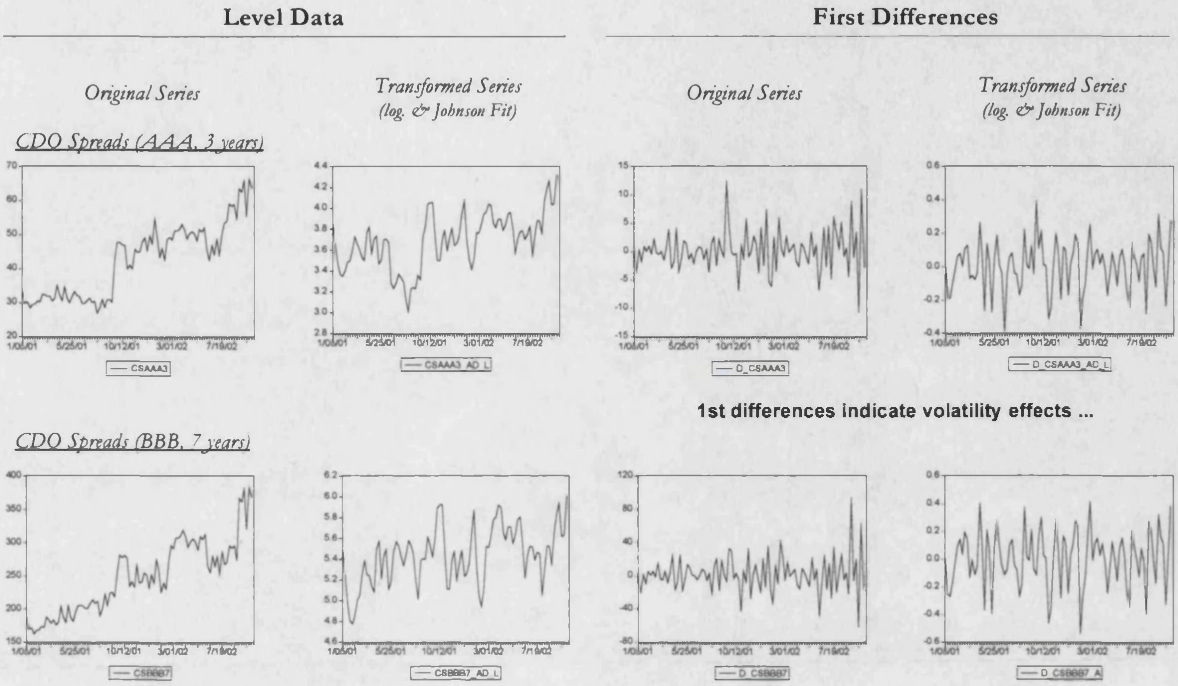


Fig. 1. *Data overview of selected spread series.*

Acronym	ABS Type	Rating Class (S&P)	Maturity	Deal Structure
CSAAA3	CDO	AAA	3 years	synthetic
CSA5	CDO	A	5 years	synthetic
CSBBB7	CDO	BBB	7 years	synthetic
CTAAA3	CDO	AAA	3 years	traditional, balance sheet
CTA5	CDO	A	5 years	traditional, balance sheet
CTBBB7	CDO	BBB	7 years	traditional, balance sheet
MAAA3	RMBS	AAA	3 years	synthetic & trad.
MAAA5	RMBS	AAA	5 years	synthetic & trad.
MA7	RMBS	A	7 years	synthetic & trad.
MBBB7	RMBS	BBB	7 years	synthetic & trad.
PAAA3	Pfandbrief	AAA	3 years	on-balance
PAAA5	Pfandbrief	AAA	5 years	on-balance
PAAA7	Pfandbrief	AAA	7 years	on-balance

Tab. 13. *Definition of nomenclature for the spread series associated with a certain asset type in the data set.*

Pfandbrief (Rating Grade)	Mean Weighted-Average Index Portion	05-Jan-01		18-Oct-02	
		Weighted-Average Index Portion	No. of Issues	Weighted-Average Index Portion	No. of Issues
with maturity 1-3 years					
AAA	78.11%	81.51%	989	74.39%	815
AA	20.81%	17.91%	191	23.71%	180
A	1.08%	0.45%	10	1.71%	29
Cash		0.12%		0.19%	
Total	100.00%	100.00%	1190	100.00%	1024
with maturity 3-5 years					
AAA	79.63%	82.78%	722	76.48%	536
AA	19.76%	17.04%	126	22.48%	144
A	0.61%	0.18%	4	1.04%	15
Cash		0.00%		0.00%	
Total	100.00%	100.00%	852	100.00%	695
with maturity 5-7 years					
AAA	81.03%	87.07%	431	74.91%	329
AA	18.31%	12.72%	53	23.90%	83
A	0.67%	0.22%	2	1.11%	11
Cash		0.00%		0.07%	
Total	100.00%	100.00%	486	100.00%	423

Tab. 14. *Definition of the Merrill Lynch EMU Pfandbrief Index and its rating class composition over time.*

Asset Class Spread Series	z-value	Selected distribution	ρ with original	Skewness	Kurtosis	JB	p_{JB}	E_P	p_E
CSAAA3_AD_L	0.9515	S_B	0.9597	0.0461	3.5767	1.3359	0.5128	3.1429	0.2077
CSA5_AD_L	0.8292	S_B	0.9173	-0.0914	3.2128	0.3051	0.8585	1.1243	0.5700
CSBBB7_AD_L	0.8341	S_B	0.9679	0.0972	3.3628	0.6636	0.7176	1.8504	0.3965
CTAAA3_AD_L	0.3029	S_U	0.4504	0.2781	2.2272	3.5511	0.1694	5.4736	0.0648
CTA5_AD_L	0.4108	S_B	0.9330	-0.2280	2.7507	1.0582	0.5891	1.0287	0.5979
CTBBB7_AD_L	0.9119	S_B	0.9317	0.0360	3.0430	0.0276	0.9863	0.4472	0.7996
MAAA3_AD_L	0.2864	S_B	0.9912	0.3847	2.5218	3.2142	0.2005	4.9582	0.0838
MAAA5_AD_L	0.2765	S_U	0.2511	-0.1348	2.0911	3.5201	0.1720	4.6662	0.0970
MA7_AD_L	0.0902	S_U	0.2592	0.0701	3.3462	0.5463	0.7610	1.7428	0.4184
MBBB7_AD_L	0.1507	S_U	-0.0331	0.1279	7.3745	75.2062	0.0000	49.1697	0.0000
PAAA3_AD_L	0.8342	S_B	0.9808	-0.1098	3.6506	1.8466	0.3972	3.6514	0.1611
PAAA5_AD_L	0.6446	S_B	0.9967	0.0258	2.8617	0.0854	0.9582	0.0657	0.9677
PAAA7_AD_L	0.8041	S_B	0.9902	0.0599	3.0421	0.0631	0.9689	0.4690	0.7910

Tab. 15. *Data transformation of spread series for each asset class by means of the Johnson Fit procedure.*

	Collateralised Debt Obligations (CDO), synthetic								
	CSAAA3	CSAAA3_L	CSAAA3_AD_L	CSA5	CSA5_L	CSA5_AD_L	CSBBB7	CSBBB7_L	CSBBB7_AD_L
Mean	43.1624	3.7314	3.7314	125.7536	4.8060	4.8060	252.0388	5.5049	5.5049
Median	46.0000	3.8286	3.8192	137.0000	4.9200	4.8697	256.0000	5.5452	5.5449
Maximum	65.0000	4.1744	4.3118	175.0000	5.1648	5.3492	375.0000	5.9269	6.0047
Minimum	30.0000	3.4012	3.2583	72.0000	4.2767	4.1993	174.0000	5.1591	5.0301
Std. Dev.	11.1472	0.2617	0.2617	28.8914	0.2447	0.2447	56.4064	0.2236	0.2236
Rel. Variation	25.83%	7.01%	7.01%	22.97%	5.09%	5.09%	22.38%	4.06%	4.06%
Skewness	0.2464	-0.0271	-0.0914	-0.2057	-0.4738	0.0461	0.3951	0.0181	0.0972
Kurtosis	1.9558	1.5821	3.2128	1.8318	1.9614	3.5767	2.4892	2.0100	3.3628
Jarque-Bera	5.1664	7.8022	0.3051	6.0075	7.7426	1.3359	3.4679	3.8437	0.6636
Prob. JB	0.0755	0.0202	0.8585	0.0496	0.0208	0.5128	0.1766	0.1463	0.7176
E_p	9.3451	16.5417	1.1243	11.3919	20.9996	3.1429	5.5840	5.0403	1.8504
Prob. E	0.0093	0.0003	0.5700	0.0034	0.0000	0.2077	0.0613	0.0804	0.3965
LB-Q (lags)*	815.09 (26)	882.6 (26)	437.37 (14)	902.86 (27)	909.24 (27)	587.16 (26)	822.25 (28)	911.34 (28)	609.65 (25)
AC value	0.1870	0.1850	0.1990	0.1860	0.1730	0.1980	0.1870	0.1710	0.1980
Observations	*93*	*93*	*93*	*93*	*93*	*93*	*93*	*93*	*93*

	Collateralised Debt Obligations (CDO), traditional								
	CTAAA3	CTAAA3_L	CTAAA3_AD_L	CTA5	CTA5_L	CTA5_AD_L	CTBBB7	CTBBB7_L	CTBBB7_AD_L
Mean	29.7670	3.3846	3.3846	94.8936	4.5263	4.5263	199.2566	5.2839	5.2839
Median	28.0000	3.3322	3.3769	90.0000	4.4998	4.5700	185.2200	5.2215	5.2672
Maximum	39.0000	3.6636	3.6240	150.0000	5.0106	5.0782	300.0000	5.7038	5.6205
Minimum	25.6000	3.2426	3.0413	72.0000	4.2767	4.2178	170.0000	5.1358	4.9377
Std. Dev.	4.0718	0.1313	0.1313	22.4846	0.2284	0.2284	31.0592	0.1428	0.1428
Rel. Variation	13.68%	3.88%	3.88%	23.69%	5.05%	5.05%	15.59%	2.70%	2.70%
Skewness	0.7577	0.6853	-0.2280	0.6303	0.3858	0.2781	1.5057	1.2042	0.0360
Kurtosis	1.9730	1.8238	2.7507	2.2566	1.7907	2.2272	4.8686	3.7495	3.0430
Jarque-Bera	13.1245	12.7770	1.0582	8.3887	8.0601	3.5511	49.1922	24.9182	0.0276
Prob. JB	0.0014	0.0017	0.5891	0.0151	0.0178	0.1694	0.0000	0.0000	0.9863
E_p	61.6615	59.8116	1.0287	24.0032	21.3419	5.4736	69.3523	49.9135	0.4472
Prob. E	0.0000	0.0000	0.5979	0.0000	0.0000	0.0648	0.0000	0.0000	0.7996
LB-Q (lags)*	581.14 (15)	583.9 (15)	420.4 (13)	1002.3 (27)	1072.8 (27)	655.46 (16)	674.81 (25)	768.14 (26)	739.28 (28)
AC value	0.1740	0.1740	0.1790	0.1600	0.1800	0.1840	0.1820	0.1710	0.1690
Observations	*93*	*93*	*93*	*93*	*93*	*93*	*93*	*93*	*93*

Time series are stated in basis point spreads of ABS tranche indices, where M="Residential Mortgage-Backed Securities (RMBS)", P="Pfandbrief", CS="Synthetic Collateralised Debt Obligation (CDO), and CT="Traditional/True Sale Collateralised Debt Obligation". Letter "AAA" to "BBB" reflect the Standard&Poor`s investment grade rating system. The number associated with each time series reflects the maturity in years. * Llung-Box Q-statistic significant at 5% level for the given number of lags and suitable AC value. AC value denotes when the H_0 of no autocorrelation can no longer be rejected at 5% level at a certain number of lags, i.e. the test statistic falls within the two standard error bounds of $+/-2T^{-0.5}$.

Tab. 16. *Descriptive statistics of all CDO spread series (level data).*

	Mortgage-Backed Securities (MBS)											
	MAAA3	MAAA3_L	MAAA3_AD_L	MAAA5	MAAA5_L	MAAA5_AD_L	MA7	MA7_L	MA7_AD_L	MBBB7	MBBB7_L	MBBB7_AD_L
Mean	20.7234	3.0217	3.0217	22.9782	3.1244	3.1244	65.1915	4.1751	4.1751	140.3138	4.9367	4.9367
Median	22.0000	3.0910	2.9947	24.0000	3.1781	3.0854	66.0000	4.1897	4.1829	142.0000	4.9558	4.9514
Maximum	25.0000	3.2189	3.2047	28.0000	3.3322	3.3879	75.0000	4.3175	4.3678	175.0000	5.1648	5.2871
Minimum	17.0000	2.8332	2.7988	17.5000	2.8622	2.8285	60.0000	4.0943	4.0988	120.0000	4.7875	4.4829
Std. Dev.	2.8099	0.1404	0.1404	3.2387	0.1446	0.1446	4.3854	0.0673	0.0673	16.9122	0.1207	0.1207
Rel. Variation	13.56%	4.65%	4.65%	14.09%	4.63%	4.63%	6.73%	1.61%	1.61%	12.05%	2.44%	2.44%
Skewness	-0.3854	-0.4277	-0.1348	-0.2056	-0.2931	0.0701	0.0774	0.0080	0.3847	0.1416	0.0127	0.1279
Kurtosis	1.3751	1.3694	2.0911	1.4860	1.4694	3.3462	1.7472	1.6577	2.5218	1.8052	1.6713	7.3745
Jarque-Bera	12.6680	13.2799	3.5201	9.6394	10.5222	0.5463	6.2409	7.0582	3.2142	5.9050	6.9174	75.2062
Prob. JB	0.0018	0.0013	0.1720	0.0081	0.0052	0.7610	0.0441	0.0293	0.2005	0.0522	0.0315	0.0000
E_p	53.6208	62.5617	4.6662	26.1014	32.9179	1.7428	11.2472	13.7045	4.9582	10.5874	13.2351	49.1697
Prob. E	0	0	0.097	0	0	0.4184	0.0036	0.0011	0.0838	0.005	0.0013	0
LB-Q (lags)*	886.74 (22)	905.08 (22)	164.22 (7)	934.77 (23)	967.94 (23)	35.073 (3)	752.65 (20)	785.63 (21)	645.58 (19)	699.72 (17)	733.1 (17)	22.393 (2)
AC value	0.1710	0.1820	0.1270	0.1760	0.1810	0.1410	0.1890	0.1720	0.1760	0.1570	0.1890	0.1300
Observations	*93*	*93*	*93*	*93*	*93*	*93*	*93*	*93*	*93*	*93*	*93*	*93*

	Pfandbriefe								
	PAAA3	PAAA3_L	PAAA3_AD_L	PAAA5	PAAA5_L	PAAA5_AD_L	PAAA7	PAAA7_L	PAAA7_AD_L
Mean	18.7766	2.9268	2.9268	24.9894	3.2045	3.2045	31.8192	3.4437	3.4437
Median	19.0000	2.9444	2.9571	25.0000	3.2189	3.2111	31.5000	3.4499	3.4540
Maximum	29.0000	3.3673	3.2652	36.0000	3.5835	3.6690	47.0000	3.8501	3.9766
Minimum	15.0000	2.7081	2.5928	17.0000	2.8332	2.8406	22.0000	3.0910	2.9558
Std. Dev.	2.1056	0.1065	0.1065	4.1543	0.1691	0.1691	5.8217	0.1819	0.1819
Rel. Variation	11.21%	3.64%	3.64%	16.62%	5.28%	5.28%	18.30%	5.28%	5.28%
Skewness	1.4225	0.8305	-0.1098	0.1397	-0.2348	0.0258	0.3768	0.0708	0.0599
Kurtosis	7.6301	4.9100	3.6506	2.6313	2.4766	2.8617	2.3737	2.0795	3.0421
Jarque-Bera	115.6686	25.0950	1.8466	0.8381	1.9371	0.0854	3.7609	3.3975	0.0631
Prob. JB	0.0000	0.0000	0.3972	0.6577	0.3796	0.9582	0.1525	0.1829	0.9689
E_p	22.4233	10.8896	3.6514	0.5585	2.1983	0.0657	6.3592	4.2158	0.469
Prob. E	0	0.0043	0.1611	0.7564	0.332	0.9677	0.0416	0.1215	0.791
LB-Q (lags)*	151.67 (10)	189.51 (12)	226.06 (12)	415.8 (15)	459.52 (15)	410.94 (14)	584.97 (20)	617.95 (19)	543.62 (17)
AC value	0.1940	0.0710	0.1090	0.1760	0.1820	0.1950	0.1810	0.1910	0.2130
Observations	*93*	*93*	*93*	*93*	*93*	*93*	*93*	*93*	*93*

Time series are stated in basis point spreads of ABS tranche indices, where M="Residential Mortgage-Backed Securities (RMBS)", P="Pfandbrief", CS="Synthetic Collateralised Debt Obligation (CDO), and CT="Traditional/True Sale Collateralised Debt Obligation". Letter "AAA" to "BBB" reflect the Standard&Poor`s investment grade rating system. The number associated with each time series reflects the maturity in years.
* Llung-Box Q-statistic significant at 5% level for the given number of lags and suitable AC value. AC value denotes when the H_0 of no autocorrelation can no longer be rejected at 5% level at a certain number of lags, i.e. the test statistic falls within the two standard error bounds of $+/-2T^{-0.5}$.

Tab. 17. *Descriptive statistics of all MBS and Pfandbrief spread series (level data).*

	Collateralised Debt Obligations (CDO), synthetic								
	CSAAA3	CSAAA3_L	CSAAA3_AD_L	CSA5	CSA5_L	CSA5_AD_L	CSBBB7	CSBBB7_L	CSBBB7_AD_L
Mean	0.3717	0.0081	0.0083	1.0860	0.0093	0.0114	2.1541	0.0082	0.0101
Median	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Maximum	15.0000	0.4055	0.5521	35.0000	0.2877	0.3907	75.0000	0.2231	0.3586
Minimum	-2.0000	-0.0426	-0.3072	-5.0000	-0.0351	-0.0935	-20.0000	-0.0690	-0.0884
Std. Dev.	2.1615	0.0509	0.0770	4.8647	0.0391	0.0568	10.0505	0.0341	0.0432
Rel. Variation	447.94%	422.77%	500.04%	447.94%	422.77%	500.04%	447.94%	422.77%	500.04%
Skewness	5.2634	5.2634	4.0859	5.1544	5.1544	5.0211	5.2045	5.2045	5.8904
Kurtosis	33.0000	33.0000	34.8839	32.8519	32.8519	30.5179	35.3596	35.3596	47.4653
Jarque-Bera	3874.7840	7307.8110	4152.8740	3864.9620	3755.5780	3325.0580	4477.5320	2774.3060	8199.2860
Prob. JB	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
LB-Q (lags)*	0.0382 (1)	0.0285 (1)	0.009 (1)	0.0159 (1)	0.0586 (1)	0.0856 (1)	0.0124 (1)	0.0151 (1)	0.0084 (1)
AC value	-0.0200	-0.0170	-0.0100	-0.0130	-0.0250	-0.0300	0.0110	0.0130	-0.0090
Observations	*92*	*92*	*92*	*92*	*92*	*92*	*92*	*92*	*92*

	Collateralised Debt Obligations (CDO), traditional								
	CTAAA3	CTAAA3_L	CTAAA3_AD_L	CTA5	CTA5_L	CTA5_AD_L	CTBBB7	CTBBB7_L	CTBBB7_AD_L
Mean	0.0237	0.0009	0.0021	0.5484	0.0056	0.0038	0.8530	0.0041	0.0050
Median	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Maximum	8.0000	0.2595	0.2038	23.0000	0.2772	0.3718	35.0000	0.1508	0.1485
Minimum	-4.0000	-0.1082	-0.1918	-25.0000	-0.1823	-0.1247	-50.0000	-0.1823	-0.1482
Std. Dev.	1.1024	0.0350	0.0446	4.6333	0.0427	0.0522	7.7770	0.0312	0.0364
Rel. Variation	447.94%	422.77%	500.04%	447.94%	422.77%	500.04%	447.94%	422.77%	500.04%
Skewness	3.3225	3.3225	0.8222	0.6595	0.6595	3.9327	-1.3280	-1.3280	0.0885
Kurtosis	33.3007	33.3007	14.8060	20.8972	20.8972	29.8630	26.5657	26.5657	12.2877
Jarque-Bera	3728.8620	4247.6470	550.5783	1247.9450	1920.5030	3035.9980	2179.2930	1386.9480	334.3823
Prob. JB	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
LB-Q (lags)*	0.3985 (1)	0.4403 (1)	0.3923 (1)	0.1126 (1)	0.098 (1)	1.1888 (1)	1.1131 (1)	0.6712 (1)	0.5088 (1)
AC value	0.0640	0.0680	0.0640	0.0340	0.0320	0.1110	0.1080	0.0840	0.0730
Observations	*92*	*92*	*92*	*92*	*92*	*92*	*92*	*92*	*92*

Time series are stated in basis point spreads of ABS tranche indices, where CS="Synthetic Collateralised Debt Obligation (CDO) and CT="Traditional/True Sale Collateralised Debt Obligation". Letter "AAA" to "BBB" reflect the Standard&Poor's investment grade rating system. The number associated with each time series reflects the maturity in years. * Llung-Box Q-statistic significant at 5% level for the given number of lags and suitable AC value. AC value denotes when the H_0 of no autocorrelation can no longer be rejected at 5% level at a certain number of lags, i.e. the test statistic falls within the two standard error bounds of $+/-2T^{-0.5}$.

Tab. 18. *Descriptive statistics of all CDO spread series (first differences).*

	MAAA3	MAAA3_L	MAAA3_AD_L	MAAA5	MAAA5_L	MAAA5_AD_L	MA7	MA7_L	MA7_AD_L	MBBB7	MBBB7_L	MBBB7_AD_L
Mean	-0.0430	-0.0022	0.0021	-0.0860	-0.0036	0.0000	-0.1075	-0.0017	-0.0016	-0.3333	-0.0025	0.0014
Median	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Maximum	3.0000	0.1278	0.4060	3.0000	0.1133	0.5595	8.0000	0.1128	0.1702	23.0000	0.1409	0.8041
Minimum	-2.0000	-0.1112	-0.4060	-1.5000	-0.0564	-0.5595	-3.0000	-0.0408	-0.0829	-13.0000	-0.0847	-0.5943
Std. Dev.	0.5450	0.0253	0.0906	0.5984	0.0251	0.1598	1.0781	0.0155	0.0220	3.5496	0.0230	0.1252
Rel. Variation	447.94%	422.77%	500.04%	447.94%	422.77%	500.04%	447.94%	422.77%	500.04%	447.94%	422.77%	500.04%
Skewness	0.7786	0.7786	-0.7285	1.1376	1.1376	-0.6800	4.0873	4.0873	4.4868	2.7928	2.7928	1.3561
Kurtosis	15.4485	15.4485	14.7080	10.0180	10.0180	10.7610	36.4269	36.4269	43.2074	23.5092	23.5092	26.1380
Jarque-Bera	609.8813	464.3998	539.4039	210.9124	95.0048	240.5687	4588.7070	4028.5860	6576.4790	1750.8160	1180.8090	2103.0570
Prob. JB	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
LB-Q (lags)*	0.379 (1)	0.0018 (1)	0.8166 (1)	0.2488 (1)	0.6727 (1)	38.913 (3)	1.6009 (1)	1.7533 (1)	1.1814 (1)	2.3927 (1)	3.1105 (1)	3.9858 (1)
AC value	-0.0630	0.0040	-0.0920	0.0510	0.0840	-0.2330	0.1290	0.1350	0.1110	0.1580	0.1800	-0.2040
Observations	*92*	*92*	*92*	*92*	*92*	*92*	*92*	*92*	*92*	*92*	*92*	*92*

Pfandbriefe

	PAAA3	PAAA3_L	PAAA3_AD_L	PAAA5	PAAA5_L	PAAA5_AD_L	PAAA7	PAAA7_L	PAAA7_AD_L
Mean	-0.0215	-0.0010	-0.0007	-0.0645	-0.0020	-0.0027	-0.1613	-0.0041	-0.0055
Median	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Maximum	12.0000	0.5341	0.4285	11.0000	0.3646	0.4579	7.0000	0.1924	0.1764
Minimum	-8.0000	-0.3228	-0.2241	-5.0000	-0.1671	-0.2312	-6.0000	-0.2151	-0.2141
Std. Dev.	2.0954	0.1002	0.0937	2.2351	0.0847	0.0913	2.2423	0.0701	0.0754
Rel. Variation	447.94%	422.77%	500.04%	447.94%	422.77%	500.04%	447.94%	422.77%	500.04%
Skewness	1.4112	1.4112	0.8764	1.1500	1.1500	1.2008	0.3424	0.3424	0.0547
Kurtosis	15.1285	15.1285	6.5829	8.1286	8.1286	8.6559	3.5867	3.5867	3.3994
Jarque-Bera	600.8837	284.2860	61.6469	122.4217	35.8703	146.3052	3.1510	1.9576	0.6646
Prob. JB	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.2069	0.3758	0.7173
LB-Q (lags)*	23.88 (2)	23.899 (2)	22.358 (2)	8.4783 (2)	9.0816 (2)	8.3868 (2)	3.3562 (1)	5.1163 (1)	1.4672 (1)
AC value	0.0570	0.0680	0.0560	-0.0170	-0.0020	-0.0190	-0.1870	-0.0230	-0.1240
Observations	*92*	*92*	*92*	*92*	*92*	*92*	*92*	*92*	*92*

Time series are stated in basis point spreads of ABS tranche indices, where M="Residential Mortgage-Backed Securities (RMBS)", P="Pfandbrief", CS="Synthetic Collateralised Debt Obligation (CDO), and CT="Traditional/True Sale Collateralised Debt Obligation". Letter "AAA" to "BBB" reflect the Standard&Poor`s investment grade rating system. The number associated with each time series reflects the maturity in years. * Llung-Box Q-statistic significant at 5% level for the given number of lags and suitable AC value. AC value denotes when the H_0 of no autocorrelation can no longer be rejected at 5% level at a certain number of lags, i.e. the test statistic falls within the two standard error bounds of $+/-2T^{-0.5}$.

Tab. 19. *Descriptive statistics of all MBS and Pfandbrief spread series (first differences).*

	LIBOR			
	level		*1 st difference*	
	LIBOR	LIBOR_L	LIBOR	LIBOR_L
Mean	4.6042	1.5174	-0.0196	-0.0040
Median	4.1875	1.4321	-0.0125	-0.0024
Maximum	5.8838	1.7722	0.0831	0.0209
Minimum	3.9113	1.3639	-0.2800	-0.0691
Std. Dev.	0.6555	0.1380	0.0591	0.0131
Rel. Variation	14.24%	9.09%	447.94%	422.77%
Skewness	0.5968	0.5214	-1.9469	-1.9469
Kurtosis	1.7500	1.6214	9.0406	9.0406
Jarque-Bera	11.6996	11.7038	200.1450	305.8752
Prob. JB	0.0029	0.0029	0.0000	0.0000
LB-Q (lags)*	995.75 (25)	1006 (25)	995.75 (2)	1006 (25)
AC value	0.1980	0.1970	0.1980	0.1970
Observations	*93*	*93*	*92*	*92*

* Llung-Box Q-statistic significant at 5% level for the given number of lags and suitable AC value. AC value denotes when the H_0 of no autocorrelation can no longer be rejected at 5% level at a certain number of lags, i.e. the test statistic falls within the two standard error bounds of $+/-2T^{-0.5}$.

Tab. 20. *Descriptive statistics of LIBOR rate series (level data and first differences).*

	Collateralised Debt Obligations (CDO), synthetic								
	CSAAA3	CSAAA3_L	CSAAA3_AD_L	CSA5	CSA5_L	CSA5_AD_L	CSBBB7	CSBBB7_L	CSBBB7_AD_L
$\rho_{0;-1}$	0.9530	0.9580	0.9270	0.9520	0.9520	0.9220	0.9480	0.9560	0.9330
Q_{LB}	87.2740	88.1170	82.5760	88.0140	88.0270	82.5140	87.1850	88.7000	84.4700
p_Q	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
$\rho_{0;-2}$	-0.0260	-0.0220	-0.0350	-0.0510	-0.0600	-0.1030	-0.0410	-0.0350	-0.0100
Q_{LB}	167.0500	169.5400	153.5400	167.8800	167.7600	150.8900	165.6400	170.1300	158.5900
p_Q	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
$\rho_{0;-3}$	-0.0220	-0.0210	-0.0570	-0.0350	-0.0390	-0.0560	-0.0350	-0.0320	-0.0370
Q_{LB}	239.6300	244.4900	213.2700	239.7800	239.3200	206.0700	235.6100	244.3900	222.8700
p_Q	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
$\rho_{0;-4}$	-0.0420	-0.0340	-0.0470	-0.0270	-0.0250	-0.0210	-0.0470	-0.0510	-0.1000
Q_{LB}	305.0400	313.0200	262.5300	304.0400	303.1200	249.9200	297.2200	311.3900	276.6900
p_Q	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
$\rho_{0;-5}$	-0.0230	-0.0210	-0.0450	0.0530	0.1090	0.1210	-0.0290	-0.0250	-0.0460
Q_{LB}	363.6300	375.3800	302.2300	362.1900	361.4500	286.7000	350.9400	371.4300	320.8800
p_Q	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
	Collateralised Debt Obligations (CDO), traditional								
	CTAAA3	CTAAA3_L	CTAAA3_AD_L	CTA5	CTA5_L	CTA5_AD_L	CTBBB7	CTBBB7_L	CTBBB7_AD_L
$\rho_{0;-1}$	0.9580	0.9580	0.9300	0.9640	0.9680	0.9640	0.9500	0.9560	0.9380
Q_{LB}	88.9800	89.1300	83.9630	90.2500	90.9060	90.1840	87.5170	88.6140	85.4380
p_Q	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
$\rho_{0;-2}$	-0.0720	-0.0720	-0.0470	-0.0600	-0.0640	-0.0250	-0.0970	-0.0710	0.0050
Q_{LB}	170.3900	170.8400	156.3400	174.3400	176.2600	174.5900	165.6300	169.3200	161.5800
p_Q	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
$\rho_{0;-3}$	-0.0840	-0.0760	-0.0110	-0.0230	-0.0120	-0.0880	-0.1380	-0.1280	-0.0450
Q_{LB}	243.6200	244.6000	218.4500	252.3600	256.2200	252.4900	232.9900	240.8900	228.5800
p_Q	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
$\rho_{0;-4}$	-0.0040	-0.0290	-0.0910	-0.0080	-0.0230	-0.0290	0.0170	-0.0090	-0.0910
Q_{LB}	309.2600	310.6700	269.9700	324.6500	330.8700	323.9900	290.8800	303.9600	285.8700
p_Q	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
$\rho_{0;-5}$	-0.1230	-0.1160	-0.1180	-0.0110	-0.0020	-0.1120	0.1140	0.0830	0.0080
Q_{LB}	366.4600	368.2600	310.4600	391.4900	400.5200	388.2400	341.9000	360.3400	334.9600
p_Q	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000

Time series are stated in basis point spreads of CDO tranche indices, where CS= "Synthetic Collateralised Debt Obligation (CDO), and CT="Traditional/True Sale Collateralised Debt Obligation". Letters "AAA" to "BBB" reflect the Standard&Poor`s investment grade rating system. The number associated with each time series reflects the maturity in years. * Significance of Llung-Box Q-statistic indicates the existence of autocorrelation.

Tab. 21. *Partial autocorrelation coefficient of CDO spread series (level data).*

	Mortgage-Backed Securities (MBS)											
	MAAA3	MAAA3_L	MAAA3_AD_L	MAAA5	MAAA5_L	MAAA5_AD_L	MA7	MA7_L	MA7_AD_L	MBBB7	MBBB7_L	MBBB7_AD_L
$\rho_{0;-1}$	0.9750	0.9780	0.7800	0.9650	0.9690	0.3950	0.9560	0.9590	0.9340	0.9680	0.9710	0.4620
Q_{LB}	92.2630	92.7800	59.0820	90.4130	91.1770	15.1250	88.6460	89.3220	84.6480	90.9430	91.5290	20.7330
p_Q	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
$\rho_{0;-2}$	-0.0060	-0.0590	0.1000	-0.0530	-0.0680	0.3220	-0.1510	-0.1490	-0.1550	-0.1390	-0.1430	-0.1060
Q_{LB}	180.8900	181.9700	100.2900	174.9100	177.0300	33.0990	168.1900	170.3200	155.9400	175.5100	177.3100	22.3930
p_Q	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
$\rho_{0;-3}$	-0.1850	-0.2130	0.0350	-0.0600	-0.0680	-0.1330	0.1060	0.0860	0.2150	-0.0770	-0.0870	-0.1930
Q_{LB}	264.3600	265.9800	129.9700	253.1300	257.1100	35.0730	240.7400	244.6000	219.6800	253.1100	256.6400	24.1400
p_Q	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
$\rho_{0;-4}$	-0.1030	-0.0940	-0.1050	0.0880	0.0750	-0.0120	0.0480	0.0430	0.0390	0.0720	0.0570	-0.2320
Q_{LB}	342.0900	344.2300	147.4900	326.4900	332.4900	36.9230	307.9900	313.5800	278.6700	324.8000	330.2900	35.0160
p_Q	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
$\rho_{0;-5}$	0.0000	0.0170	-0.0530	-0.0740	-0.0760	0.1780	-0.0360	-0.0370	0.0050	-0.0650	-0.0780	0.2830
Q_{LB}	414.1700	416.8000	157.0600	394.5400	402.7300	39.6900	370.0100	377.3300	332.9700	390.5000	397.9800	35.4200
p_Q	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000

	Pfandbriefe								
	PAAA3	PAAA3_L	PAAA3_AD_L	PAAA5	PAAA5_L	PAAA5_AD_L	PAAA7	PAAA7_L	PAAA7_AD_L
$\rho_{0;-1}$	0.4820	0.5340	0.5950	0.8200	0.8480	0.8190	0.8900	0.8990	0.8680
Q_{LB}	22.5850	27.7090	34.3760	65.3190	69.7340	65.1260	76.8030	78.4860	73.1580
p_Q	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
$\rho_{0;-2}$	0.3040	0.3270	0.3380	0.2330	0.2460	0.2370	0.1630	0.1810	0.1620
Q_{LB}	43.8990	54.1280	66.4950	120.4000	130.6200	120.1500	143.6400	148.2700	134.9800
p_Q	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
$\rho_{0;-3}$	0.1440	0.1390	0.1410	0.0540	0.0450	0.0620	0.0740	0.0870	0.1370
Q_{LB}	60.0660	74.2330	91.9920	166.1900	182.6100	166.1900	203.1500	211.7500	190.9400
p_Q	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
$\rho_{0;-4}$	0.0060	-0.0030	-0.0050	0.0800	0.0450	0.0720	0.0600	0.0270	0.0240
Q_{LB}	69.7600	87.0500	109.5400	206.8900	228.4200	206.9100	257.2500	269.4300	240.6600
p_Q	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
$\rho_{0;-5}$	0.1570	0.1630	0.1580	0.0440	0.0340	0.0390	-0.0250	-0.0330	-0.0070
Q_{LB}	83.6090	104.1500	130.6500	243.0500	269.1400	242.9300	305.0600	320.6900	284.1200
p_Q	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000

Time series are stated in basis point spreads of MBS and Pfandbrief tranche indices, where M="Residential Mortgage-Backed Securities (RMBS)" and P="Pfandbrief". Letters "AAA" to "BBB" reflect the Standard&Poor's investment grade rating system. The number associated with each time series reflects the maturity in years. * Significance of Llung-Box Q-statistic indicates the existence of autocorrelation.

Tab. 22. *Partial autocorrelation coefficient of MBS and Pfandbrief spread series (level data).*

	Collateralised Debt Obligations (CDO), synthetic								
	CSAAA3	CSAAA3_L	CSAAA3_AD_L	CSA5	CSA5_L	CSA5_AD_L	CSBBB7	CSBBB7_L	CSBBB7_AD_L
μ	0.5630	0.0481	0.0811	3.1125*	0.12638*	0.13182	0.0808	0.0359	0.0808
(t-stat.)	(0.5786)	(0.5405)	(0.4613)	(1.4733)	(1.4469)	(0.7595)	(0.8063)	(0.5319)	(0.8063)
γ	-0.0045	-0.0107	-0.0195	-0.0162	-0.02439*	-0.0251	-0.0129	-0.0050	-0.0129
(t-stat.)	-(0.2199)	-(0.4671)	-(0.4264)	-(1.0478)	-(1.3733)	-(0.7021)	-(0.6973)	-(0.4015)	-(0.6973)
Adj. R^2	-0.0106	-0.0081	-0.0068	-0.0018	0.0122	0.0003	-0.0067	-0.0099	-0.0067
F-stat.	0.0460	0.2687	0.3813	0.8304	2.1397	1.02956	0.3861	0.0969	0.3861
(p-value)	(0.8306)	(0.6055)	(0.5385)	(0.3646)	(0.1470)	(0.3130)	(0.5359)	(0.7563)	(0.5359)
θ	126.3710	4.4836	4.1497	192.3321	5.1816	5.2527	6.2838	7.1301	6.2838
η	155.5886	64.6231	35.4696	42.8318	28.4205	27.6198	53.9246	137.5019	53.9246
θ/μ	224.4669	93.2314	51.1718	61.7932	41.0021	39.8470	77.7968	198.3733	77.7968

	Collateralised Debt Obligations (CDO), traditional								
	CTAAA3	CTAAA3_L	CTAAA3_AD_L	CTA5	CTA5_L	CTA5_AD_L	CTBBB7	CTBBB7_L	CTBBB7_AD_L
μ	1.2292*	0.13618*	0.2382*	2.0870	-0.0934	-0.0705	5.1733	0.0809	0.2279
(t-stat.)	(1.3024)	(1.4485)	(1.4590)	(0.6603)	-(1.0666)	-(0.5424)	(0.4285)	(0.3245)	(0.9830)
γ	-0.0405	-0.03997*	-0.0698*	-0.0163	0.0219	0.0164	-0.0217	-0.0145	-0.0422
(t-stat.)	-(1.2759)	-(1.4449)	-(1.4712)	-(0.4531)	(1.0931)	(0.5551)	-(0.3396)	-(0.3051)	-(0.9646)
Adj. R^2	0.0118	0.0120	0.0320	-0.0047	0.0028	-0.0058	-0.0035	-0.0066	0.0165
F-stat.	2.0989	2.1163	4.0454	0.5658	1.2627	0.4679	0.6784	0.3970	2.5474
(p-value)	(0.1508)	(0.1492)	(0.0473)	(0.4539)	(0.2641)	(0.4957)	(0.4123)	(0.5302)	(0.1139)
θ	30.3704	3.4072	3.4144	128.2759	4.2710	4.2987	237.9495	5.5637	5.3997
η	17.1253	17.3426	9.9367	42.6028	-31.6954	-42.2445	31.8820	47.6816	16.4202
θ/μ	24.7066	25.0200	14.3357	61.4628	-45.7268	-60.9459	45.9960	68.7900	23.6894

We define the level of mean reversion as $\theta=-\gamma/\mu$ and the speed of mean reversion as $\eta=\ln(0.5)/\gamma$.

Tab. 23. *Test of mean reversion – OLS regression of secondary market spreads of CDO spread series (actual, transformed and Johnson Fit adjusted spreads).*

	Mortgage-Backed Securities (MBS)											
	MAAA3	MAAA3_L	MAAA3_AD_L	MAAA5	MAAA5_L	MAAA5_AD_L	MA7	MA7_L	MA7_AD_L	MBBB7	MBBB7_L	MBBB7_AD_L
μ	0.2636	-0.0611	-0.5959**	-0.2842	0.0654	-1.8904***	1.8013*	0.1033*	0.2182*	1.9679	0.0581	2.6557**
(t-stat.)	(0.8084)	-(0.9828)	-(2.2887)	-(0.5940)	(1.2756)	-(3.5561)	(1.4059)	(1.3462)	(1.4033)	(0.9085)	(0.7702)	(2.0783)
γ	-0.0148	0.0195	0.1977**	0.0086	-0.0221*	0.6049***	-0.0293*	-0.02515*	-0.0526*	-0.0164	-0.0123	-0.5377**
(t-stat.)	-(0.8807)	(0.9405)	(2.3133)	(0.3927)	-(1.3390)	(3.5717)	-(1.4082)	-(1.3482)	-(1.4011)	-(0.9430)	-(0.7847)	-(2.0810)
Adj. R^2	-0.0051	0.0010	0.0824	-0.0088	0.0053	0.2948	0.0033	0.0011	0.0151	-0.0049	-0.0068	0.2635
F-stat.	0.5315	1.0906	9.2631	0.1964	1.4938	39.4681	1.3013	1.0977	2.4147	0.5545	0.3766	33.9136
(p-value)	(0.4679)	(0.2991)	(0.0031)	(0.6587)	(0.2248)	(0.0000)	(0.2570)	(0.2975)	(0.1237)	(0.4584)	(0.5409)	(0.0000)
θ	17.8416	3.1315	3.0135	32.8770	2.9619	3.1248	61.5714	4.1101	4.1458	120.1776	4.7367	4.9392
η	46.9103	-35.5333	-3.5053	-80.1975	31.3982	-1.1458	23.6933	27.5660	13.1704	42.3296	56.5142	1.2892
θ/μ	67.6773	-51.2636	-5.0571	-115.7006	45.2981	-1.6530	34.1822	39.7693	19.0009	61.0687	81.5328	1.8599

	Pfandbriefe								
	PAAA3	PAAA3_L	PAAA3_AD_L	PAAA5	PAAA5_L	PAAA5_AD_L	PAAA7	PAAA7_L	PAAA7_AD_L
μ	9.5776***	1.3409***	1.16206***	4.2115***	0.4587***	0.5525***	3.3490***	0.3420***	0.4476***
(t-stat.)	(4.8210)	(4.9629)	(4.8191)	(3.8409)	(3.3895)	(3.5922)	(3.2638)	(3.1760)	(2.6783)
γ	-0.5119***	-0.4587***	-0.3975***	-0.1714***	-0.1439***	-0.1734***	-0.1103***	-0.1005***	-0.1316***
(t-stat.)	-(4.9210)	-(4.9995)	-(4.8838)	-(3.8803)	-(3.4199)	-(3.6002)	-(3.3983)	-(3.2397)	-(2.7277)
Adj. R^2	0.2561	0.2284	0.1949	0.0917	0.0725	0.0933	0.0729	0.0585	0.0920
F-stat.	32.6744	28.2328	23.2714	10.2867	8.1909	10.4697	8.2300	6.7212	10.3186
(p-value)	(0.0000)	(0.0000)	(0.0000)	(0.0019)	(0.0052)	(0.0017)	(0.0051)	(0.0111)	(0.0018)
θ	0.9797	0.9927	2.9238	24.5698	3.1887	3.1870	30.3553	3.4023	3.4018
η	0.1409	0.1386	1.7440	4.0438	4.8180	3.9982	6.2826	6.8958	5.2678
θ/μ	0.2032	0.2000	2.5160	5.8340	6.9509	5.7682	9.0639	9.9485	7.5998

We define the level of mean reversion as $\theta=-\gamma/\mu$ and the speed of mean reversion as $\eta=\ln(0.5)/\gamma$.

Tab. 24. *Test of mean reversion – OLS regression of secondary market spreads of MBS and Pfandbrief spread series (actual, transformed and Johnson Fit adjusted spreads).*

Asset Class Spread Series	Augmented Dickey-Fuller (ADF)				Phillips-Perron (PP)			
	level		*on first difference*		*level*		*on first difference*	
	test stat.#	F-stat.	test stat.	F-stat.	test stat.	F-stat.	test stat.	F-stat.
CSAAA3	-2.3140**	1.5576	-5.5484***	22.2851	-2.4223**	3.1151	-9.6455***	46.4573
CSAAA3_L	-0.4839	0.9531	-5.5683***	29.5000	-0.4904	0.6055	-9.6009***	92.1149
CSAAA3_AD_L	*-2.1156***	*1.3658*	*-5.4391****	*21.9381*	*-2.1046***	*2.4597*	*-9.5749****	*45.8374*
CSA5	-2.5714**	1.6863	-5.7524***	22.1030	-2.5505**	3.0210	-9.5820***	45.8853
CSA5_L	-2.6638***	2.0236	-5.9545***	23.2591	-2.3890**	3.0565	-9.8002***	47.9418
CSA5_AD_L	*-3.3677****	*2.8945*	*-6.2532****	*23.6575*	*-2.7279****	*3.5594*	*-9.9196****	*49.1234*
CSBBB7	-2.5313**	1.7858	-5.4888***	21.1444	-2.5878**	3.2069	-9.3913***	44.1208
CSBBB7_L	-2.6056**	1.7604	-5.4044***	20.9290	-2.6831**	3.2168	-9.3288***	43.5410
CSBBB7_AD_L	*-2.1521***	*1.2455*	*-5.8862****	*23.3047*	*-2.3390***	*2.5349*	*-9.5909****	*45.9627*
CTAAA3	-1.4439	0.8831	-5.3088***	19.3894	-1.3659	1.2306	-8.9347***	39.8270
CTAAA3_L	-1.4229	0.8646	-5.2056***	19.1877	-1.3609	1.2461	-8.9104***	39.5956
CTAAA3_AD_L	*-1.8073**	*1.0596*	*-7.0360****	*26.7650*	*-1.8599**	*2.0212*	*-8.9250****	*39.9795*
CTA5	-3.0885***	2.4290	-5.4990***	19.9566	-3.0655***	4.2334	-9.1314***	41.7461
CTA5_L	-3.0500***	2.3745	-5.4322***	20.0319	-3.1217***	4.3954	-9.1637***	42.0493
CTA5_AD_L	*-1.4271*	*1.0235*	*-4.9343****	*17.2697*	*-1.3810*	*1.1353*	*-8.6148****	*36.8747*
CTBBB7	-3.2841***	3.6199	-5.1932***	18.7573	-2.7308**	2.9486	-8.5495***	36.0481
CTBBB7_L	-3.1429***	3.3880	-5.0281***	19.5884	-2.6448**	2.8272	-8.7677***	37.8804
CTBBB7_AD_L	*-3.8687****	*3.8989*	*-7.1995****	*28.3019*	*-3.5079****	*5.2950*	*-8.9273****	*39.9059*
MAAA3	-1.7679*	1.2054	-4.6158***	25.5425	-2.1149**	2.1762	-10.2174***	52.6226
MAAA3_L	-1.7920*	1.2790	-4.3566***	22.5060	-2.0457**	1.9105	-9.5844***	45.8448
MAAA3_AD_L	*-2.6696****	*2.3823*	*-5.6247****	*27.9576*	*-4.0668****	*7.6201*	*-11.7885****	*68.7735*
MAAA5	-1.7236*	0.9351	-5.4159***	20.3606	-1.7681	1.5475	-8.9980***	40.5530
MAAA5_L	-1.6178	0.9349	-5.2955***	18.7964	-1.6538	1.2912	-8.6936***	37.9098
MAAA5_AD_L	*-3.9070*	*13.6306*	*-7.0601****	*70.6754*	*-6.4086****	*19.6483*	*-18.2340****	*144.1522*
MA7	-2.0783**	2.4331	-6.1644***	18.0974	-2.2989**	2.4371	-8.2614***	34.7440
MA7_L	-2.0272**	2.2151	-6.0274***	17.5368	-2.2188**	2.2264	-8.2097***	34.3158
MA7_AD_L	*-2.2938***	*4.1190*	*-6.6164****	*21.2514*	*-2.7183****	*3.6791*	*-8.4312****	*35.9602*
MBBB7	-1.8053*	1.5161	-5.6216***	16.6324	-1.6638	1.2180	-8.0614***	32.5201
MBBB7_L	-1.7667*	1.7375	-5.4615***	16.0057	-1.6060	1.1357	-7.8950***	31.0959
MBBB7_AD_L	*-6.0350****	*10.9508*	*-7.2394****	*35.9587*	*-5.7618****	*16.8164*	*-12.1448****	*68.2325*
PAAA3	-3.1250***	13.0609	-7.5542***	72.1750	-6.5740***	20.8522	-18.8840***	133.2142
PAAA3_L	-2.8552***	12.1875	-7.3476***	70.8088	-6.1020***	18.0583	-18.5838***	132.9419
PAAA3_AD_L	*-2.5263***	*10.6802*	*-7.2234****	*66.8306*	*-5.4183****	*14.5363*	*-18.0251****	*127.5861*
PAAA5	-1.5787	3.8632	-7.1813***	43.9521	-2.7667***	5.3391	-13.9087***	85.7595
PAAA5_L	-1.3258	3.7093	-6.8171***	43.6746	-2.3216***	4.1785	-13.8450***	87.2536
PAAA5_AD_L	*-1.5908*	*3.8489*	*-7.1147****	*43.7777*	*-2.8242****	*5.4351*	*-13.8917****	*85.7927*
PAAA7	-1.6260	2.1706	-6.5231***	34.9019	-2.5999***	4.4974	-11.9813***	68.9135
PAAA7_L	-1.3387	2.4807	-6.4202***	37.0432	-2.2305**	3.6349	-12.4745***	74.0244
PAAA7_AD_L	*-1.5950*	*2.0476*	*-6.4679****	*32.5846*	*-2.9957****	*5.5289*	*-11.6370****	*63.6673*

Sample (adjusted): 21/01/2001-18/10/2002; 92 weekly observations; constant and linear time trend (shift) included in the text as exogenous variables. # MacKinnon (1996) critical values for rejection of hypothesis of a unit root based on one-sided p-values. Significance: * significant at 10% level, ** significant at 5% level, *** significant at 1% level. PP test completed with three-lag truncation for Bartlett (1981) kernel given Newey-West (1987) test.

Augmented Dickey-Fuller (ADF) test is based on: $\Delta y_t=\mu+\gamma_1 t+\gamma_2 y_{t-1}+\delta_1\Delta y_{t-1}+\delta_2\Delta y_{t-2}+\varepsilon_t$ with $H_0:\gamma_2=0$ vs. $H_1:\gamma_2<0$

Phillips-Perron (PP) test is based on: $\Delta y_t=\mu+\beta_1(t-T/2)+\beta_2 y_{t-1}+\varepsilon_t$ with $H_0:\beta_2=1$ vs. $H_1:\beta_2<1$

Tab. 25. *Test of unit root – all spread series of CDO, MBS and Pfandbrief transactions (actual, transformed and Johnson Fit adjusted spreads).*

	Collateralised Debt Obligations (CDO), synthetic																	
	CSAAA3		CSAAA3_L		CSAAA3_AD_L		CSA5		CSA5_L		CSA5_AD_L		CSBBB7		CSBBB7_L		CSBBB7_AD_L	
	BHHH	M	BHHH	M	BHHH	M	BHHH	M	BHHH	M	BHHH	M	BHHH	M	BHHH	M	BHHH	M
α_0	5.6629	11.6277**	0.3736	0.8084***	0.1681	0.5673**	82.1876***	36.7125***	1.3413*	1.0422***	0.8561	0.8234**	60.6480***	50.1377**	0.1505	0.7801**	1.0612	0.6703
	(0.7887)	(2.0442)	(0.4278)	(4.3991)	(0.3228)	(2.3169)	(5.3921)	(3.8377)	(1.8484)	(3.2132)	(0.6994)	(2.3969)	(2.9289)	(2.1338)	(0.5926)	(2.3033)	(0.9432)	(1.1831)
$\alpha_{1,1}$	-0.0292	-0.0843*	-0.0492	-0.1245***	0.0100	-0.0861**	-0.2565***	-0.11026***	-0.1707*	-0.1452***	-0.1161	-0.0996***	-0.0950***	-0.0609*	-0.0167	-0.0891**	-0.1325	-0.0737
	-(0.3667)	-(1.8029)	-(0.3634)	-(4.8184)	(0.1381)	-(2.1500)	-(5.6064)	-(3.8146)	-(1.8960)	-(3.3035)	-(0.8382)	-(2.5819)	-(2.6592)	-(1.9317)	-(0.5853)	-(2.0950)	-(1.0774)	-(1.1921)
$\alpha_{1,2}$	-0.0944	-0.1304**	-0.0624	-0.1358***	-0.0205	-0.1069**	-0.2862***	-0.1443***	-0.1782**	-0.1519***	-0.1266	-0.1041***	-0.1369***	-0.0963**	-0.0236	-0.0941**	-0.1404	-0.0811
	-(1.1794)	-(2.2624)	-(0.4571)	-(5.1952)	-(0.2787)	-(2.4369)	-(5.9723)	-(4.5266)	-(1.9683)	-(3.3717)	-(0.9098)	-(2.6786)	-(3.3330)	-(2.4910)	-(0.8070)	-(2.1667)	-(1.1281)	-(1.2729)
$\alpha_{2,1}$	-0.9928	-1.7704***	-0.1368	-0.2251***	-0.1482	-0.1686**	-10.9896***	-5.0398***	-0.3374*	-0.2212***	-0.1990	-0.2166**	-7.6613***	-7.0530**	-0.0357	-0.1835**	-0.2061	-0.1635
	-(1.0796)	-(2.6898)	-(0.6058)	-(3.5891)	-(0.9615)	-(2.2852)	-(5.2046)	-(3.8125)	-(1.8255)	-(2.7464)	-(0.5777)	-(2.1525)	-(2.6252)	-(2.1273)	-(0.5799)	-(2.2239)	-(0.7286)	-(1.1351)
$\alpha_{2,2}$	-0.7045	-1.6302**	-0.1208	-0.2178***	-0.1224	-0.1554**	-10.3384***	-4.6166***	-0.3258*	-0.2135***	-0.1812	-0.2129**	-6.9744***	-6.4840**	-0.0343	-0.1784**	-0.1955	-0.1543
	-(0.8030)	-(2.2152)	-(0.5368)	-(3.7199)	-(0.8175)	-(2.3193)	-(5.1427)	-(3.7183)	-(1.7578)	-(2.7797)	-(0.5291)	-(2.1487)	-(2.5168)	-(2.1519)	-(0.5490)	-(2.2342)	-(0.6962)	-(1.0871)
α_3	0.0725	0.2051	10.8264	3.1593	0.8867	2.4101	0.0069	0.0290	-3.8201	-4.2320***	-0.5681	-3.1765	0.0115	-0.0025	11.9613	-2.2831	-9.0706	-8.2993
	(0.4139)	(1.3289)	(0.2799)	(1.0714)	(0.1735)	(1.3336)	(0.2280)	(1.1875)	-(0.2980)	(0.5920)	-(0.0374)	-(0.4909)	(0.3437)	-(0.1052)	(1.2357)	-(0.4054)	-(1.1289)	-(0.7596)
β_0	4.6916	2.0758	-0.0025	0.0016	0.0825	0.0036	-117.5480	13.2978	0.0454***	0.0015	0.0402**	0.0048	-202.1772	57.3044	0.0326	0.0019	0.0212	0.0025
	(1.1534)	(0.2388)	-(0.1594)	(0.3757)	(1.4821)	(0.0560)	-(1.0040)	(0.0607)	(3.5771)	(0.0337)	(2.0382)	(0.8641)	-(0.5807)	(0.1156)	(1.0211)	(0.1910)	(0.6551)	(0.1658)
β_1	0.0007	-0.0321	-0.0029	-0.0313	0.0183	-0.0224	-0.0401**	-0.0313	0.0373	-0.0181	-0.0026	-0.0291	-0.0151	-0.0265	0.0299	0.0989	0.0744	-0.0187
	(0.0397)	-(0.6457)	-(0.6009)	-(0.8673)	(0.4590)	-(0.6368)	-(2.0888)	-(0.8348)	(1.1921)	-(0.6800)	-(0.1131)	-(1.3545)	-(0.3371)	-(0.5455)	(0.9771)	(1.1819)	(1.1934)	-(0.8653)
β_2	1.3508	0.7059	1.8411	0.7861	-0.2161	0.1569	1.1389	0.2230	1.7378	0.1816	0.5707	0.4609	0.3949	0.0671	0.8798	0.0753	0.0623	0.1350
	(1.2619)	(0.5441)	(0.2309)	(1.0094)	-(1.5171)	(0.6341)	(0.6263)	(0.0534)	(1.0053)	(0.0561)	(0.3310)	(1.0849)	(0.2824)	(0.0712)	(0.5946)	(0.0875)	(0.1393)	(0.4765)
β_3	0.0043	-0.0130	0.0008	-0.0001	-0.0114	-0.0005	0.6032**	-0.0072	-0.0058***	-0.0004	-0.0047**	-0.0004	0.5670	-0.0054	-0.0034	0.0001	-0.0026	0.0001
	(0.0887)	-(0.1814)	(0.3109)	-(0.1777)	-(1.3641)	-(0.0424)	(2.0434)	-(0.0118)	-(3.5538)	-(0.0681)	-(1.9611)	-(0.5894)	(0.7037)	-(0.0058)	-(0.8763)	(0.0885)	-(0.7561)	(0.0571)
β_4	-0.8316	-0.1798	0.0002	-0.0007	-0.0228	0.0001	12.7831	-0.1413	-0.0111***	0.0006	-0.0110**	-0.0018	18.4805	-0.4459	-0.0084	-0.0015	-0.0041	-0.0016
	-(1.6276)	-(0.1538)	(0.0555)	-(0.6244)	-(1.5008)	(0.0114)	(0.7843)	-(0.0048)	-(3.5940)	(0.0675)	-(2.0897)	-(1.1541)	(0.5247)	-(0.0150)	-(1.2269)	-(1.2034)	-(0.4896)	-(0.3404)
β_5	0.2786	0.5402***	-0.0080	0.7080***	0.1876	0.5772	0.2185	0.5794	0.2630**	0.5358	0.5468**	0.8814***	0.5842	0.5801	-0.3852**	0.5760***	0.5387***	0.6524
	(1.3202)	(3.3529)	-(0.0244)	(13.0004)	(0.3804)	(0.8391)	(0.9346)	(1.5814)	(1.9765)	(0.7306)	(2.0165)	(12.4155)	(1.1636)	(0.3931)	-(2.3793)	(6.6436)	(2.8658)	(0.8460)

Z-statistics in parentheses; ***=1% significance, **=5% significance, *=10% significance. $ no Bollerslev-Woolridge robust standard errors and variance.

Tab. 26. *Estimation Results of GARCH(1,1) model for synthetic CDO spreads (actual, transformed and Johnson Fit adjusted spreads) – LIBOR at level data.*

	Collateralised Debt Obligations (CDO), synthetic																		
	CTAAA3		CTAAA3_L		CTAAA3_AD_L		CTA5		CTA5_L		CTA5_AD_L		CTBBB7		CTBBB7_L		CTBBB'
	BHHH	M	BHHH	M	BHHH	M§	BHHH	M	BHHH	M	BHHH	M	BHHH	M	BHHH	M	BHHH
α_0	0.5409	0.5852	-0.0837	0.0601	-0.7135	0.2943	11.1646	16.0871	0.3411	0.4467	0.1866	0.0937	3.7886	6.9902	-0.1282	0.1158	0.4390
	(0.5399)	(0.7471)	-(0.2749)	(1.0171)	-(0.5266)	(1.0250)	(1.0199)	(0.9238)	(0.8970)	(1.0432)	(0.7681)	(0.1888)	(0.3888)	(0.4518)	-(0.5296)	(2.0102)	(0.6291)
$\alpha_{1,1}$	-0.0101	-0.0126	0.0133	-0.0120	0.1775	-0.0511	-0.0402	-0.0522	-0.0513	-0.0688	-0.0280	-0.0318	-0.0585***	-0.0117	0.0328	-0.0160***	-0.0769
	-(0.5628)	-(0.7535)	(0.1853)	-(0.7090)	(0.5247)	-(0.7022)	-(0.6870)	-(0.6057)	-(0.6734)	-(0.9355)	-(0.7225)	-(0.5013)	-(10.3849)	-(0.2991)	(0.7713)	-(2.7979)	-(0.6902)
$\alpha_{1,2}$	-0.0948***	-0.0928***	-0.0146	-0.0379**	0.1528	-0.0758	-0.1066*	-0.1105	-0.0642	-0.0797	-0.0391	-0.0390	-0.1035***	-0.0415	0.0287	-0.0261***	-0.0892
	-(5.3820)	-(5.2279)	-(0.2054)	-(2.2705)	(0.4525)	-(1.0653)	-(1.6536)	-(1.2438)	-(0.7932)	-(1.0712)	-(0.9835)	-(0.6297)	-(7.1422)	-(0.9013)	(0.6629)	-(6.1301)	-(0.7861)
$\alpha_{2,1}$	-0.1292	-0.0823	0.0251	-0.0119	0.0564	-0.0813**	-1.0001	-1.6299	-0.0745	-0.0654	-0.0369	0.0378	-0.4421	-0.8705	-0.0245	-0.0220	-0.0196
	-(1.2914)	-(0.9193)	(0.5625)	-(0.5299)	(0.5495)	-(2.3773)	-(0.8092)	-(0.8066)	-(1.2070)	-(0.9093)	-(0.7351)	(0.2229)	-(0.2285)	-(0.5828)	-(0.5793)	-(0.7608)	-(0.2799)
$\alpha_{2,2}$	-0.0050	-0.0257	0.0286	-0.0108	0.0635	-0.0762**	-1.0054	-1.6279	-0.0708	-0.0670	-0.0362	0.0431	-0.6195	-0.6917	-0.0201	-0.0120	-0.0178
	-(0.0513)	-(0.3345)	(0.6702)	-(0.5185)	(0.6198)	-(2.3188)	-(0.8809)	-(0.8451)	-(1.1766)	-(0.9721)	-(0.7214)	(0.2597)	-(0.2971)	-(0.4787)	-(0.5203)	-(0.4291)	-(0.2563)
α_3	0.2307	0.1851**	8.0880	2.9834	21.5533	11.7871	-0.0942	-0.1492	7.4916	-12.5652	2.5065	-4.5571	2.1909***$^{\$}$	0.0073	2.0140	20.0742***$^{\$}$	7.9509
	(1.2681)	(1.9830)	(0.3698)	(0.6428)	(0.4549)	(1.0322)	-(0.7191)	-(1.1969)	(0.7506)	-(0.9305)	(1.0794)	-(0.3882)	(3.8512)	(0.1435)	(0.4297)	(4.9169)	(0.9429)
β_0	0.5376	0.5145	0.0044	-0.0007	0.0202	0.0012	-6.0672	9.4582	0.0263	0.0015	0.0243**	-0.0016	-18.2465	25.6589	0.0058	0.0004	0.0129
	(0.4812)	(0.4514)	(1.3944)	-(0.2501)	(1.0666)	(0.1793)	-(0.2531)	(0.2326)	(0.7287)	(0.1377)	(2.4426)	-(1.2960)	-(0.9476)	(0.2289)	(0.5457)	(0.2362)	(0.7765)
β_1	-0.0214	-0.0209*	-0.0089	-0.0147	-0.0114	-0.0246	-0.0313	-0.0370*	0.1382	-0.0291	0.1741	0.0397	-0.2356	0.1776	0.2464	0.1680	0.3558*
	-(1.3491)	-(1.7145)	-(0.5908)	-(0.5516)	-(0.3718)	-(1.2860)	-(1.3884)	-(1.8033)	(1.3139)	-(1.4490)	(0.9792)	(1.2659)	-(1.1028)	(0.7828)	(0.9969)	(1.4149)	(1.6544)
β_2	0.4425	0.0735	0.9194	0.0867	0.1371	0.2851	-0.0750	-0.0291	-0.1256	0.0659	-0.6778**	-0.1088	0.4408	-0.2316	0.2613	0.0683	-0.1365
	(0.1257)	(0.0173)	(0.2117)	(0.0304)	(0.3769)	(1.3934)	-(0.5181)	-(0.2633)	-(0.5272)	(0.4846)	-(2.5173)	-(0.9324)	(1.7377)	-(0.7993)	(0.3959)	(0.6003)	-(0.4364)
β_3	-0.0025	-0.0005	-0.0013	-0.0005	-0.0050	-0.0008	0.0694	0.0298	-0.0032	-0.0002	-0.0036**	-0.0003***	0.1725	0.0187	-0.0009	0.0000	-0.0020
	-(0.1340)	-(0.0148)	-(1.1331)	-(0.4761)	-(1.0883)	-(0.5056)	(0.4119)	(0.1285)	-(0.5237)	-(0.1160)	-(2.4146)	-(10.3164)	(11.1763)	(0.0557)	-(0.5038)	(0.0309)	-(0.7841)
β_4	-0.0030	-0.0007	0.0002	0.0018	-0.0014	0.0013	1.1979	-0.9925	-0.0071	0.0001	-0.0046**	0.0021**	-0.2055	-4.4633	-0.0007	-0.0002	-0.0014
	-(0.0350)	-(0.0061)	(0.1692)	(1.5088)	-(0.7239)	(0.9064)	(0.4797)	-(0.2285)	-(1.2444)	(0.0791)	-(2.3085)	(2.1239)	-(0.0516)	-(0.4683)	-(0.8061)	-(0.5885)	-(0.7085)
β_5	0.5787**	0.5921**	0.3471	0.5303	0.2834	0.5115*	0.7020**	0.5842*	0.3533	0.6283	0.5237**	0.7522***	0.6533***	0.6592	0.7080	0.6035***	0.4624
	(2.0079)	(1.9120)	(0.4950)	(0.5383)	(0.3945)	(1.8500)	(2.0848)	(1.8914)	(1.4323)	(2.5105)	(2.2190)	(7.8176)	(5.6901)	(1.1907)	(3.3915)	(2.8132)	(1.2741)

Z-statistics in parentheses; ***=1% significance, **=5% significance, *=10% significance. § no Bollerslev-Woolridge robust standard errors and variance; $^{\$}$ SQR-GARCH result.

Tab. 27. *Estimation Results of GARCH(1,1) model for traditional CDO spreads (actual, transformed and Johnson Fit adjusted spreads) – LIBOR at level data.*

	Mortgage-Backed Securities (MBS)											
	MAAA3		MAAA3_L		MAAA3_AD_L		MAAA5		MAAA5_L		MAAA5_AD_L	
	BHHH	M	BHHH	M[§]	BHHH	M	BHHH	M[§]	BHHH	M[§]	BHHH	M
α_0	0.0698	-0.0726	-0.0533	0.0039	0.9237	0.3424	0.1344	-0.1093	0.0792**	0.0492	1.13716***	1.2931***
	(0.1339)	-(0.2750)	-(0.4787)	(0.0310)	(1.0183)	(1.1870)	(0.5856)	-(1.3769)	(1.9771)	(0.8006)	(4.2574)	(4.6541)
$\alpha_{1,1}$	0.0317	0.0058	0.0224	-0.0078	-0.2341	-0.18967**	-0.0435***	-0.0149***	-0.0405***	-0.0257	-0.4084***	-0.4882***
	(0.4216)	(0.4881)	(0.3548)	-(0.1530)	-(1.0996)	-(2.0648)	-(5.4542)	-(2.2072)	-(2.8977)	-(0.8428)	-(4.1699)	-(4.4655)
$\alpha_{1,2}$	0.0083	-0.0428***	0.0087	-0.0255	-0.2939	-0.1916**	-0.0872***	-0.0588***	-0.0551***	-0.0403	-0.4302***	-0.4889***
	(0.1150)	-(4.1383)	(0.1402)	-(0.5042)	-(1.4322)	-(2.0874)	-(9.1186)	-(8.7137)	-(3.8996)	-(1.3417)	-(4.4030)	-(4.4651)
$\alpha_{2,1}$	-0.0774	-0.0009	-0.0038	0.0147	-0.0545	0.1656	0.2235***	0.1191***	0.0382***	0.0237	0.0951	0.1543*
	-(0.2920)	-(0.0104)	-(0.0675)	(0.4824)	-(0.1876)	(1.4387)	(3.6672)	(2.7425)	(2.4978)	(0.3622)	(1.4032)	(1.6910)
$\alpha_{2,2}$	-0.0728	0.0196	-0.0036	0.0180	-0.0682	0.1630	0.2165***	0.1318***	0.0392***	0.0238	0.1006	0.1485*
	-(0.2949)	(0.2663)	-(0.0657)	(0.5922)	-(0.2422)	(1.4285)	(3.8529)	(2.9256)	(2.6728)	(0.3684)	(1.4829)	(1.6540)
α_3	-1.0954	-0.1041	-13.1130	-0.0002	-16.8725	-8.5146	0.1158	0.0477	-4.8700	10.7097	-0.1351	-0.4513
	-(1.0686)	-(0.3472)	-(0.7192)	(0.0000)	-(0.8079)	-(1.3835)	(0.3980)	(0.1772)	-(0.4817)	(0.3017)	-(0.9746)	-(0.7901)
β_0	-0.0625	0.0906	-0.0005	-0.0004	0.0024	-0.0104*	-0.1749	0.0210	0.0002	0.0000	-0.1489**	-0.0264
	-(0.2568)	(0.4329)	-(0.7642)	-(0.5182)	(0.4813)	-(1.6789)	-(0.7659)	(0.3797)	(0.1980)	(0.0732)	-(2.3609)	-(0.7384)
β_1	0.0093	0.0030	0.0612	0.1223	-0.0190	-0.0013	0.3279	0.8260***	0.1862	0.1629	0.3987*	1.0853
	(0.0614)	(0.0998)	(1.0336)	(0.4899)	-(0.9008)	-(0.0077)	(0.2853)	(5.9285)	(0.5922)	(1.0381)	(1.8461)	(1.1291)
β_2	0.4527	-0.1782**	0.4175	0.0544	0.0950	0.0494	-1.3062	0.8982	-0.7514**	0.0518	1.4608*	0.4080
	(0.7403)	-(1.9816)	(0.5363)	(0.1452)	(1.1319)	(0.2688)	-(0.9057)	(0.7670)	-(2.0120)	(0.0973)	(1.8608)	(0.4617)
β_3	0.0325	0.0001	0.0001	0.0002	0.0000	0.0005	-0.0044	-0.0026***	-0.0002	-0.0002**	0.0457**	0.0056
	(0.7572)	(0.0171)	(0.9736)	(0.3874)	(0.2178)	(1.3507)	-(0.5244)	-(3.5536)	-(0.8432)	-(2.4012)	(2.1344)	(0.5025)
β_4	-0.0928	0.0003	-0.0003	0.0000	-0.0005	0.0006**	0.0962	0.0108	0.0005	0.0004**	0.0061	0.0067***
	-(0.6479)	(0.0105)	-(0.6355)	(0.0826)	-(0.6713)	(1.8720)	(1.5304)	(0.5943)	(1.1136)	(2.2468)	(0.8620)	(2.9066)
β_5	0.0136	0.5482	0.0107	0.5774	0.8653	0.3978***	0.0518	0.1638	0.4637	0.5950***	-0.0122	0.0079
	(0.0893)	(1.1846)	(0.1088)	(1.3767)	(4.4138)	(2.9750)	(0.4083)	(1.5546)	(1.4356)	(6.3988)	-(0.7778)	(0.6601)
	MA7		MA7_L		MA7_AD_L		MBBB7		MBBB7_L		MBBB7_AD_L	
	BHHH	M	BHHH	M[§]	BHHH	M[§]	BHHH	M	BHHH	M[§]	BHHH	M
a_0	0.9846	-0.1528	-0.0505	-0.0119	-0.0364	-0.0068	9.6640	-3.5135	-0.2022**	-0.0420	1.5360**	2.9156***
	(0.4708)	-(0.1344)	-(0.1042)	-(0.0992)	-(0.2059)	-(0.0403)	(0.6319)	-(0.9835)	-(2.4117)	-(0.4306)	(2.2702)	(4.8699)
$a_{1,1}$	-0.0449	0.0032	0.0107	-0.0007	0.0165	-0.0047	-0.0751	-0.0011	0.0334***	-0.0019	-0.3043**	-0.5922***
	-(0.6737)	(0.1556)	(0.0768)	-(0.0206)	(0.3643)	-(0.1170)	-(0.7548)	-(0.0711)	(4.5207)	-(0.1234)	-(2.3303)	-(4.8137)
$a_{1,2}$	-0.0722	-0.0227	0.0089	-0.0070	0.0135	-0.0104	-0.1093	-0.0271*	0.0280***	-0.0065	-0.3270**	-0.6115***
	-(1.2098)	-(1.1280)	(0.0643)	-(0.2074)	(0.3041)	-(0.2618)	-(1.1208)	-(1.6582)	(3.8276)	-(0.4559)	-(2.4617)	-(4.9738)
$a_{2,1}$	0.3379	0.0096	0.0013	0.0104	-0.0162	0.0185	0.0558	0.8405**	0.0318	0.0368	-0.0193	0.0115
	(0.7182)	(0.0668)	(0.0196)	(0.2813)	-(0.9998)	(0.3221)	(0.0549)	(2.0711)	(0.5625)	(0.6938)	-(0.2680)	(0.1889)
$a_{2,2}$	0.3919	-0.0012	0.0014	0.0117	-0.0136	0.0210	0.0703	0.8250**	0.0328	0.0366	-0.0219	0.0081
	(0.8644)	-(0.0099)	(0.0212)	(0.3152)	-(0.7925)	(0.3683)	(0.0691)	(2.1183)	(0.5766)	(0.6841)	-(0.3031)	(0.1304)
a_3	0.4709*[$]	0.0297	23.7852*	24.6253	-5.1952	-0.0001	0.2348	0.0581	-24.9125	4.3805	1.7645	3.9074
	(1.8230)	(0.0916)	(1.8000)	(0.6458)	-(0.5337)	(0.0000)	(0.5600)	(0.7364)	-(1.2921)	(0.1401)	(0.8142)	(0.8978)
β_0	-5.3516	0.4602	0.0004	-0.0002	0.0016	-0.0006**	-46.0613	4.8028	-0.0001	-0.0006***	-0.0776**	-0.0100
	-(0.7215)	(0.0969)	(3.5248)	-(1.7584)	(0.2996)	-(1.9298)	-(1.3728)	(0.1296)	-(0.1843)	-(4.1222)	-(2.2549)	-(0.1379)
β_1	-0.0089	-0.0170	0.1453**	0.1343	0.1241	0.1401	-0.0182	-0.0206	0.0434	0.1454	0.2669	0.5514
	-(0.1728)	-(0.6640)	(2.1786)	(0.5083)	(1.1818)	(0.6356)	-(0.4764)	-(0.6482)	(1.4703)	(0.9352)	(1.2400)	(0.4615)
β_2	2.2857	-0.0922	0.0592	0.0453	0.0210	0.0509	0.1554	-0.0647	0.5090	0.0527	0.4774	-0.1345
	(0.9686)	-(0.1161)	(0.2265)	(0.1417)	(0.0431)	(0.0550)	(0.4910)	-(0.7827)	(1.3938)	(0.2001)	(0.5279)	-(0.1432)
β_3	0.1600	-0.0002	-0.0001***	-0.0000***	-0.0004	-0.0001***	0.3101	-0.0006	-0.0002***	-0.0000***	0.0145**	0.0002
	(0.8477)	-(0.0027)	-(10.2957)	-(6.4880)	-(0.3236)	-(7.3532)	(1.2139)	-(0.0039)	-(7.3622)	-(5.2730)	(2.2189)	(0.0148)
β_4	-0.9421	-0.0010	0.0000	0.0003***	0.0002	0.0008***	2.3255*	0.0245	0.0008	0.0006***	0.0041***	0.0065**
	-(1.0215)	-(0.0093)	(0.1944)	(2.6140)	(0.9834)	(2.8981)	(1.6750)	(0.0112)	(1.5848)	(4.4062)	(2.7368)	(2.4768)
β_5	-0.0677	0.5849	0.6162	0.5953***	0.6633	0.5962***	-0.0406	0.5261	0.4580***	0.5960***	0.3891**	0.0892
	-(0.1284)	(0.3992)	(1.1891)	(4.3514)	(3.4786)	(4.6666)	-(0.1129)	(0.4391)	(3.1386)	(8.0502)	(1.8906)	(0.3278)

Z-statistics in parentheses; ***=1% significance, **=5% significance, *=10% significance. [§] no Bollerslev-Woolridge robust standard errors and variance; [$] SQR-GARCH result.

Tab. 28. *Estimation Results of GARCH(1,1) model MBS spreads (actual, transformed and Johnson Fit adjusted spreads) – LIBOR at level data.*

	Pfandbriefe																	
	PAAA3		PAAA3_L		PAAA3_AD_L		PAAA5		PAAA5_L		PAAA5_AD_L		PAAA7		PAAA7_L		PAAA7_AD_L	
	BHHH	M	BHHH	M	BHHH	M§	BHHH	M	BHHH	M	BHHH	M	BHHH	M	BHHH	M	BHHH	M
α_0	3.9549***	4.1712***	0.6664**	0.8484***	0.3371*	0.6694***	-0.3175	-1.8157**	-0.0265	-0.0061	0.0096	0.1029	10.2552	1.5828	0.2707	0.2698	0.1282	0.8264***
	(4.5495)	(4.5403)	(2.3498)	(4.8825)	(1.9480)	(3.1636)	-(0.1399)	-(1.9784)	-(0.2131)	-(0.0656)	(0.0527)	(0.7087)	(0.0084)	(0.8220)	(0.6421)	(1.2464)	(1.2063)	(3.5174)
$\alpha_{1,1}$	-0.2361	-0.2763***	-0.2508*	-0.2993***	-0.1328**	-0.2377***	0.0416	-0.0076	-0.0007	-0.0329	0.0034	-0.0562	0.0044	-0.0288	-0.0894	-0.0810	-0.0433	-0.3019***
	-(1.5904)	-(3.1123)	-(1.6861)	-(2.5761)	-(2.1319)	-(2.7505)	(0.8726)	-(0.2733)	-(0.0161)	-(1.0944)	(0.0715)	-(1.5046)	(0.0015)	-(0.7455)	-(0.5900)	-(0.9745)	-(1.0492)	-(3.5624)
$\alpha_{1,2}$	-0.3200***	-0.3398***	-0.2800**	-0.3273***	-0.1576**	-0.2647***	-0.0726	-0.1171***	-0.0322	-0.0692**	-0.0338	-0.0936**	-0.0454	-0.1239***	-0.1182	-0.1089	-0.0751*	-0.3270***
	-(2.6170)	-(4.2243)	-(1.9870)	-(2.9545)	-(2.5466)	-(3.1353)	-(1.4602)	-(4.7159)	-(0.7343)	-(2.3776)	-(0.6981)	-(2.5064)	-(0.0157)	-(3.3592)	-(0.7796)	-(1.3064)	-(1.8392)	-(3.8437)
$\alpha_{2,1}$	0.2305	0.2922	0.0732	0.0466	0.0439	0.0455	0.2300	0.6491***	0.0480	0.1021**	0.0315	0.0787	0.0282	-0.1206	0.0781	0.0559	0.0381	0.2143
	(0.5676)	(1.3821)	(0.7773)	(0.3340)	(1.4013)	(0.5294)	(0.3928)	(2.8443)	(0.4410)	(2.2135)	(0.2627)	(0.9720)	(0.0001)	-(0.2112)	(0.6001)	(0.6694)	(0.7809)	(1.5737)
$\alpha_{2,2}$	0.2986	0.3440	0.0773	0.0497	0.0483*	0.0479	0.2046	0.7283***	0.0491	0.1101**	0.0284	0.0849	0.1044	0.0077	0.0878	0.0651	0.0503	0.2277*
	(0.6549)	(1.4898)	(0.7657)	(0.3502)	(1.6853)	(0.5454)	(0.3595)	(3.1888)	(0.4507)	(2.3588)	(0.2419)	(1.0786)	(0.0004)	(0.0134)	(0.6839)	(0.7949)	(1.0518)	(1.6733)
α_3	-0.0983	-0.0887	-3.3732	-6.6377	0.1799	-6.5453	-0.0653	-0.1278***	0.8377	-2.5695	-0.4139	-0.0091	-7.3575$	0.4745*	-23.0264	-21.5251	-0.0609	-43.8189**
	-(0.6256)	-(1.1115)	-(0.9918)	-(0.4747)	(0.0838)	-(0.5626)	-(0.1483)	-(2.6473)	(0.0702)	-(0.8588)	-(0.0392)	-(0.0014)	-(0.0724)	(1.6579)	-(0.5045)	-(1.1081)	-(0.0143)	-(1.8944)
β_0	-1.6088	1.9050**	-0.0087	0.0159***	0.0128*	0.0218***	-0.9827	-0.7278	-0.0023	-0.0018	-0.0013	-0.0001	0.8594	-0.1347	0.0096	0.0087*	0.0022	0.0045***
	-(0.5469)	(2.1147)	-(0.4421)	(3.3432)	(7.2262)	(3.6464)	-(0.4079)	-(0.7681)	-(0.5749)	-(0.5860)	-(0.2556)	-(0.0276)	(0.0043)	-(0.1308)	(1.1431)	(1.7911)	(0.2713)	(3.6997)
β_1	0.0313	0.3166*	0.1884	0.0886	0.1103	0.1248	-0.0096	0.0781*	-0.0188	0.0137	-0.0080	-0.0367	0.1515	-0.1592	0.0801	0.1711	0.4441*	0.0446
	(0.4247)	(1.6423)	(1.4286)	(0.7803)	(0.8971)	(0.9484)	-(0.1736)	(1.7815)	-(0.3292)	(0.4646)	-(0.0938)	-(0.2232)	(0.0359)	-(1.0426)	(0.3453)	(1.2058)	(1.9043)	(1.0182)
β_2	1.3898	3.2809	1.1873	1.3155	2.2513***	0.5987	0.0207	3.8487*	0.1994	1.6646**	0.0068	-0.0728	-0.2496	0.1515	-0.0452	-0.0480	-0.3781	0.14646*
	(0.6180)	(0.9827)	(0.7876)	(0.4713)	(2.7118)	(0.4979)	(0.0795)	(1.8231)	(0.9099)	(2.2041)	(0.0326)	-(0.5866)	-(0.0294)	(1.1131)	-(0.3076)	-(0.4493)	-(1.4165)	(1.6698)
β_3	0.1248	0.0128	0.0041	-0.0030	-0.0020*	-0.0062*	0.0117	0.0060	-0.0003	0.0002	-0.0001	0.0000	0.0290	0.0313**	-0.0033	-0.0029	-0.0017	-0.0020***
	(0.5577)	(0.0706)	(0.5417)	-(0.9299)	-(1.9074)	-(1.8656)	(0.5712)	(0.3136)	-(0.2365)	(0.2524)	-(0.1146)	(0.0526)	(0.0510)	(2.4827)	-(1.0660)	-(1.4439)	-(0.5843)	-(10.2139)
β_4	-0.1577	-0.3340	-0.0021	-0.0036	-0.0038***	-0.0015	0.2066	0.1869	0.0027	0.0011	0.0012	0.0001	-0.2154	-0.1366	0.0024	0.0018	0.0039	0.0018**
	-(0.5073)	-(0.5567)	-(0.8658)	-(0.6569)	-(3.2261)	-(0.3510)	(0.3503)	(0.8512)	(0.8189)	(0.7552)	(0.3012)	(0.0273)	-(0.0069)	-(0.3914)	(0.7751)	(0.7492)	(1.2765)	(2.3578)
β_5	0.6747**	-0.0181	0.6548***	0.0557	0.0428	0.0825	0.8754*	0.3792*	0.6935*	0.4336	0.9378	1.0295***	0.6210	0.9664***	-0.0477	0.1142	-0.1975	0.6096***
	(2.5617)	-(0.2694)	(4.2347)	(0.4662)	(0.4804)	(0.6022)	(1.7454)	(1.9577)	(1.7257)	(1.4117)	(2.2243)	(3.0848)	(0.0394)	(4.6496)	-(0.0613)	(0.4620)	-(1.4082)	(6.5966)

Z-statistics in parentheses; ***=1% significance, **=5% significance, *=10% significance. § no Bollerslev-Woolridge robust standard errors and variance; $ SQR-GARCH result.

Tab. 29. *Estimation Results of GARCH(1,1) model for Pfandbrief spreads (actual, transformed and Johnson Fit adjusted spreads) – LIBOR at level data.*

	Collateralised Debt Obligations (CDO), synthetic																
	CSAAA3		CSAAA3_L		CSAAA3_AD_L		CSA5		CSA5_L		CSA5_AD_L		CSBBB7		CSBBB7_L		CSBBB7
	BHHH	M	BHHH	M	BHHH	M	BHHH	M	BHHH	M	BHHH	M	BHHH	M	BHHH	M	BHHH
α_0	7.9788	12.7725***	0.4420	0.8244	0.4512*	0.4900	4.0043	41.6226**	0.8631***	0.9854***	0.9461*	0.9770**	93.0984***	87.8123***	1.2159**	1.2243*	1.1291**
	(0.7090)	(2.8526)	(1.0239)	(0.9245)	(1.7998)	(1.2518)	(0.9378)	(2.5123)	(3.7288)	(2.6027)	(1.7644)	(2.0314)	(4.0323)	(2.8247)	(2.4032)	(1.7528)	(2.0673)
$\alpha_{1,1}$	-0.1576	-0.1360**	-0.3165	-0.1527	-0.5265***	-0.0742	0.0448	-0.1112	-0.5389***	-0.1538	-0.2365	-0.1521***	-0.1971***	-0.1604	-0.5286**	-0.2045	-0.3345***
	-(1.2616)	-(2.1247)	-(1.5516)	-(0.7655)	-(3.3951)	-(0.6637)	(0.7880)	-(1.2405)	-(3.8971)	-(0.7907)	-(1.5629)	-(2.6568)	-(3.7334)	-(1.1820)	-(2.2025)	-(0.8349)	-(3.2618)
$\alpha_{1,2}$	-0.1892	-0.1702***	-0.3252	-0.1623	-0.5232***	-0.0892	0.0230	-0.1245	-0.5407***	-0.1565	-0.2390	-0.1541***	-0.2121***	-0.1835	-0.5289**	-0.2074	-0.3362***
	-(1.5588)	-(2.7327)	-(1.5746)	-(0.8140)	-(3.4540)	-(0.8003)	(0.4376)	-(1.4116)	-(3.9069)	-(0.8044)	-(1.5863)	-(2.7158)	-(4.0134)	-(1.3159)	-(2.1923)	-(0.8502)	-(3.2779)
$\alpha_{2,1}$	0.1146	0.0512	0.2573	0.0336	0.4876***	0.0019	-0.0854	-0.0127	0.4234***	0.0200	0.1174	0.0398**	0.1063**	0.0686	0.3789*	0.0705	0.2047***
	(1.4179)	(1.3623)	(0.9789)	(0.3351)	(2.8917)	(0.0373)	-(1.3783)	-(0.1919)	(3.1670)	(0.1169)	(0.7602)	(2.5641)	(1.9588)	(0.5542)	(1.7900)	(0.2713)	(3.7188)
$\alpha_{2,2}$	0.0869	0.0185	0.2531	0.0305	0.4675***	-0.0032	-0.0936*	-0.0402	0.4163***	0.0156	0.1087	0.0364**	0.0742	0.0441	0.3717*	0.0675	0.1979***
	(1.1439)	(0.5267)	(0.9569)	(0.3069)	(2.8508)	-(0.0655)	-(1.7148)	-(0.6068)	(3.1236)	(0.0912)	(0.7092)	(2.4113)	(1.4016)	(0.3397)	(1.7693)	(0.2599)	(3.5631)
$\alpha_{3,1}$	-1.3348	-1.9666***	-0.1536	-0.2456	-0.2089***	-0.1501	-0.4498	-5.9072**	-0.1952***	-0.2185**	-0.2400	-0.2695**	-13.6506***	-12.1689***	-0.2487**	-0.3075	-0.2557**
	-(0.8983)	-(3.0973)	-(1.3604)	-(0.8048)	-(2.6787)	-(1.5846)	-(0.6158)	-(2.7318)	-(3.6057)	-(2.3200)	-(1.5306)	-(2.0732)	-(4.1595)	-(3.4613)	-(2.4015)	-(1.6330)	-(2.2377)
$\alpha_{3,2}$	-1.1029	-1.7746***	-0.1405	-0.2355	-0.1718***	-0.1363	0.0414	-5.3946*	-0.1936***	-0.2094**	-0.2182	-0.2629**	-13.3445***	-12.4147***	-0.2436**	-0.2994	-0.2506**
	-(0.7626)	-(2.9835)	-(1.2549)	-(0.7600)	-(2.2718)	-(1.5869)	(0.0624)	-(2.5534)	-(3.6172)	-(2.3347)	-(1.4292)	-(2.0562)	-(4.1993)	-(3.5787)	-(2.3949)	-(1.5803)	-(2.2008)
α_4	0.0659	0.1653	12.6202	-4.6430	0.2385	1.7231	0.1641**	0.0717	4.4645***	-5.1008	-3.3676	-10.6189	-0.0531	-0.0496	0.1807	-14.5659	-8.8101
	(0.3729)	(0.8499)	(0.3752)	-(0.0559)	(0.1367)	(0.3261)	(2.4348)	(0.6923)	(0.9450)	-(0.0895)	-(0.3630)	-(1.5540)	-(0.6366)	-(0.2666)	(0.0175)	-(0.3535)	-(1.5093)
β_0	-14.5372	2.1177	-0.0076	0.0028	0.0918**	0.0035	127.8183***	13.1115	0.0141	0.0011	0.0308	0.0032	-129.7419	54.5565	0.0109	0.0037	0.0067
	-(0.6572)	(0.2507)	-(2.3390)	(0.3127)	(2.1182)	(0.0403)	(2.7676)	(0.0786)	(1.2250)	(0.0304)	(1.1176)	(0.5237)	-(1.4244)	(0.4001)	(1.4559)	(1.3142)	(0.7215)
β_1	0.0372	-0.0318	0.0096	-0.0106	0.4130	-0.0215	-0.0115	-0.0301	0.1056*	-0.0161	0.0619	-0.0319	-0.0260	-0.0127	0.0940	-0.0240	0.0611
	(0.7905)	-(0.9545)	(0.2512)	-(0.2304)	(1.2536)	-(0.5969)	-(0.9392)	-(0.6129)	(1.8152)	-(0.6207)	(1.1260)	-(1.4870)	-(1.1804)	-(0.8405)	(1.0954)	-(1.2809)	(0.6275)
β_2	2.0004	0.5680	1.9087	0.7363	-0.4774	0.1675	1.5589*	0.1989	1.9600	0.2526	0.0272	0.3497	1.2635	2.1876	0.0609	0.1964	0.1205
	(0.8089)	(0.4273)	(0.2001)	(0.2820)	-(1.4226)	(0.6034)	(1.8318)	(0.0647)	(0.4711)	(0.0550)	(0.0301)	(0.7898)	(1.3324)	(0.7900)	(0.0898)	(0.5913)	(0.3837)
β_3	0.1192	-0.0117	0.0014***	-0.0003	-0.0133	-0.0004	-0.2954**	-0.0068	-0.0018	-0.0002	-0.0039	-0.0003	0.3021*	0.0149	-0.0014	-0.0001	-0.0007
	(0.6753)	-(0.2342)	(3.1306)	-(0.1851)	-(2.0757)	-(0.0284)	-(2.1389)	-(0.0146)	-(1.1367)	-(0.0502)	-(1.1666)	-(0.8885)	(1.7168)	(0.0659)	-(1.3941)	-(0.3470)	-(0.6463)
β_4	6.7962	-0.4344	0.0018	-0.0011	-0.0254**	0.0002	-18.0546***	-0.1214	-0.0035	0.0004	-0.0075	-0.0010	13.3568	-4.3228	-0.0022	-0.0018	-0.0017
	(0.6633)	-(0.1029)	(1.5991)	-(0.4500)	-(2.1487)	(0.0143)	-(2.8365)	-(0.0054)	-(1.3333)	(0.0502)	-(1.0411)	-(0.4001)	(1.2583)	-(0.2626)	-(1.5327)	-(1.5358)	-(0.8310)
β_5	0.2884	0.4936	0.0648	0.5770	-0.0053	0.5230	-0.1828	0.5083	-0.0732	0.4463	0.3139	0.76623***	0.9441***	0.32858***	1.16305***	0.5297	0.6896
	(0.4842)	(1.0473)	(0.1915)	(1.5705)	-(0.0209)	(0.8905)	-(0.9887)	(1.0890)	-(0.4811)	(0.6734)	(0.9934)	(3.7768)	(5.6159)	(2.7351)	(2.6311)	(0.5571)	(0.4944)
β_6	-0.0170	-0.0183	0.1859	-0.0314	0.1209	0.0248	0.5671***	0.0171	0.0087	-0.0651	0.2954	0.2048**	-0.2172**	-0.1381	-0.3871	0.0259	0.1188
	-(0.0945)	-(0.1318)	(0.2845)	-(0.1757)	(0.9002)	(0.0300)	(2.5995)	(0.0313)	(0.2239)	-(0.1051)	(0.8117)	(2.0187)	-(2.0889)	-(1.0310)	-(0.8424)	(0.0399)	(0.0953)

Z-statistics in parentheses; ***=1% significance, **=5% significance, *=10% significance. § no Bollerslev-Woolridge robust standard errors and variance.

Tab. 30. *Estimation Results of GARCH(2,1) model for synthetic CDO spreads (actual, transformed and Johnson Fit adjusted spreads) – LIBOR at level data.*

Collateralised Debt Obligations (CDO), traditional

	CTAAA3		CTAAA3_L		CTAAA3_AD_L		CTA5		CTA5_L	
	BHHH	M	BHHH	M§	BHHH	M§	BHHH	M	BHHH	M
α_0	-1.6504	0.4481	0.0639	0.0473	-1.3025***	0.2386	14.5228	16.0989	0.0236	0.4432
	-(0.9151)	(0.3168)	(0.9077)	(0.6798)	-(2.5877)	(1.0214)	(1.4443)	(1.2618)	(0.0328)	(0.7378)
$\alpha_{1,1}$	0.1646	0.0257	0.0212	-0.0030	0.2034*	0.0347	0.0408	-0.0013	0.0016	-0.0029
	(0.7158)	(0.3474)	(0.2776)	-(0.0426)	(1.7791)	(0.1912)	(0.4395)	-(0.0088)	(0.0165)	-(0.0082)
$\alpha_{1,2}$	0.0987	-0.0582	-0.0018	-0.0272	0.1891*	0.0105	-0.1421	-0.0334	-0.0074	-0.0143
	(0.4481)	-(0.8456)	-(0.0235)	-(0.3978)	(1.6724)	(0.0583)	-(0.5187)	-(0.1269)	-(0.0780)	-(0.0411)
$\alpha_{2,1}$	-0.1375	-0.0429	-0.0379	-0.0104	0.1029	-0.0675	-0.1078	-0.0570	-0.0069	-0.0617
	-(0.5812)	-(0.5524)	-(0.6433)	-(0.2661)	(1.1419)	-(0.4766)	-(1.2188)	-(0.4220)	-(0.0922)	-(0.1865)
$\alpha_{2,2}$	-0.1407	-0.0416	-0.0382	-0.0113	0.0957	-0.0669	-0.0303	-0.0943	-0.0114	-0.0634
	-(0.6441)	-(0.5941)	-(0.6595)	-(0.2975)	(1.0706)	-(0.4862)	-(0.1118)	-(0.3524)	-(0.1520)	-(0.1941)
$\alpha_{3,1}$	0.0463	-0.0849	-0.0067	0.0007	0.1374*	-0.0931	-1.3347	-1.7306	-0.0144	-0.0832
	(0.3460)	-(0.8519)	(0.2077)	(0.0116)	(1.8453)	-(0.4711)	-(1.1845)	-(1.2832)	-(0.1210)	(0.5470)
$\alpha_{3,2}$	0.1122	-0.0295	-0.0066	-0.0004	0.1479**	-0.0896	-1.1742	-1.7052	-0.0143	-0.0851
	(0.8303)	-(0.3405)	-(0.2132)	-(0.0080)	(1.9641)	-(0.4519)	-(1.0442)	-(1.3815)	-(0.1195)	-(0.5672)
α_4	0.6263	0.4875	11.6594	3.4497	32.3039***	17.0636	-0.0366	-0.0771	18.1668	-7.5247
	(1.0109)	(0.8213)	(0.3674)	(0.1633)	(2.7027)	(0.2382)	-(0.4287)	-(0.3951)	(0.2382)	-(0.0759)
β_0	1.8618	0.5107	0.0005	0.0004	0.0222***	0.0004	4.1226	10.1080	0.0077	0.0012
	(0.3560)	(0.3989)	(0.1179)	(0.0980)	(140.1111)	(0.1159)	(0.1570)	(0.2243)	(0.2763)	(0.1118)
β_1	0.0146	-0.0191	-0.0108	-0.0123	-0.0285	-0.0212*	0.0533	0.0744	0.0053	-0.0245
	(0.5403)	-(1.2948)	-(0.3650)	-(0.3908)	-(1.4088)	-(1.6859)	(0.9788)	(0.9522)	(0.1310)	-(1.3934)
β_2	0.3916	0.1744	0.0598	0.0715	0.2067***	0.2023	0.2397	-0.2049	0.0000	0.0564
	(0.4797)	(0.0395)	(0.0320)	(0.0381)	(2.5649)	(0.3284)	(0.6577)	-(0.8307)	(0.0001)	(0.1523)
β_3	-0.0203	-0.0011	-0.0003	-0.0005	-0.0051***	-0.0007	0.0378	-0.0050	-0.0010	-0.0001
	-(0.2062)	-(0.0612)	-(0.2181)	-(0.3320)	-(1468.4230)	-(0.6889)	(0.2649)	-(0.0199)	-(0.2870)	-(0.0506)
β_4	-0.0933	0.0001	0.0006	0.0012	-0.0028***	0.0017	-0.5270	-0.1556	-0.0014	-0.0001
	-(0.3240)	(0.0008)	(0.3463)	(0.6410)	-(28.4047)	(1.0501)	-(0.1736)	-(0.0471)	-(0.2431)	-(0.0203)
β_5	0.3386	0.5233	0.5197	0.5130	0.5079**	0.4568	1.2875***	0.5117	1.0084	0.5039
	(0.3871)	(1.2273)	(0.4470)	(0.4560)	(2.0074)	(0.6355)	(5.5904)	(1.0732)	(0.4823)	(0.2697)
β_6	-0.0615	0.0341	0.0333	0.0137	0.0224	-0.0962	-0.6716***	0.0231	-0.7084	0.0169
	-(0.0878)	(0.0684)	(0.0222)	(0.0197)	(0.1435)	-(0.1559)	-(2.5748)	(0.0558)	-(0.2760)	(0.0087)

	CTA5_AD_L		CTBBB7		CTBBB7_L		CTBBB7_AD_L	
	BHHH	M§	BHHH	M§	BHHH	M	BHHH	M
α_0	0.4565***	0.1675	11.7002	6.3271	-0.0617	0.2296	0.9452*	0.3330
	(3.2101)	(0.2551)	(0.5427)	(0.1269)	-(0.0804)	(0.2613)	(1.7063)	(0.8089)
$\alpha_{1,1}$	-0.1127	0.0445	0.0828	-0.0021	0.0058	0.0123	0.1230	-0.0173
	-(1.0673)	(0.2009)	(0.6241)	-(0.0032)	(0.0296)	(0.0652)	(0.4810)	-(0.0704)
$\alpha_{1,2}$	-0.1256	0.0375	0.0540	-0.0297	0.0024	0.0085	0.1139	-0.0262
	-(1.2021)	(0.1700)	(0.4216)	-(0.0452)	(0.0121)	(0.0451)	(0.4452)	-(0.1094)
$\alpha_{2,1}$	0.0494	-0.0946	-0.1194	-0.0078	-0.0016	-0.0660	-0.2595	-0.0452
	(0.5199)	-(0.6474)	-(0.8267)	-(0.0117)	-(0.0110)	-(0.4973)	-(1.1244)	-(0.1853)
$\alpha_{2,2}$	0.0435	-0.0941	-0.1158	-0.0102	-0.0032	-0.0670	-0.2601	-0.0465
	(0.4661)	-(0.6522)	-(0.8322)	-(0.0157)	-(0.0215)	-(0.5076)	-(1.1316)	-(0.1956)
$\alpha_{3,1}$	-0.0991***	0.0447	-1.0347	-0.7434	0.0255	0.0293	-0.1412**	0.0086
	(3.1577)	(0.2249)	-(0.6889)	-(0.1392)	(0.4847)	(0.6051)	-(2.2327)	(0.0788)
$\alpha_{3,2}$	-0.0957***	0.0462	-0.5135	-0.6348	0.0270	0.0302	-0.1340**	0.0093
	-(3.1995)	(0.2338)	-(0.3414)	-(0.1284)	(0.5126)	(0.6147)	-(2.2001)	(0.0861)
α_4	-1.6554	-8.1021	0.0159	0.0093	9.0876**	20.6387	-10.3923	-10.9276
	-(0.4600)	-(0.7213)	(0.5381)	(0.0856)	(2.3352)	(0.9236)	-(1.1939)	-(0.4733)
β_0	0.0237***	-0.0001	-16.0578	24.9945	0.0048	0.0017	0.0171	-0.0040
	(2.5758)	-(0.0626)	-(0.0564)	(0.3383)	(0.2047)	(0.1071)	(1.2880)	-(0.7115)
β_1	0.1772	0.0543	0.0713	0.2398	0.1983	0.0591	0.2941*	0.0762
	(1.3784)	(1.1411)	(0.3033)	(0.5401)	(1.1328)	(0.7425)	(1.6461)	(0.9299)
β_2	0.9762	0.0026	0.0347	-0.2818	0.1063	-0.0108	-0.2284	0.0003
	(1.2649)	(0.0157)	(0.0921)	-(0.4978)	(0.4647)	-(0.0983)	-(0.7793)	(0.0020)
β_3	-0.0037**	-0.0005***	0.3054	0.0023	-0.0005	0.0001	-0.0026	0.0004
	-(2.5371)	-(3.9475)	(0.2691)	(0.0098)	-(0.1178)	(0.0397)	-(1.2705)	(0.5728)
β_4	-0.0047**	0.0016	-5.2871	-2.6552	-0.0014	-0.0013	-0.0020	0.0014
	-(2.5382)	(0.9803)	-(0.3250)	-(0.3464)	-(0.6942)	-(0.8303)	-(1.3047)	(0.9509)
β_5	0.1138***	0.6167	0.9058***	0.5256	0.5236	0.5052	0.5414	0.6151
	(3.7852)	(0.7225)	(3.6261)	(0.3656)	(0.8021)	(0.4595)	(0.8417)	(0.5777)
β_6	0.6477***	0.1813	-0.4763***	0.0339	0.0296	-0.0024	-0.0211	-0.0035
	(6.2909)	(0.2576)	-(2.6100)	(0.0329)	(0.0496)	-(0.0031)	-(0.0464)	-(0.0041)

Z-statistics in parentheses; ***=1% significance, **=5% significance, *=10% significance. § no Bollerslev-Woolridge robust standard errors and variance.

Tab. 31. *Estimation Results of GARCH(2,1) model for traditional CDO spreads (actual, transformed and Johnson Fit adjusted spreads) – LIBOR at level data.*

	MAAA3		MAAA3_L		MAAA3_AD_L		MAAA5		MAAA5_L		MAAA5_AD_L	
	Mortgage-Backed Securities (MBS)											
	BHHH	M	BHHH	M	BHHH	M	BHHH	M	BHHH§	M§	BHHH	M
α_0	-0.0260	0.0094	0.0004	-0.0157	0.3194***	0.3525**	-0.1397	-0.0286	-0.0367	0.0229	1.2504***	0.9530***
	-(0.0778)	(0.0423)	(0.0082)	-(0.3858)	(2.8108)	(1.9392)	-(0.4275)	-(0.0922)	-(0.8657)	(0.4172)	(2.8365)	(2.9930)
$\alpha_{1,1}$	-0.0896	0.0031	-0.1129	0.0122	-0.1772***	-0.1247	-0.0484	0.0025	0.0119	-0.0477	-0.6625***	-0.6684***
	-(0.5246)	(0.0254)	-(0.7687)	(0.0796)	-(2.8007)	-(1.3521)	-(0.3227)	(0.0449)	(0.1471)	-(0.3118)	-(6.1594)	-(5.5622)
$\alpha_{1,2}$	-0.1201	-0.0406	-0.1194	-0.0026	-0.2051***	-0.1665*	-0.0864	-0.0329	-0.0012	-0.0606	-0.6949***	-0.6937***
	-(0.7142)	-(0.3446)	-(0.8115)	-(0.0172)	-(3.3320)	-(1.8223)	-(0.5754)	-(0.6092)	-(0.0154)	-(0.3997)	-(6.6998)	-(5.7991)
$\alpha_{2,1}$	0.1607*	0.0043	0.1244	-0.0050	0.0630	0.0170	0.0393	-0.0036	-0.0288	0.0170	0.2645**	0.3568***
	(1.7483)	(0.0361)	(0.8172)	-(0.0323)	(0.9134)	(0.1851)	(0.2446)	-(0.0516)	-(0.3724)	(0.1146)	(2.2946)	(3.4265)
$\alpha_{2,2}$	0.1505*	-0.0003	0.1224	-0.0082	0.0400	0.0051	0.0316	-0.0042	-0.0300	0.0151	0.2355**	0.3321***
	(1.7088)	-(0.0029)	(0.8089)	-(0.0534)	(0.6480)	(0.0595)	(0.2035)	-(0.0656)	-(0.3922)	(0.1033)	(2.0586)	(3.2385)
$\alpha_{3,1}$	-0.2732	-0.0202	-0.0207	-0.0036	0.0223	-0.0103	0.1222	0.0266	0.0665	0.0551	0.0292	0.0197
	-(0.5360)	-(0.3452)	-(0.9320)	-(0.2688)	(0.6670)	-(0.1916)	(0.9923)	(0.2741)	(0.6983)	(0.3678)	(0.3767)	(0.2281)
$\alpha_{3,2}$	-0.2497	0.0047	-0.0162	0.0018	0.0390	0.0034	0.1174	0.0230	0.0697	0.0584	0.0370	0.0400
	-(0.4941)	(0.0878)	-(0.7845)	(0.1521)	(1.2150)	(0.0617)	(0.9925)	(0.2830)	(0.7353)	(0.3896)	(0.4998)	(0.4797)
α_4	-1.0271	-0.2745	-3.9059	-0.0002	-0.7260	-5.6636	-0.4344	0.1806	-63.4937	-35.7051	-1.2715	-0.7484
	-(0.7212)	-(0.2283)	-(0.3059)	(0.0000)	-(0.3230)	-(0.5495)	-(0.2567)	(0.2838)	-(0.7967)	-(0.3262)	-(0.5421)	-(0.4148)
β_0	-0.0424	0.0698	-0.0008	0.0000	-0.0181	0.0023	-0.0622	0.0877	-0.0001	-0.0001	-0.0458	0.0042
	-(0.5901)	(0.2588)	-(0.4354)	-(0.0388)	-(0.6834)	(0.1306)	-(0.2659)	(0.1497)	-(0.6072)	-(0.1762)	-(1.3632)	(0.1582)
β_1	0.0123	0.0199	0.0086	0.1187	0.1647**	0.1324	0.2671	-0.0249	-0.0070	0.0210	0.0841	0.1591*
	(0.3209)	(0.3665)	(0.0514)	(1.1962)	(2.4651)	(0.6184)	(0.3316)	-(0.6698)	-(0.4583)	(0.3596)	(1.1114)	(1.9194)
β_2	-0.0850	-0.1538*	0.2664	0.0641	-0.0970	-0.1869	-0.2616	-0.5114	-0.0562	0.0571	0.4669*	0.4121
	-(0.8488)	-(1.7104)	(0.5121)	(0.1257)	-(1.0344)	-(0.8561)	-(0.2638)	-(0.7295)	-(0.1330)	(0.0697)	(1.8585)	(1.2123)
β_3	0.0342	0.0016	0.0007	0.0001	0.0033	-0.0005	0.0119	0.0004	-0.0002***	-0.0003***	0.0135	0.0011
	(0.9029)	(0.1303)	(0.7166)	(0.1246)	(0.4810)	-(0.0860)	(0.9230)	(0.0309)	-(3.1056)	-(5.3743)	(1.1257)	(0.1098)
β_4	-0.1266	0.0045	-0.0007	0.0000	0.0100	0.0011	-0.0123	0.0021	0.0004**	0.0006	0.0040	-0.0039
	-(0.9047)	(0.1348)	-(0.9155)	(0.0853)	(1.0364)	(0.2044)	-(0.1721)	(0.0514)	(2.2154)	(1.4234)	(0.8448)	-(0.8201)
β_5	0.6909***	0.3878	0.5098*	0.5105	-0.9052***	0.2583	-0.1882	0.5012	0.2661	0.5052	0.8476***	0.8306***
	(2.9001)	(0.6076)	(1.7944)	(0.7042)	-(4.8651)	(0.5547)	-(0.5138)	(0.6808)	(0.4739)	(0.7221)	(5.0418)	(8.0419)
β_6	-0.1459	-0.0938	-0.2301	0.0139	0.0736	-0.2539	-0.0854	0.0094	0.3901	0.0185	-0.3504***	-0.3146***
	-(1.1510)	-(0.1768)	-(0.8760)	(0.0246)	(0.3962)	-(0.6311)	-(0.3877)	(0.0102)	(0.8316)	(0.0404)	-(2.7044)	-(3.7821)

	MA7		MA7_L		MA7_AD_L		MBBB7		MBBB7_L		MBBB7_AD_L	
	BHHH	M	BHHH	M§	BHHH	M	BHHH	M	BHHH	M	BHHH	M
α_0	-1.7969	-0.1637	0.0196	-0.0046	-0.0208	-0.0001	-0.9935	-1.4183	0.0385	-0.0501	0.6839***	0.7650**
	-(0.4029)	-(0.2633)	(0.1598)	-(0.0315)	-(0.1026)	(0.0000)	-(0.0326)	-(0.1700)	(0.3129)	-(0.3385)	(3.4583)	(2.0976)
$\alpha_{1,1}$	0.0396	0.0008	-0.0074	-0.0010	-0.0425	-0.0052	-0.0195	-0.0911***	-0.0680	-0.0862	-0.2034	-0.2182*
	(0.2664)	(0.0113)	-(0.0280)	-(0.0086)	-(0.2263)	-(0.0389)	-(0.0506)	-(2.6878)	-(0.3546)	-(0.9872)	-(1.2460)	-(1.7698)
$\alpha_{1,2}$	0.0264	-0.0232	-0.0080	-0.0064	-0.0433	-0.0018	-0.0429	-0.1153***	-0.0723	-0.0905	-0.2185	-0.2313*
	(0.1802)	-(0.3358)	-(0.0304)	-(0.0532)	-(0.2306)	-(0.0108)	-(0.1112)	-(3.3220)	-(0.3781)	-(1.0389)	-(1.3388)	-(1.9069)
$\alpha_{2,1}$	-0.0165	-0.0001	0.0026	-0.0023	0.0536	-0.0067	0.0499	0.0932*	0.0710	0.0750	0.0359	0.0429
	-(0.1750)	-(0.0013)	(0.0098)	-(0.0185)	(0.2551)	-(0.0413)	(0.3325)	(1.7193)	(0.3806)	(0.8891)	(0.2010)	(0.6068)
$\alpha_{2,2}$	-0.0167	-0.0017	0.0026	-0.0028	0.0515	-0.0039	0.0410	0.0849*	0.0686	0.0745	0.0319	0.0376
	-(0.1814)	-(0.0229)	(0.0098)	-(0.0228)	(0.2472)	-(0.0253)	(0.2853)	(1.6992)	(0.3698)	(0.8923)	(0.1799)	(0.5317)
$\alpha_{3,1}$	0.1441	0.0158	0.0003	0.0133	-0.0117	-0.0052	0.0879	0.7289	-0.0188	0.0754	0.1017***	0.0710
	(0.3248)	(0.1181)	(0.0221)	(0.1618)	-(0.6220)	-(0.0338)	(0.0797)	(1.2250)	-(0.4201)	(0.9097)	(4.7600)	(1.2623)
$\alpha_{3,2}$	0.1364	0.0275	0.0006	0.0137	-0.0096	0.0211	0.0960	0.6863	-0.0177	0.0767	0.1014***	0.0728
	(0.3187)	(0.2656)	(0.0428)	(0.1666)	-(0.4651)	(0.4219)	(0.0877)	(1.1681)	-(0.3975)	(0.9335)	(4.7216)	(1.3155)
α_4	-0.2871	0.1691	-2.3559	0.0000	-7.3350	0.0000	-0.2539	-0.1261	-34.5735	-23.4130	1.0722	3.5558**
	-(1.1755)	(0.2958)	-(0.1512)	(0.0000)	-(0.6728)	(0.0000)	-(0.1688)	-(0.6168)	-(0.6318)	-(0.4800)	(0.5258)	(2.3450)
β_0	-2.3698	0.4439	0.0004	-0.0003	0.0013	-0.0004	-25.4507	4.8318	0.0007	-0.0010	0.0085***	0.0026
	-(0.5851)	(0.0553)	(0.0656)	-(0.8541)	(0.2029)	-(0.7429)	-(0.3893)	(0.1158)	(0.8911)	-(1.4393)	(49.2055)	(0.2307)
β_1	0.0325	-0.0151	0.1200	0.1303	0.0966	0.1268	-0.0018	-0.0202	0.0911	0.0741	0.3862***	0.2877***
	(1.3150)	-(0.5010)	(1.1870)	(0.5706)	(0.8433)	(0.6495)	-(0.0514)	-(0.6574)	(0.8356)	(0.5047)	(6.2671)	(5.8947)
β_2	-0.2679	-0.0997	0.0792	0.0459	0.0962	0.0472	0.0102	-0.0767	-0.0723	0.0649	0.1948	0.0589
	-(0.8353)	-(0.0513)	(0.1516)	(0.0576)	(0.2275)	(0.0452)	(0.0669)	-(0.6835)	-(0.4334)	(0.3094)	(0.7854)	(0.5145)
β_3	0.0575	-0.0002	-0.0001	-0.0001	-0.0004	-0.0001**	0.2675	0.0021	-0.0001	0.0000	-0.0015***	-0.0006
	(0.6072)	-(0.0025)	-(0.0587)	-(0.6035)	-(0.2241)	-(2.3959)	(0.4196)	(0.0136)	-(0.9606)	-(0.8701)	-(217.87)	-(0.2911)
β_4	-0.2378	-0.0007	0.0001	0.0004	0.0002	0.0006	-0.4622	0.0752	0.0000	0.0008	-0.0006***	0.0006
	-(0.6141)	-(0.0064)	(0.1512)	(0.8438)	(0.6192)	(1.1075)	-(0.1749)	(0.0313)	(0.0755)	(1.3570)	-(4.4976)	(0.4473)
β_5	1.2458***	0.5115	0.4291	0.5335	0.5880	0.5337	-0.3250	0.4681	0.2766	0.5122	0.3243	0.4136***
	(4.2168)	(0.3526)	(0.8079)	(0.3928)	(0.4339)	(0.5510)	-(0.2134)	(0.7493)	(0.3931)	(0.6915)	(1.3768)	(3.5039)
β_6	-0.5432***	0.0295	0.1453	0.0442	0.0412	0.0423	0.2416	-0.0309	0.3403	0.0181	0.1073	-0.1178***
	-(2.5564)	(0.0103)	(0.2091)	(0.0490)	(0.0379)	(0.0691)	(0.3407)	-(0.0291)	(0.6119)	(0.0411)	(0.7290)	-(3.6302)

Z-statistics in parentheses; ***=1% significance, **=5% significance, *=10% significance. § no Bollerslev-Woolridge robust standard errors and variance.

Tab. 32. *Estimation Results of GARCH(2,1) model for MBSspreads (actual, transformed and Johnson Fit adjusted spreads) – LIBOR at level data.*

	Pfandbriefe																	
	PAAA3		PAAA3_L		PAAA3_AD_L		PAAA5		PAAA5_L		PAAA5_AD_L		PAAA7		PAAA7_L		PAAA7_AD_L	
	BHHH	M	BHHH	M	BHHH	M	BHHH	M	BHHH	M	BHHH	M	BHHH	M	BHHH	M	BHHH	M
α_0	-2.3941	-0.2784	-0.1304	-0.0094	-0.1462	0.0411	-5.1302	-0.2240	0.5168	-0.0250	-0.8795	-0.0888	2.0082	0.4605	0.0658	0.0848	0.0688	0.0831
	-(1.5990)	-(0.1282)	-(0.7725)	-(0.0338)	-(0.4601)	(0.1581)	-(1.0624)	-(0.1519)	(0.6451)	-(0.2159)	-(0.3157)	-(0.8203)	(0.7805)	(0.4084)	(0.7976)	(1.0266)	(0.7261)	(0.8460)
$\alpha_{1,1}$	-0.4068***	0.0499	-0.3360***	-0.0013	-0.4316***	-0.4995	-0.3059***	0.0439	0.0593	-0.1912***	-0.4301	-0.1856***	-0.4062***	-0.2983***	-0.2664***	-0.4321***	-0.2950***	-0.3040***
	-(4.1678)	(0.1627)	-(4.4035)	-(0.0044)	-(5.4273)	-(5.6524)	-(3.4736)	(0.2951)	(0.1864)	-(2.7051)	-(0.3165)	-(2.7298)	-(4.1546)	-(3.6863)	-(3.0252)	-(6.1489)	-(4.0992)	-(3.0449)
$\alpha_{1,2}$	-0.4900***	-0.0497	-0.3639***	-0.0327	-0.4636***	-0.5246	-0.3833***	-0.0678	0.0351	-0.2204***	-0.4546	-0.2155***	-0.4624***	-0.3666***	-0.2821***	-0.4496***	-0.3139***	-0.3204***
	-(5.4476)	-(0.1768)	-(4.8857)	-(0.1117)	-(6.0432)	-(6.1235)	-(4.6246)	-(0.4724)	(0.1115)	-(3.2051)	-(0.3384)	-(3.2446)	-(4.9955)	-(4.6966)	-(3.2629)	-(6.4867)	-(4.4373)	-(3.2653)
$\alpha_{2,1}$	0.5691***	0.0238	0.4201***	0.0099	0.4935***	0.4928	0.3990***	0.0394	-0.1092	0.1814**	0.2790	0.2231***	0.4078***	0.3123***	0.2511***	0.4170***	0.2860***	0.2821***
	(4.8941)	(0.1881)	(6.0639)	(0.0571)	(5.6383)	(8.1106)	(4.5803)	(0.2552)	-(0.3729)	(2.3258)	(0.5371)	(2.8094)	(4.6626)	(3.9314)	(3.0988)	(5.7003)	(3.8173)	(3.1812)
$\alpha_{2,2}$	0.4933***	0.0032	0.4063***	0.0061	0.4677***	0.4639	0.3268***	-0.0014	-0.1160	0.1637**	0.2540	0.2084***	0.3316***	0.2500***	0.2372***	0.3953***	0.2669***	0.2617***
	(4.8632)	(0.0275)	(6.4286)	(0.0363)	(5.4355)	(7.9264)	(4.1366)	-(0.0103)	-(0.4061)	(2.1707)	(0.5002)	(2.7004)	(4.1878)	(3.4845)	(3.0112)	(5.5471)	(3.6558)	(3.0405)
$\alpha_{3,1}$	0.0236	-0.0168	-0.0409	0.0166	0.0206	0.0228	1.8008	0.1611	-0.0997	0.0786	0.7674	0.0112	0.6039	0.3345	0.0224	0.0241	-0.0023	0.0236
	(0.0738)	-(0.0432)	-(0.3640)	(0.1786)	(0.5280)	(0.5070)	(0.7062)	(0.3976)	-(0.2350)	(1.2522)	(0.2832)	(0.1851)	(0.9894)	(0.7495)	(0.3813)	(0.5276)	-(0.0449)	(0.5446)
$\alpha_{3,2}$	0.0321	0.0686	-0.0372	0.0243	0.0219	0.0298	1.8911	0.1734	-0.1120	0.0810	0.7694	0.0266	0.6732	0.4295	0.0268	0.0301	0.0090	0.0330
	(0.1088)	(0.1517)	-(0.3133)	(0.2409)	(0.5753)	(0.6524)	(0.7431)	(0.4291)	-(0.2660)	(1.3331)	(0.2909)	(0.4511)	(1.1092)	(0.9810)	(0.4768)	(0.6743)	(0.1774)	(0.7809)
α_4	0.5476*[§]	-0.0925	-2.1979	-0.0323	-2.3015	-1.2285	-3.2573[$]	-0.3491	-2.3905***[$]	-0.0059	3.4222	-0.1315	-2.9661	-0.7117*	-5.9001	-12.5255	7.1095	3.0617
	(1.6852)	-(0.7407)	-(0.6480)	-(0.0256)	-(0.2789)	-(0.1282)	-(0.4928)	-(1.3048)	-(3.7470)	-(0.0005)	(0.5860)	-(0.0680)	-(0.8965)	-(1.7393)	-(0.6166)	-(1.4828)	(0.9129)	(0.3779)
β_0	1.2857**	0.4113	-0.0132	0.0009	0.0062	0.0012	-3.0263	0.9931	0.0192**	0.0008	0.0166	-0.0097	-0.0079	-0.1827	0.0003	0.0008	0.0070*	0.0012
	(2.3264)	(0.2432)	-(0.6235)	(0.0406)	(1.1436)	(0.1290)	-(0.8276)	(0.7776)	(2.8732)	(0.1556)	(5.4446)	-(0.7166)	-(0.0315)	-(0.3475)	(0.3162)	(0.7119)	(1.8599)	(0.3990)
β_1	0.0158	0.4810**	0.0001	0.2823	-0.0030	-0.0289	-0.0101	0.0645**	0.1839	-0.0182	-0.4906	0.0785	0.0753	0.0117	0.0420	0.1064	0.0441	-0.0991
	(0.2044)	(2.1355)	(0.0042)	(0.7782)	-(0.0499)	-(1.1847)	-(0.4442)	(2.1689)	(1.3150)	-(0.0750)	-(0.3434)	(1.2205)	(0.9257)	(0.2531)	(1.1117)	(1.3394)	(1.0463)	-(1.5350)
β_2	0.5682	0.9440	1.6474	0.5491	0.4379	0.2439	0.0489	-0.3367**	-0.3161	-0.1631	0.6608	0.2777*	-0.1687	-0.0392	0.0749	0.1640	0.0408	0.3725*
	(1.5483)	(0.5197)	(1.5652)	(0.3142)	(1.5409)	(0.7780)	(0.6002)	-(2.3860)	-(1.2887)	-(1.2989)	(0.3407)	(1.8896)	-(1.0324)	-(0.2797)	(0.5234)	(0.8946)	(0.9146)	(1.9103)
β_3	-0.0777*	-0.0242	0.0054	-0.0004	-0.0030	-0.0003	-0.0002	0.0061	-0.00211**	-0.0004	0.0046	-0.0006	-0.0085	-0.0032	0.0001	-0.0006	-0.0032***	-0.0005
	-(1.7336)	-(0.1563)	(0.6020)	-(0.0363)	-(1.4466)	-(0.0897)	-(0.0097)	(0.1587)	-(2.0261)	-(0.4678)	(4.5493)	-(0.5880)	-(0.7260)	-(0.3247)	(0.1619)	-(1.2094)	-(3.5052)	-(0.4422)
β_4	0.0676	0.1015	-0.0012	0.0010	0.0018**	0.0004	0.8574	0.0098	-0.0067	0.0005	-0.0181	0.0092	0.1090	0.0553	-0.0001	0.0009	0.0037***	0.0008
	(0.5978)	(0.3428)	-(0.4373)	(0.1832)	(1.8611)	(0.2067)	(0.8787)	(0.0252)	-(1.1441)	(0.2132)	-(15.7505)	(1.1068)	(1.0118)	(0.3689)	-(0.2084)	(1.4480)	(3.0172)	(0.6071)
β_5	0.9142***	0.4895***	0.0119	0.5151**	0.2033	0.5628	-0.1501	0.4660	0.0293	0.7204	0.8679	0.6453***	0.7682	0.6639	1.3542***	0.6280	0.8942***	0.5448
	(3.5209)	(4.6545)	(0.1187)	(2.2618)	(0.8088)	(1.0273)	-(0.3066)	(1.1312)	(0.0837)	(0.6576)	(1.1119)	(2.7110)	(1.3589)	(0.2052)	(4.9589)	(0.9648)	(11.1602)	(1.3991)
β_6	-0.2710	-0.1295*	0.2613	-0.1408	0.5787**	0.0215	0.5745	0.0452	0.6567**	0.3195	-0.1246	-0.4895***	0.0286	0.3472	-0.6758***	0.1134	-0.7964***	-0.0451
	-(1.4105)	-(1.6898)	(0.6503)	-(1.1566)	(2.5586)	(0.0693)	(1.1935)	(0.1272)	(2.3056)	(0.4463)	-(0.1929)	-(2.6539)	(0.0622)	(0.1066)	-(2.7202)	(0.2019)	-(10.2685)	-(0.1055)

Z-statistics in parentheses; ***=1% significance, **=5% significance, *=10% significance. [§] no Bollerslev-Woolridge robust standard errors and variance; [$] SQR-GARCH result.

Tab. 33. *Estimation Results of GARCH(2,1) model for Pfandbrief spreads (actual, transformed and Johnson Fit adjusted spreads) – LIBOR at level data.*

	Collateralised Debt Obligations (CDO), synthetic					
	CSAAA3		CSAAA3_L		CSAAA3_AD_L	
	BHHH	M	BHHH	M	BHHH	M
Wald-test H_0: $\alpha_{1,1}=\alpha_{1,2}$ (t-stat.)	36.0405***	7.5079***	31.9245***	30.8982***	6.7844**	4.44058**
(p-value)	0.0000	0.0076	0.0000	0.0000	0.0110	0.0382
Wald-test H_0: $\alpha_{1,1}+\alpha_{1,2}=0$ (t-stat.)	0.6018	4.2942**	0.1685	25.1154***	0.0052	5.3525**
(p-value)	0.4402	0.0415	0.6825	0.0000	0.9425	0.0233
LB-Q Statistic (lags)	1.0334 (1)	NA (-)	1.0628 (1)	0.6721 (1)	0.5394 (1)	0.0055 (1)
(p-value)	0.3090	NA	0.3030	0.4120	0.4630	0.9410
LB^2-Q Statistic (lags)	0.0289 (1)	NA (-)	0.0439 (1)	0.9712 (1)	0.0067 (1)	0.0411 (1)
(p-value)	0.8650	NA	0.8340	0.3240	0.9350	0.8390
Jarque-Bera	1578.18***	NA	7013.79***	1075.78***	3164.16 (1)	2759.87***
(p-value)	0.0000	NA	0.0000	0.0000	0.0000	0.0000

	Collateralised Debt Obligations (CDO), synthetic					
	CSA5		CSA5_L		CSA5_AD_L	
	BHHH	M	BHHH	M	BHHH	M
Wald-test H_0: $\alpha_{1,1}=\alpha_{1,2}$ (t-stat.)	18.0798***	23.6982***	11.4597***	18.1055***	12.7732***	16.6566***
(p-value)	0.0001	0.0000	0.0011	0.0001	0.0006	0.0001
Wald-test H_0: $\alpha_{1,1}+\alpha_{1,2}=0$ (t-stat.)	33.7353***	17.7308***	11.4597***	11.1440***	0.7641	6.9203**
(p-value)	0.0000	0.0001	0.0011	0.0013	0.3846	0.0102
LB-Q Statistic (lags)	2.9472 (1)	0.0026 (1)	0.6383 (1)	0.0343 (1)	0.0226 (1)	0.0000 (1)
(p-value)	0.0860	0.9590	0.4240	0.8530	0.8800	0.9990
LB^2-Q Statistic (lags)	0.0000 (1)	0.0287 (1)	0.0931 (1)	0.0477 (1)	0.0202 (1)	0.2457 (1)
(p-value)	0.9960	0.8660	0.7600	0.8270	0.8870	0.6200
Jarque-Bera	1347.63***	2994.27***	2591.68***	3371.84***	2346.54***	1695.81***
(p-value)	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000

	Collateralised Debt Obligations (CDO), synthetic					
	CSBBB7		CSBBB7_L		CSBBB7_AD_L	
	BHHH	M	BHHH	M	BHHH	M
Wald-test H_0: $\alpha_{1,1}=\alpha_{1,2}$ (t-stat.)	14.4963***	10.8793***	10.1577***	8.8309***	13.3682***	5.3048**
(p-value)	0.0003	0.0014	0.0020	0.0039	0.0005	0.0238
Wald-test H_0: $\alpha_{1,1}+\alpha_{1,2}=0$ (t-stat.)	9.2623***	5.0824**	0.4869	4.5433**	1.2165	1.5213
(p-value)	0.0032	0.0269	0.4873	0.0361	0.2733	0.2210
LB-Q Statistic (lags)	0.0210 (1)	0.0731 (1)	NA (-)	0.0050 (1)	NA (-)	0.0389 (1)
(p-value)	0.8850	0.7870	NA	0.9440	NA	0.8440
LB^2-Q Statistic (lags)	0.0323 (1)	0.0366 (1)	NA (-)	0.0774 (1)	NA (-)	0.0746 (1)
(p-value)	0.8570	0.8480	NA	0.7810	NA	0.7850
Jarque-Bera	4415.49***	4753.40***	NA	2834.24***	NA	6542.72***
(p-value)	0.0000	0.0000	NA	0.0000	NA	0.0000

$^{\$}$ no Bollerslev-Woolridge robust standard errors and variance; ***=1% significance, **=5% significance, *=10% significance. *NA* indicates that no results could be generated by the statistics software due to data overflow.

Tab. 34. *Coefficient and residual tests of GARCH(1,1) model for synthetic CDO spreads (actual, transformed and Johnson Fit adjusted spreads) – LIBOR at level data.*

	Collateralised Debt Obligations (CDO), traditional					
	CTAAA3		CTAAA3_L		CTAAA3_AD_L	
	BHHH	M	BHHH	M	BHHH	M[§]
Wald-test H_0: $\alpha_{1,1}=\alpha_{1,2}$ (t-stat.)	108.9847***	108.9847***	253.5534***	152.6011***	79.9122***	83.3839***
(p-value)	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Wald-test H_0: $\alpha_{1,1}+\alpha_{1,2}=0$ (t-stat.)	9.1467***	9.1467***	0.0001	2.2105	0.2387	0.7777
(p-value)	0.0033	0.0033	0.9928	0.1410	0.6264	0.3805
LB-Q Statistic (lags)	0.0214 (1)	0.0214 (1)	NA (-)	0.0162 (1)	NA (-)	2.009 (1)
(p-value)	0.8840	0.8840	NA	0.8990	NA	0.1560
LB^2-Q Statistic (lags)	0.0067 (1)	0.0067 (1)	NA (-)	0.0244 (1)	NA (-)	0.2317 (1)
(p-value)	0.9350	0.9350	NA	0.8760	NA	0.6300
Jarque-Bera	7737.57***	12315.67***	NA	13144.28***	NA	660.55***
(p-value)	0.0000	0.0000	NA	0.0000	NA	0.0000
	Collateralised Debt Obligations (CDO), traditional					
	CTA5		CTA5_L		CTA5_AD_L	
	BHHH	M	BHHH	M	BHHH	M
Wald-test H_0: $\alpha_{1,1}=\alpha_{1,2}$ (t-stat.)	11.8138***	7.6877***	5.0434**	3.7712*	15.2958***	4.9260**
(p-value)	0.0009	0.0069	0.0274	0.0556	0.0002	0.0293
Wald-test H_0: $\alpha_{1,1}+\alpha_{1,2}=0$ (t-stat.)	1.4571	0.8765	0.5407	1.0089	0.7311	0.3190
(p-value)	0.2309	0.3519	0.4643	0.3182	0.3950	0.5738
LB-Q Statistic (lags)	0.7101 (1)	0.6813 (1)	2.0100 (1)	0.7248 (1)	0.0994 (1)	0.2557 (1)
(p-value)	0.3990	0.4090	0.1560	0.3950	0.7530	0.6130
LB^2-Q Statistic (lags)	0.1828 (1)	0.0967 (1)	3.6191 (1)	0.0282 (1)	0.0209 (1)	0.0981 (1)
(p-value)	0.6690	0.7560	0.0570	0.8670	0.8850	0.7540
Jarque-Bera	2172.71***	881.33***	1359.71***	1992.07***	5902.84***	2297.89***
(p-value)	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
	Collateralised Debt Obligations (CDO), traditional					
	CTBBB7		CTBBB7_L		CTBBB7_AD_L	
	BHHH	M	BHHH	M	BHHH	M
Wald-test H_0: $\alpha_{1,1}=\alpha_{1,2}$ (t-stat.)	10.2911***	10.6905***	8.3745***	9.5689***	15.7247***	16.6589***
(p-value)	0.0019	0.0016	0.0049	0.0027	0.0002	0.0001
Wald-test H_0: $\alpha_{1,1}+\alpha_{1,2}=0$ (t-stat.)	0.1091	0.3920	0.5136	14.0592***	0.5455	1.2380
(p-value)	0.7420	0.5330	0.4757	0.0003	0.4623	0.2691
LB-Q Statistic (lags)	0.2969 (1)	0.3335 (1)	18.9560 (11)	2.3554 (1)	NA (-)	1.0750 (1)
(p-value)	0.5860	0.5640	0.0620	0.1250	NA	0.3000
LB^2-Q Statistic (lags)	0.1829 (1)	0.0516 (1)	2.6250 (1)	0.0621 (1)	NA (-)	0.0409 (1)
(p-value)	0.6690	0.8200	0.1050	0.8030	NA	0.8400
Jarque-Bera	903.10***	1578.17***	780.72***	27672.90***	NA	199.43***
(p-value)	0.0000	0.0000	0.0000	0.0000	NA	0.0000

[§] no Bollerslev-Woolridge robust standard errors and variance; ***=1% significance, **=5% significance, *=10% significance. *NA* indicates that no results could be generated by the statistics software due to data overflow.

Tab. 35. *Coefficient and residual tests of GARCH(1,1) model for traditional CDO spreads (actual, transformed and Johnson Fit adjusted spreads) – LIBOR at level data.*

	Mortgage-Backed Securities (MBS)											
	MAAA3		MAAA3_L		MAAA3_AD_L		MAAA5		MAAA5_L		MAAA5_AD_L	
	BHHH	M	BHHH	M§	BHHH	M	BHHH	M§	BHHH§	M§	BHHH	M
Wald-test H_0: $\alpha_{1,1}=\alpha_{1,2}$ (t-stat.)	9.7558***	54.1433***	63.2212***	26.3544***	17.6523***	1.4256	150.8776***	1792.4630***	248.6674***	118.4728***	11.6254***	5.9025**
(p-value)	0.0025	0.0000	0.0000	0.0000	0.0001	0.2360	0.0000	0.0000	0.0000	0.0000	0.0010	0.0173
Wald-test H_0: $\alpha_{1,1}+\alpha_{1,2}=0$ (t-stat.)	0.0740	3.0367*	0.0616	0.1076	1.5961	4.3106**	57.4436***	29.9905***	11.5838***	1.1889	18.3921***	19.9390***
(p-value)	0.7863	0.0852	0.8045	0.7438	0.2101	0.0410	0.0000	0.0000	0.0010	0.2788	0.0000	0.0000
LB-Q Statistic (lags)	8.2894 (4)	2.7906 (1)	1.9684 (1)	0.5128 (1)	0.1071 (1)	0.0378 (1)	0.0033 (1)	0.978 (1)	2.9706 (1)	0.9241 (1)	0.1214 (1)	1.0248 (1)
(p-value)	0.0820	0.0950	0.1610	0.4740	0.7430	0.8460	0.9540	0.3230	0.0850	0.3360	0.7270	0.3110
LB^2-Q Statistic (lags)	0.4031 (1)	0.3592 (1)	0.7890 (1)	0.0295 (1)	0.0466 (1)	0.4199 (1)	0.0112 (1)	0.1106 (1)	0.0203 (1)	0.6161 (1)	0.0753 (1)	1.5304 (1)
(p-value)	0.5250	0.5490	0.3740	0.8640	0.8290	0.5170	0.9160	0.7390	0.8870	0.4330	0.7840	0.2160
Jarque-Bera	17107.26***	3416.07***	1923.7310***	2243.06***	268.68***	329.03***	30808.85***	227.85***	279.46***	416.55***	93.2860***	150.3086***
(p-value)	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000

	Mortgage-Backed Securities (MBS)											
	MA7		MA7_L		MA7_AD_L		MBBB7		MBBB7_L		MBBB7_AD_L	
	BHHH	M	BHHH	M§	BHHH	M§	BHHH	M	BHHH	M§	BHHH	M
Wald-test H_0: $\alpha_{1,1}=\alpha_{1,2}$ (t-stat.)	11.7194***	47.5542***	0.4832	66.0740***	2.3304	22.3917***	71.4082***	66.0505***	73.1955***	23.1904***	8.4351***	10.0377***
(p-value)	0.0010	0.0000	0.4890	0.0000	0.1308	0.0000	0.0000	0.0000	0.0000	0.0000	0.0047	0.0022
Wald-test H_0: $\alpha_{1,1}+\alpha_{1,2}=0$ (t-stat.)	0.8600	0.2331	0.0050	0.0128	0.1119	0.0356	0.8763	0.7945	17.4695***	0.0817	5.7481**	23.9630***
(p-value)	0.3565	0.6305	0.9439	0.9100	0.7388	0.8508	0.3520	0.3754	0.0001	0.7757	0.0188	0.0000
LB-Q Statistic (lags)	0.0020 (1)	0.0815 (1)	NA (-)	0.9440 (1)	0.4851 (1)	0.0036 (1)	27.5200 (3)	18.9110 (11)	0.0199 (1)	0.0659 (1)	1.4258 (1)	0.1592 (1)
(p-value)	0.9650	0.7750	NA	0.3310	0.4860	0.9520	0.0000	0.0630	0.8880	0.7970	0.2320	0.6900
LB^2-Q Statistic (lags)	0.0142 (1)	0.0134 (1)	NA (-)	0.0000 (1)	0.0014 (1)	0.0163 (1)	0.0006 (1)	21.7170 (13)	0.0081 (1)	0.0376 (1)	7.2609 (1)	0.0114 (1)
(p-value)	0.9050	0.9080	NA	0.9960	0.9710	0.8980	0.9810	0.0600	0.9280	0.8460	0.0640	0.9150
Jarque-Bera	15072.62***	16250.28***	NA	16106.35***	14268.90***	18763.83***	1971.09***	2203.59***	4748.05***	3909.90***	78.90***	2919.99***
(p-value)	0.0000	0.0000	NA	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000

§ *no Bollerslev-Woolridge robust standard errors and variance*; ***=1% significance, **=5% significance, *=10% significance. *NA* indicates that no results could be generated by the statistics software due to data overflow.

Tab. 36. *Coefficient and residual tests of GARCH(1,1) model for MBS spreads (actual, transformed and Johnson Fit adjusted spreads) – LIBOR at level data.*

	Pfandbriefe					
	PAAA3		PAAA3_L		PAAA3_AD_L	
	BHHH	M	BHHH	M	BHHH	M[$]
Wald-test H_0: $\alpha_{1,1}=\alpha_{1,2}$ (t-stat.)	6.8409**	31.9393***	11.2868***	16.0852***	109.4263***	48.5179***
(p-value)	0.0106	0.0000	0.0012	0.0001	0.0000	0.0000
Wald-test H_0: $\alpha_{1,1}+\alpha_{1,2}=0$ (t-stat.)	4.2396*	13.2826***	3.3585*	0.4808	5.4711**	8.6506***
(p-value)	0.0427	0.0005	0.0705	0.4900	0.0218	0.0043
LB-Q Statistic (lags)	2.5576 (1)	1.4352 (1)	0.0865 (1)	0.0264 (1)	9.4366 (4)	0.0024 (1)
(p-value)	0.1100	0.2310	0.7690	0.8710	0.0510	0.9610
LB^2-Q Statistic (lags)	0.0263 (1)	0.0265 (1)	0.0396 (1)	0.1840 (1)	0.7654 (4)	0.1560 (1)
(p-value)	0.8710	0.8710	0.8420	0.6680	0.3820	0.6930
Jarque-Bera	433.45***	634.1820***	1751.75***	2071.82***	145.98***	502.40***
(p-value)	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
	Pfandbriefe					
	PAAA5		PAAA5_L		PAAA5_AD_L	
	BHHH	M	BHHH	M	BHHH	M
Wald-test H_0: $\alpha_{1,1}=\alpha_{1,2}$ (t-stat.)	96.4146***	175.1976***	65.6694***	118.4801***	97.1823***	164.5061***
(p-value)	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Wald-test H_0: $\alpha_{1,1}+\alpha_{1,2}=0$ (t-stat.)	0.1031	5.7279**	0.1424	2.9867*	0.1003	4.0279**
(p-value)	0.7489	0.0190	0.7069	0.0878	0.7523	0.0481
LB-Q Statistic (lags)	3.6470 (1)	0.9733 (1)	0.2344 (1)	0.5830 (1)	3.2244 (1)	0.3085 (1)
(p-value)	0.0560	0.3240	0.6280	0.4450	0.0730	0.5790
LB^2-Q Statistic (lags)	0.2203 (1)	2.0041 (1)	0.4414 (1)	0.2155 (1)	9.2248 (1)	0.0016 (1)
(p-value)	0.6390	0.1570	0.5060	0.6430	0.0020	0.9680
Jarque-Bera	15413.08***	26.64***	262.94***	1156.14***	70.42***	3635.51***
(p-value)	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
	Pfandbriefe					
	PAAA7		PAAA7_L		PAAA7_AD_L	
	BHHH	M	BHHH	M	BHHH	M
Wald-test H_0: $\alpha_{1,1}=\alpha_{1,2}$ (t-stat.)	0.0747	132.6121***	129.1162***	123.3417***	144.5944***	101.6267***
(p-value)	0.7853	0.0000	0.0000	0.0000	0.0000	0.0000
Wald-test H_0: $\alpha_{1,1}+\alpha_{1,2}=0$ (t-stat.)	0.0000	4.1373**	0.4691	1.3015	2.0817	13.7176***
(p-value)	0.9944	0.0452	0.4954	0.2573	0.1529	0.0004
LB-Q Statistic (lags)	227.9500 (7)	0.1680 (1)	NA (-)	NA (-)	0.0120 (1)	NA (-)
(p-value)	0.0000	0.6820	NA	NA	0.9130	NA
LB^2-Q Statistic (lags)	269.87 (8)	0.0284 (1)	NA (-)	NA (-)	0.0035 (1)	NA (-)
(p-value)	0.0000	0.8660	NA	NA	0.9530	NA
Jarque-Bera	426.80***	7680.63***	NA	NA	0.6626	NA
(p-value)	0.0000	0.0000	NA	NA	0.7180	NA

[$] no Bollerslev-Woolridge robust standard errors and variance; ***=1% significance, **=5% significance, *=10% significance. *NA* indicates that no results could be generated by the statistics software due to data overflow.

Tab. 37. *Coefficient and residual tests of GARCH(1,1) model for Pfandbrief spreads (actual, transformed and Johnson Fit adjusted spreads) – LIBOR at level data.*

	Collateralised Debt Obligations (CDO), synthetic					
	CSAAA3		CSAAA3_L		CSAAA3_AD_L	
	BHHH	M	BHHH	M	BHHH	M
Wald-test H_0: $\alpha_{1,1}=\alpha_{1,2}$ (t-stat.)	6.7751**	9.3459***	3.7257*	26.5706***	0.1271	2.2928
(p-value)	0.0111	0.0031	0.0573	0.0000	0.7224	0.1341
Wald-test H_0: $\alpha_{1,1}+\alpha_{1,2}=0$ (t-stat.)	1.9872	5.9244**	2.4436	0.6237	11.7339***	0.5367
(p-value)	0.1627	0.0173	0.1222	0.4321	0.0010	0.4660
Wald-test H_0: $\alpha_{2,1}=\alpha_{2,2}$ (t-stat.)	6.7284**	8.4518***	2.0350	4.3959**	4.2960**	1.2270
(p-value)	0.0114	0.0048	0.1578	0.0394	0.0416	0.2715
Wald-test H_0: $\alpha_{2,1}+\alpha_{2,2}=0$ (t-stat.)	1.6578	0.9402	0.9367	0.1031	8.2510***	0.0002
(p-value)	0.2018	0.3353	0.3362	0.7490	0.0053	0.9901
LB-Q Statistic (lags)	0.0077 (1)	0.4873 (1)	1.9216 (1)	0.1346 (1)	0.5394 (1)	0.0665 (1)
(p-value)	0.9300	0.4850	0.1660	0.7140	0.4630	0.7960
LB^2-Q Statistic (lags)	0.0333 (1)	0.0907 (1)	0.1954 (1)	0.0455 (1)	0.0067 (1)	0.0480 (1)
(p-value)	0.8550	0.7630	0.6580	0.8310	0.9350	0.8270
Jarque-Bera	3267.45***	802.12***	5786.53***	5838.44***	1712.16***	3077.07***
(p-value)	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000

	Collateralised Debt Obligations (CDO), synthetic					
	CSA5		CSA5_L		CSA5_AD_L	
	BHHH	M	BHHH	M	BHHH	M
Wald-test H_0: $\alpha_{1,1}=\alpha_{1,2}$ (t-stat.)	3.5244*	2.3731	0.4414	5.0931**	1.7234	6.8480**
(p-value)	0.0643	0.1275	0.5084	0.0269	0.1932	0.0107
Wald-test H_0: $\alpha_{1,1}+\alpha_{1,2}=0$ (t-stat.)	0.3878	1.7606	15.2267***	0.6361	2.4795	7.2158***
(p-value)	0.5353	0.1885	0.0002	0.4276	0.1194	0.0088
Wald-test H_0: $\alpha_{2,1}=\alpha_{2,2}$ (t-stat.)	0.3621	9.1094***	22.1788***	6.6009**	14.0394***	3.6399*
(p-value)	0.5491	0.0034	0.0000	0.0121	0.0003	0.0601
Wald-test H_0: $\alpha_{2,1}+\alpha_{2,2}=0$ (t-stat.)	2.3818	0.1604	9.8934***	0.0108	0.5399	6.2133**
(p-value)	0.1269	0.6899	0.0024	0.9174	0.4647	0.0148
LB-Q Statistic (lags)	NA	0.0001 (1)	NA (-)	0.2230 (1)	1.0199 (1)	1.4055 (1)
(p-value)	NA	0.9900	NA	0.6370	0.3130	0.2360
LB^2-Q Statistic (lags)	NA	0.0126 (1)	NA (-)	0.0363 (1)	0.5661 (1)	1.3667 (1)
(p-value)	NA	0.9110	NA	0.8490	0.4520	0.2420
Jarque-Bera	NA	2375.76***	NA	3528.01***	957.54***	1339.42***
(p-value)	NA	0.0000	NA	0.0000	0.0000	0.0000

	Collateralised Debt Obligations (CDO), synthetic					
	CSBBB7		CSBBB7_L		CSBBB7_AD_L	
	BHHH	M	BHHH	M	BHHH	M
Wald-test H_0: $\alpha_{1,1}=\alpha_{1,2}$ (t-stat.)	5.3318**	13.6743***	0.0155	1.0279	0.0491	0.0574
(p-value)	0.0236	0.0004	0.9013	0.3138	0.8252	0.8113
Wald-test H_0: $\alpha_{1,1}+\alpha_{1,2}=0$ (t-stat.)	15.0605***	1.5626	4.8285**	0.7098	2.6887	0.4347
(p-value)	0.0002	0.2151	0.0310	0.4021	0.1051	0.5117
Wald-test H_0: $\alpha_{2,1}=\alpha_{2,2}$ (t-stat.)	16.1542***	8.1008***	7.9645***	2.2627	0.9576	0.5550
(p-value)	0.0001	0.0057	0.0061	0.1366	0.3309	0.4585
Wald-test H_0: $\alpha_{2,1}+\alpha_{2,2}=0$ (t-stat.)	2.8502*	0.1976	3.1673*	0.0705	0.6819	0.0515
(p-value)	0.0954	0.6579	0.0791	0.7913	0.4115	0.8210
LB-Q Statistic (lags)	0.0075 (1)	0.0055 (1)	13.1000 (7)	0.4112 (1)	NA (-)	0.1473 (1)
(p-value)	0.9310	0.9410	0.0700	0.5210	NA	0.7010
LB^2-Q Statistic (lags)	0.0502 (1)	0.0701 (1)	1.9839 (1)	0.0069 (1)	NA (-)	0.0478 (1)
(p-value)	0.8230	0.7910	0.1590	0.9340	NA	0.8270
Jarque-Bera	3616.38***	2535.47***	1353.82***	1936.01***	NA	5533.32***
(p-value)	0.0000	0.0000	0.0000	0.0000	NA	0.0000

[$] no Bollerslev-Woolridge robust standard errors and variance; ***=1% significance, **=5% significance, *=10% significance. *NA* indicates that no results could be generated by the statistics software due to data overflow.

Tab. 38. *Coefficient and residual tests of GARCH(2,1) model for synthetic CDO spreads (actual, transformed and Johnson Fit adjusted spreads) – LIBOR at level data.*

	Collateralised Debt Obligations (CDO), traditional					
	CTAAA3		CTAAA3_L		CTAAA3_AD_L	
	BHHH	M	BHHH	M[$]	BHHH	M[$]
Wald-test H_0: $\alpha_{1,1}=\alpha_{1,2}$ (t-stat.)	12.2311***	45.4637***	83.9468***	97.8820***	5.4014**	3.4914*
(p-value)	0.0008	0.0000	0.0000	0.0000	0.0228	0.0655
Wald-test H_0: $\alpha_{1,1}+\alpha_{1,2}=0$ (t-stat.)	0.3424	0.0523	0.0164	0.0479	2.9815*	0.0156
(p-value)	0.5602	0.8198	0.8983	0.8273	0.0882	0.9008
Wald-test H_0: $\alpha_{2,1}=\alpha_{2,2}$ (t-stat.)	0.0260	0.0185	0.0300	0.7142	2.2902	0.0018
(p-value)	0.8723	0.8922	0.8630	0.4007	0.1343	0.9664
Wald-test H_0: $\alpha_{2,1}+\alpha_{2,2}=0$ (t-stat.)	0.3740	0.3278	0.4242	0.0793	1.2250	0.2322
(p-value)	0.5426	0.5686	0.5168	0.7790	0.2718	0.6313
LB-Q Statistic (lags)	NA (-)	0.0245 (1)	0.0993 (1)	0.0508 (1)	NA (-)	0.1827 (1)
(p-value)	NA	0.8760	0.7530	0.8220	NA	0.6690
LB^2-Q Statistic (lags)	NA (-)	0.0135 (1)	0.0138 (1)	0.0209 (1)	NA (-)	0.1776 (1)
(p-value)	NA	0.9070	0.9060	0.8850	NA	0.6730
Jarque-Bera	NA	11389.16***	13242.40***	12863.58***	NA	999.72***
(p-value)	NA	0.0000	0.0000	0.0000	NA	0.0000
	Collateralised Debt Obligations (CDO), traditional					
	CTA5		CTA5_L		CTA5_AD_L	
	BHHH	M	BHHH	M	BHHH	M[$]
Wald-test H_0: $\alpha_{1,1}=\alpha_{1,2}$ (t-stat.)	0.4277	0.0202	2.3699	0.2219	39.6823***	0.8163
(p-value)	0.5151	0.8873	0.1278	0.6389	0.0000	0.3691
Wald-test H_0: $\alpha_{1,1}+\alpha_{1,2}=0$ (t-stat.)	0.1151	0.0091	0.0009	0.0006	1.2868	0.0344
(p-value)	0.7353	0.9243	0.9756	0.9804	0.2602	0.8533
Wald-test H_0: $\alpha_{2,1}=\alpha_{2,2}$ (t-stat.)	0.0754	0.0288	5.5128**	0.0065	7.8005***	0.0041
(p-value)	0.7843	0.8657	0.0214	0.9361	0.0066	0.9493
Wald-test H_0: $\alpha_{2,1}+\alpha_{2,2}=0$ (t-stat.)	0.2297	0.1744	0.0149	0.0363	0.2433	0.4225
(p-value)	0.6331	0.6774	0.9032	0.8495	0.6232	0.5176
LB-Q Statistic (lags)	2.7012 (1)	2.0031 (1)	0.9812 (1)	0.0926 (1)	104.0900 (7)	0.7942 (1)
(p-value)	0.1000	0.1570	0.3220	0.7610	0.0000	0.3730
LB^2-Q Statistic (lags)	0.0817 (1)	0.1220 (1)	4.1944 (1)	0.0979 (1)	36.9010 (7)	0.0128 (1)
(p-value)	0.7750	0.7270	0.1230	0.7540	0.0000	0.9100
Jarque-Bera	557.85***	1025.17***	1446.97***	2095.24***	808.52***	6190.15***
(p-value)	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
	Collateralised Debt Obligations (CDO), traditional					
	CTBBB7		CTBBB7_L		CTBBB7_AD_L	
	BHHH	M[$]	BHHH	M	BHHH	M
Wald-test H_0: $\alpha_{1,1}=\alpha_{1,2}$ (t-stat.)	3.3580*	0.0004	7.9272***	11.5509***	7.1080***	3.0521*
(p-value)	0.0707	0.9839	0.0062	0.0011	0.0093	0.0846
Wald-test H_0: $\alpha_{1,1}+\alpha_{1,2}=0$ (t-stat.)	0.2762	0.0000	0.0004	0.0030	0.2144	0.0213
(p-value)	0.6007	0.9996	0.9834	0.9561	0.6446	0.8842
Wald-test H_0: $\alpha_{2,1}=\alpha_{2,2}$ (t-stat.)	0.0838	0.0000	4.2373**	1.5779	0.0748	0.0768
(p-value)	0.7730	0.9945	0.0429	0.2129	0.7852	0.7825
Wald-test H_0: $\alpha_{2,1}+\alpha_{2,2}=0$ (t-stat.)	0.6891	0.0000	0.0003	0.2524	1.2723	0.0313
(p-value)	0.4090	0.9996	0.9871	0.6168	0.2628	0.8601
LB-Q Statistic (lags)	0.0536 (1)	0.1160 (1)	NA (-)	3.0265 (1)	NA (-)	1.2850 (1)
(p-value)	0.8170	0.7330	NA	0.0820	NA	0.2570
LB^2-Q Statistic (lags)	0.0195 (1)	0.0001 (1)	NA (-)	0.0147 (1)	NA (-)	0.0132 (1)
(p-value)	0.8890	0.9910	NA	0.9030	NA	0.9090
Jarque-Bera	10451.73***	30228.41***	NA	577.64***	NA	242.31***
(p-value)	0.0000	0.0000	NA	0.0000	NA	0.0000

[$] no Bollerslev-Woolridge robust standard errors and variance; ***=1% significance, **=5% significance, *=10% significance. *NA* indicates that no results could be generated by the statistics software due to data overflow.

Tab. 39. *Coefficient and residual tests of GARCH(2,1) model for traditional CDO spreads (actual, transformed and Johnson Fit adjusted spreads) – LIBOR at level data.*

	Mortgage-Backed Securities (MBS)											
	MAAA5		MAAA5_L		MAAA5_AD_L		MAAA3		MAAA3_L		MAAA3_AD_L	
	BHHH	M	BHHH[§]	M[§]	BHHH	M	BHHH	M	BHHH	M	BHHH	M
Wald-test H_0: $\alpha_{1,1}=\alpha_{1,2}$ (t-stat.)	32.5711***	88.3360***	32.8384***	5.2058**	5.1387**	60.2948***	26.8723***	29.5187***	11.7610***	21.3593***	4.7236**	5.8495**
(p-value)	0.0000	0.0000	0.0000	0.0253	0.0262	0.0000	0.0000	0.0000	0.0010	0.0000	0.0328	0.0179
Wald-test H_0: $\alpha_{1,1}+\alpha_{1,2}=0$ (t-stat.)	0.2018	0.0776	0.0044	0.1265	41.4529***	8.9119***	0.3829	0.0241	0.6243	0.0010	9.4775***	2.5382
(p-value)	0.6545	0.7813	0.9474	0.7231	0.0000	0.0038	0.5379	0.8770	0.4319	0.9749	0.0029	0.1152
Wald-test H_0: $\alpha_{2,1}=\alpha_{2,2}$ (t-stat.)	1.4840	0.0078	0.2107	0.1068	22.7569***	18.6160***	4.0453**	0.5541	1.0973	1.3953	6.1316**	1.9223
(p-value)	0.2269	0.9298	0.6475	0.7447	0.0000	0.0000	0.0478	0.4589	0.2981	0.2411	0.0155	0.1696
Wald-test H_0: $\alpha_{2,1}+\alpha_{2,2}=0$ (t-stat.)	0.0504	0.0034	0.1461	0.0119	4.7428**	7.5959***	2.9903*	0.0003	0.6611	0.0018	0.6222	0.0155
(p-value)	0.8230	0.9537	0.7033	0.9135	0.0325	0.0073	0.0878	0.9865	0.4187	0.9660	0.4326	0.9013
LB-Q Statistic (lags)	0.1855 (1)	0.1697 (1)	0.3824 (1)	0.7196 (1)	2.0220 (1)	0.8496 (1)	1.7085 (1)	1.7543 (1)	0.1339 (1)	1.8920 (1)	0.0643 (1)	1.1198 (1)
(p-value)	0.6670	0.6800	0.5360	0.3960	0.1550	0.3570	0.1910	0.1850	0.7140	0.1690	0.8000	0.2900
LB^2-Q Statistic (lags)	0.0096 (1)	0.0006 (1)	0.0328 (1)	0.0002 (1)	0.1321 (1)	1.1775 (1)	0.0243 (1)	0.0609 (1)	2.7637 (1)	0.0176 (1)	0.6286 (1)	0.2226 (1)
(p-value)	0.9220	0.9800	0.8560	0.9900	0.7160	0.2780	0.8760	0.8050	0.0960	0.8950	0.4280	0.6370
Jarque-Bera	26790.68***	1901.43***	82.29***	2333.07***	20.32***	60.62***	459.91***	5307.79***	1368.40***	1901.99***	76.75***	110.87***
(p-value)	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000

	Mortgage-Backed Securities (MBS)											
	MA7		MA7_L		MA7_AD_L		MBBB7		MBBB7_L		MBBB7_AD_L	
	BHHH	M	BHHH	M[§]	BHHH	M	BHHH	M	BHHH	M	BHHH	M
Wald-test H_0: $\alpha_{1,1}=\alpha_{1,2}$ (t-stat.)	9.4249***	49.9306***	0.1524	14.2554***	0.2979	14.7772***	64.6798***	71.5939***	24.7189***	1.2911	33.6852***	11.7910***
(p-value)	0.0030	0.0000	0.6973	0.0003	0.5868	0.0002	0.0000	0.0000	0.0000	0.2594	0.0000	0.0010
Wald-test H_0: $\alpha_{1,1}+\alpha_{1,2}=0$ (t-stat.)	0.0500	0.0255	0.0009	0.0013	0.0522	0.0007	0.0065	9.0669***	0.1342	1.0267	1.6704	3.3781*
(p-value)	0.8236	0.8735	0.9768	0.9715	0.8199	0.9793	0.9357	0.0035	0.7151	0.3141	0.2001	0.0699
Wald-test H_0: $\alpha_{2,1}=\alpha_{2,2}$ (t-stat.)	0.0082	0.2458	0.0000	0.0396	0.9567	0.4792	1.2104	2.7693	3.3093*	0.0130	2.1379	4.8648**
(p-value)	0.9283	0.6215	0.9974	0.8428	0.3311	0.4909	0.2747	0.1002	0.0728	0.9096	0.1478	0.0304
Wald-test H_0: $\alpha_{2,1}+\alpha_{2,2}=0$ (t-stat.)	0.0317	0.0001	0.0001	0.0005	0.0631	0.0009	0.0957	2.9248	0.1408	0.7937	0.0363	0.3241
(p-value)	0.8591	0.9905	0.9922	0.9822	0.8023	0.9765	0.7578	0.0913	0.7086	0.3757	0.8494	0.5708
LB-Q Statistic (lags)	3.1814 (1)	0.0050 (1)	1.1880 (1)	0.0131 (1)	0.6432 (1)	0.0004 (1)	0.2046 (1)	0.6785 (1)	NA (-)	6.8808 (3)	9.5759 (5)	0.4099 (1)
(p-value)	0.0740	0.9440	0.2760	0.9090	0.4230	0.9850	0.6510	0.4100	NA	0.0760	0.0880	0.5220
LB^2-Q Statistic (lags)	10.7210 (1)	0.0184 (1)	0.0231 (1)	0.0156 (1)	0.0105 (1)	0.0139 (1)	0.0385 (1)	0.0353 (1)	NA (-)	0.0048 (1)	7.0510 (3)	11.2830 (6)
(p-value)	0.0010	0.8920	0.8790	0.9010	0.9180	0.9060	0.8440	0.8510	NA	0.9450	0.0700	0.0800
Jarque-Bera	6115.21***	17410.78***	6817.44***	19525.19***	12551.25***	21186.81***	4154.05***	4998.98***	NA	2086.77***	235.03***	92.3033***
(p-value)	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	NA	0.0000	0.0000	0.0000

[§] no Bollerslev-Woolridge robust standard errors and variance; ***=1% significance, **=5% significance, *=10% significance. *NA* indicates that no results could be generated by the statistics software due to data overflow.

Tab. 40. *Coefficient and residual tests of GARCH(2,1) model for MBS spreads (actual, transformed and Johnson Fit adjusted spreads) – LIBOR at level data.*

	Pfandbriefe					
	PAAA3		PAAA3_L		PAAA3_AD_L	
	BHHH	M	BHHH	M	BHHH	M
Wald-test H_0: $\alpha_{1,1}=\alpha_{1,2}$ (t-stat.)	19.9055***	14.0971***	93.9649***	17.8898***	72.0880***	46.5572***
(p-value)	0.0000	0.0003	0.0000	0.0001	0.0000	0.0000
Wald-test H_0: $\alpha_{1,1}+\alpha_{1,2}=0$ (t-stat.)	23.0527***	0.0000	21.5501***	0.0033	32.8384***	34.6323***
(p-value)	0.0000	0.9997	0.0000	0.9543	0.0000	0.0000
Wald-test H_0: $\alpha_{2,1}=\alpha_{2,2}$ (t-stat.)	14.8641***	2.2041	1.8807	0.4962	65.6099***	82.2001***
(p-value)	0.0002	0.1417	0.1742	0.4833	0.0000	0.0000
Wald-test H_0: $\alpha_{2,1}+\alpha_{2,2}=0$ (t-stat.)	23.8952***	0.012316	39.0546***	0.002194	30.6751***	64.3480***
(p-value)	0.0000	0.9119	0.0000	0.9628	0.0000	0.0000
LB-Q Statistic (lags)	0.0065	2.2069 (1)	1.9969 (1)	5.6423 (2)	0.4320 (1)	0.2826 (1)
(p-value)	0.9360	0.1370	0.1580	0.0600	0.5110	0.5950
LB^2-Q Statistic (lags)	1.6212	0.0541 (1)	0.1360 (1)	0.0495 (1)	0.0292 (1)	0.2164 (1)
(p-value)	0.2030	0.8160	0.7120	0.8240	0.8640	0.6420
Jarque-Bera	1950.50***	1479.74***	3159.79***	703.26***	603.62***	467.81***
(p-value)	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
	Pfandbriefe					
	PAAA5		PAAA5_L		PAAA5_AD_L	
	BHHH	M	BHHH	M	BHHH	M
Wald-test H_0: $\alpha_{1,1}=\alpha_{1,2}$ (t-stat.)	70.2573***	111.8280***	9.4890***	96.8696***	0.7314	60.2948***
(p-value)	0.0000	0.0000	0.0029	0.0000	0.3951	0.0000
Wald-test H_0: $\alpha_{1,1}+\alpha_{1,2}=0$ (t-stat.)	16.2869***	0.0067	0.0223	8.7148***	0.1072	8.9119***
(p-value)	0.0001	0.9351	0.8818	0.0042	0.7443	0.0038
Wald-test H_0: $\alpha_{2,1}=\alpha_{2,2}$ (t-stat.)	31.9256***	2.8370*	0.5845	24.6538***	0.3015	18.6160***
(p-value)	0.0000	0.0962	0.4469	0.0000	0.5846	0.0000
Wald-test H_0: $\alpha_{2,1}+\alpha_{2,2}=0$ (t-stat.)	19.15840***	0.017646	0.151561	5.06178**	0.269685	7.5959***
(p-value)	0.0000	0.8947	0.6981	0.0273	0.6050	0.0073
LB-Q Statistic (lags)	0.4544 (1)	0.4712 (1)	221.4200 (10)	0.0074 (1)	50.9990 (4)	0.8496 (1)
(p-value)	0.5000	0.4920	0.0000	0.9310	0.0000	0.3570
LB^2-Q Statistic (lags)	0.0698 (1)	0.0004 (1)	236.9200 (10)	0.0099 (1)	59.1510 (4)	1.1775 (1)
(p-value)	0.7920	0.9850	0.0000	0.9210	0.0000	0.2780
Jarque-Bera	723.33***	925.93***	731.85***	338.33***	6864.36***	1557.34***
(p-value)	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
	Pfandbriefe					
	PAAA7		PAAA7_L		PAAA7_AD_L	
	BHHH	M	BHHH	M	BHHH	M
Wald-test H_0: $\alpha_{1,1}=\alpha_{1,2}$ (t-stat.)	32.2521***	90.3554***	45.7684***	75.4514***	82.7466***	39.3219***
(p-value)	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Wald-test H_0: $\alpha_{1,1}+\alpha_{1,2}=0$ (t-stat.)	20.8666***	17.5222***	9.8789***	39.9064***	18.2086***	9.9496***
(p-value)	0.0000	0.0001	0.0024	0.0000	0.0001	0.0023
Wald-test H_0: $\alpha_{2,1}=\alpha_{2,2}$ (t-stat.)	44.5057***	46.6682***	20.4185***	89.8797***	52.9039***	36.9836***
(p-value)	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Wald-test H_0: $\alpha_{2,1}+\alpha_{2,2}=0$ (t-stat.)	19.7309***	13.84745***	9.3386***	31.6402***	13.9719***	9.6854***
(p-value)	0.0000	0.0004	0.0031	0.0000	0.0004	0.0026
LB-Q Statistic (lags)	0.6069 (1)	0.0771 (1)	0.0180 (1)	1.2534 (1)	0.3850 (1)	0.3263 (1)
(p-value)	0.4360	0.7810	0.8930	0.2630	0.5350	0.5680
LB^2-Q Statistic (lags)	0.0414 (1)	0.0088 (1)	0.6194 (1)	1.3203 (1)	1.2235 (1)	0.1346 (1)
(p-value)	0.8390	0.9250	0.4310	0.2510	0.2690	0.7140
Jarque-Bera	4576.94***	19536.74***	14.2607***	1.86	4.25	0.75
(p-value)	0.0000	0.0000	0.0008	0.3938	0.1193	0.6860

$ no Bollerslev-Woolridge robust standard errors and variance; ***=1% significance, **=5% significance, *=10% significance.
NA indicates that no results could be generated by the statistics software due to data overflow.

Tab. 41. *Coefficient and residual tests of GARCH(2,1) model for Pfandbrief spreads (actual, transformed and Johnson Fit adjusted spreads) – LIBOR at level data.*

	Collateralised Debt Obligations (CDO), synthetic																	
	CSAAA3		CSAAA3_L		CSAAA3_AD_L		CSA5		CSA5_L		CSA5_AD_L		CSBBB7		CSBBB7_L		CSBBB7_AD_L	
	BHHH[&]	M	BHHH	M	BHHH	M	BHHH	M	BHHH	M	BHHH	M	BHHH	M	BHHH	M	BHHH	M
α_0	-0.8551	-1.2154	-0.0610	-0.0190	-0.3359***	-0.0410	0.9887	-0.2715	0.0772	0.0678	0.1323***	0.0913	2.1930	2.1807	0.0496***	-0.0523	-0.0297***	0.0284
	-(1.2474)	-(1.3049)	-(1.4471)	-(0.1149)	-(3.3259)	-(0.7740)	(0.5276)	-(0.2101)	(0.8883)	(0.4151)	(205.4196)	(0.6388)	(0.5213)	(0.5911)	(5.6289)	-(0.2437)	-(2.9629)	(0.2427)
$\alpha_{1,1}$	0.0062	0.0150	0.0118	0.0034	0.0891***	0.0064	0.0128	-0.0009	-0.0106	-0.0137	-0.0249***	-0.0181	-0.0319	-0.0043	-0.0107***	0.0098	0.0071***	-0.0044
	(0.4746)	(1.0837)	(0.9444)	(0.0798)	(2.9162)	(0.4887)	(0.6929)	-(0.1097)	-(0.5459)	-(0.3918)	-(14207.88)	-(0.7259)	-(1.3675)	-(0.4321)	-(7.7536)	(0.2392)	(3.8994)	-(0.2047)
$\alpha_{1,2}$	-0.0446***	-0.0804***	-0.0006	-0.0059	0.0598*	-0.0166	-0.0219	-0.0313***	-0.0167	-0.0206	-0.0360***	-0.0271	-0.0762***	-0.0226*	-0.0143***	0.0068	-0.0031***	-0.0060
	-(2.8761)	-(2.9259)	-(0.0499)	-(0.1247)	(1.9246)	-(1.1533)	-(1.0991)	-(2.8461)	-(0.8167)	-(0.5433)	-(15.7886)	-(1.0937)	-(3.0201)	-(1.7341)	-(18.8033)	(0.1679)	-(2.9980)	-(0.2853)
$\alpha_{2,1}$	2.1073	1.6028	0.1847	0.4288	-1.6439	0.6318	-51.8906***	-1.3986	-1.9048***	-0.0360	-1.1522	-1.0708	95.5457**	-0.0138	-0.5551	0.0244	-0.2637	-0.0498
	(0.2666)	(0.2022)	(0.2396)	(0.2102)	-(1.3817)	(0.8343)	-(4.0234)	-(0.1424)	-(2.5399)	-(0.0079)	-(1.6226)	-(1.1388)	(2.1589)	-(0.0006)	-(0.7127)	(0.0820)	-(0.7213)	-(0.0593)
$\alpha_{2,2}$	-1.3642	-18.3401*	-0.6329	-1.5902*	-1.6393	-2.6656**	1.2630	-33.0674*	0.4336	-0.9184	-0.0550	-0.7110	-74.3427***	-0.0841	-0.2729	-0.1064	-0.5683***	-0.6308
	-(0.1514)	-(1.9008)	-(0.5831)	-(1.7558)	-(0.9808)	-(2.0165)	(0.1026)	-(1.9225)	(0.4467)	-(0.8527)	-(0.1485)	-(0.9964)	-(2.6201)	-(0.0033)	-(0.5332)	-(0.5095)	-(4.1118)	-(1.0676)
α_3	0.3069***	0.1149**	13.7955**	3.2842	2.0765	2.1496	-0.0323	0.0438**	-3.6839	4.0844	14.9445***	2.0489	0.0650**	0.0157	21.2035*	9.3126	4.2287	5.2430
	(2.4949)	(1.9733)	(2.4474)	(0.2451)	(0.4274)	(1.0491)	-(0.7248)	(2.3145)	-(0.3764)	(0.1944)	(5.4122)	(0.3819)	(2.3532)	(0.9509)	(1.7476)	(0.3916)	(0.6065)	(0.7013)
β_0	-1.1175***	3.2366	-0.0032**	0.0008	-0.0120	0.0040	-3.7391*	12.3671	-0.0026*	0.0006	-0.0056***	0.0026	-121.45***	56.5935	-0.0022***	-0.0037***	-0.0021***	0.0016
	-(3.6197)	(0.5155)	-(2.3255)	(0.4656)	-(1.3781)	(0.4336)	-(1.9243)	(0.3284)	-(1.6543)	(0.3703)	-(217.00)	(1.5288)	-(2.5961)	(0.2248)	-(48.6419)	-(39.9617)	-(21.7155)	(0.1283)
β_1	-0.0602***	-0.0484	-0.0212	0.1371	0.0003	-0.0450	0.0112	-0.0422	0.0304	0.1338	-0.0308	-0.0364	-0.0457	-0.0249	-0.0232	-0.0243***	-0.0059	0.0031
	-(2.7453)	-(1.0961)	-(0.9586)	(0.6786)	(0.0161)	-(0.9273)	(0.6565)	-(0.8478)	(1.1758)	(0.6770)	-(0.5067)	-(0.6998)	-(1.6215)	-(0.6326)	-(1.4512)	-(2.8280)	-(0.6064)	(0.0553)
β_2	0.0610	0.0609	0.0663	0.0510	0.2444	-0.0812	2.6823	0.1243	1.7925*	0.0493	0.6496***	0.0492	0.2086	-0.4027	-0.1469	0.0492	0.4211**	0.0380
	(0.4172)	(0.2768)	(0.5439)	(0.1197)	(1.2922)	-(0.9271)	(1.3949)	(0.2780)	(1.7741)	(0.0782)	(2.9599)	(0.0197)	(0.7776)	-(1.0217)	-(0.8498)	(0.1487)	(2.2967)	(0.1503)
β_3	0.0605***	-0.0100	0.0010**	-0.0001	0.0047*	-0.0002	0.0619**	-0.0099	0.0006*	-0.0001	0.0012***	-0.0001	0.7272***	-0.0017	0.0004***	0.0007***	0.0004***	0.0000
	(5.2784)	-(0.1243)	(2.3903)	-(0.2960)	(1.8499)	-(0.0892)	(2.2859)	-(0.0498)	(1.7177)	-(0.1810)	(145.12)	-(1.1325)	(2.9500)	-(0.0025)	5.36E+101	(29.3998)	3.53E+101	-(0.0039)
β_4	-40.4670***	-6.5551	-0.0637**	-0.0298***	-0.2075**	-0.0463	-79.4555	-0.1514	-0.0227	-0.0321*	-0.0043	0.0092	-185.14*	-0.0066	-0.0059*	-0.0287**	0.0004***	0.0374
	-(6.9422)	-(0.1756)	-(2.5128)	-(3.9705)	-(2.3513)	-(0.2913)	-(0.9551)	-(0.0011)	-(0.7251)	-(1.8692)	-(0.1624)	(0.1444)	-(1.9248)	(0.0000)	-(1.9510)	-(2.2316)	(2.6800)	(1.6291)
β_5	0.5662***	0.5455	0.5513***	0.5869**	-0.1685	0.5379*	0.2359***	0.5699	0.3130*	0.5902**	0.4014***	0.5482	0.4401	0.5850	0.8551***	0.6160***	0.8667***	0.5850
	(3.9847)	(0.9619)	(3.8009)	(2.3640)	-(0.7951)	(1.7867)	(2.6031)	(0.8541)	(1.8792)	(2.2750)	(2.8251)	(1.1179)	(1.4188)	(0.6391)	(14.3558)	(3.9683)	(9.8654)	(1.0821)

Z-statistics in parentheses; ***=1% significance, **=5% significance, *=10% significance. [&] singular covariance coefficients are not unique.

Tab. 42. *Estimation Results of GARCH(1,1) model for synthetic CDO spreads (actual, transformed and Johnson Fit adjusted spreads) – LIBOR at first differences.*

	Collateralised Debt Obligations (CDO), traditional																	
	CTAAA3		CTAAA3_L		CTAAA3_AD_L		CTA5		CTA5_L		CTA5_AD_L		CTBBB7		CTBBB7_L		CTBBB7_AD_L	
	BHHH	M	BHHH	M	BHHH	M	BHHH	M	BHHH	M	BHHH	M	BHHH	M	BHHH[&]	M	BHHH[&]	M
α_0	0.6439*	0.3405	0.1112**	0.0797	-0.1968	0.1684*	5.1104***	0.4793	0.1968***	0.1231	0.0602	0.1112	-6.8337	-15.183***	0.0466	0.0084	0.0966	0.0468
	(1.6773)	(0.4399)	(2.3644)	(1.2882)	-(0.6718)	(1.6841)	(3.0757)	(0.1535)	(2.8226)	(0.6176)	(0.2972)	(0.6731)	-(1.2584)	-(4.6180)	(0.5029)	(0.1937)	(0.6875)	(0.3555)
$\alpha_{1,1}$	-0.0155	-0.0097	-0.0347***	-0.0242	0.0534	-0.0513*	-0.0519***	-0.0007	-0.0413***	-0.0181	-0.0079	-0.0227	0.0400	0.0881***	-0.0080	0.0047	-0.0175	-0.0087
	-(1.1210)	-(0.4387)	-(2.6546)	-(1.3929)	(0.6599)	-(1.7668)	-(3.1279)	-(0.0273)	-(2.7795)	-(0.4221)	-(0.1807)	-(0.6256)	(1.3498)	(4.7368)	-(0.4527)	(0.1114)	-(0.6644)	-(0.3519)
$\alpha_{1,2}$	-0.0740***	-0.0853***	-0.0543***	-0.0448***	0.0288	-0.0817***	-0.1420***	-0.0653	-0.0587***	-0.0318	-0.0225	-0.0335	-0.0074	0.0718***	-0.0141	0.0290	-0.0339	-0.0219
	-(4.4509)	-(3.8488)	-(4.0510)	-(2.5886)	(0.3705)	-(2.8829)	-(4.4476)	-(1.0632)	-(3.6716)	-(0.7193)	-(0.5283)	-(0.9477)	-(0.2194)	(3.8625)	-(0.7595)	(0.0718)	-(1.3042)	-(0.8794)
$\alpha_{2,1}$	-3.7499*	0.7793	-0.9576	0.3960	1.0116	0.4629	0.5567	-0.0878	0.0708	-0.6704	0.2295	-0.2453	-19.2870	-53.805***	-0.2521	-0.1546	0.1529	0.0762
	-(1.7488)	(0.2379)	-(0.9285)	(0.7865)	(1.5034)	(1.1539)	(0.0514)	-(0.0075)	(0.3459)	-(1.4487)	(0.2843)	-(0.1584)	-(1.1994)	-(2.5247)	-(0.8844)	-(0.7698)	(0.3942)	(0.2273)
$\alpha_{2,2}$	0.7453	-7.1908	-0.0819	-0.9900**	-0.3110	-0.8679	4.0575	-0.0517	0.2132	0.0616	-0.1719	-0.0663	-18.0423	-86.122***	-0.2140	0.0000	-0.1412	-0.2355
	(0.1005)	-(0.8859)	-(0.0965)	-(2.4953)	(0.6428)	-(1.4785)	(0.3405)	-(0.0133)	(0.4035)	(0.1476)	-(0.3232)	-(0.0546)	-(1.3956)	-(3.7368)	-(0.6164)	(0.0000)	-(0.3633)	-(0.7941)
α_3	-0.2005	-0.0742	24.0456	-3.9680	17.8444*	10.4784***	0.0460*	0.0403	1.1624	-11.1224	-4.9717	-6.6773	0.0319	-0.0003	10.4854*	-0.0490	9.5078*	14.2827**
	-(1.3920)	-(0.3263)	(0.9971)	-(0.2504)	(1.6697)	(2.3432)	(1.7870)	(0.9802)	(0.4792)	-(1.0695)	-(1.1266)	-(0.6684)	(1.3985)	-(0.3021)	(1.6325)	-(0.2067)	(1.9613)	(2.3327)
β_0	-0.4030*	0.5727	-0.0023	0.0003	-0.0201	0.0008***	-1.3138	9.4850	0.0018	0.0012	0.0038	0.0021*	-40.2400*	1.6435	-0.0067***	0.0912	-0.0000*	0.0005***
	-(1.7366)	(0.2595)	-(0.9308)	(0.8843)	-(0.3914)	(13.0040)	-(0.4541)	(0.2947)	(0.6150)	(0.2566)	(0.4829)	(1.8218)	-(1.7964)	(0.4939)	-(260.9160)	(0.8980)	-(1.7402)	(32.6239)
β_1	0.2810**	-0.0296	0.0052	0.1186**	0.3203**	0.0856	0.1183	0.1155	0.2092**	-0.0421*	0.0978	0.0167	0.1338	0.7755*	0.0035	0.0433	0.1564	0.2020
	(2.2457)	-(0.2744)	(0.1936)	(2.3615)	(2.0288)	(1.4534)	(1.3381)	(0.8928)	(2.0725)	-(1.6687)	(1.0565)	(0.8621)	(1.4277)	(1.9425)	(0.0326)	(0.0971)	(1.4661)	(1.5809)
β_2	-0.0517	0.0147	0.1429	0.0432	0.3782***	0.1703	-0.1163	-0.1885	-0.2815	0.0570	-0.4667	0.0112	0.0366	1.9784	-0.0602	0.5887***	0.1654	0.0908
	-(0.1951)	(0.0280)	(0.3591)	(0.1191)	(3.5246)	(0.3619)	-(0.4841)	-(1.1400)	-(1.4343)	(0.5604)	-(0.9162)	(0.0342)	(0.3043)	(1.5357)	-(0.4615)	(2.6827)	(0.2296)	(0.3364)
β_3	0.0185**	-0.0029	0.0007	-0.0001	0.0000	-0.0001**	0.0691*	-0.0168	-0.0003	-0.0001	-0.0007	-0.0004*	0.2361**	-0.0059	0.0013***	0.0000	0.0000***	-0.0001***
	(2.1868)	-(0.0792)	(1.0154)	-(0.7072)	(0.0000)	-(2.4866)	(1.7080)	-(0.0653)	-(0.4859)	-(0.0731)	-(0.3940)	-(1.7410)	(1.9731)	-(0.3185)	(305.9971)	(0.0000)	(2.6604)	-(5.6946)
β_4	-4.5136	-0.4556	-0.0227***	-0.0138***	-0.0018	-0.0257	-187.53***	-0.1148	-0.0649***	-0.0253	-0.0503	-0.0226	-210.06***	-98.0413**	-0.0192***	0.0002*	-0.0170	-0.0130
	-(1.0223)	-(0.0254)	-(3.9802)	-(6.0019)	-(1.3512)	-(1.4139)	-(3.7688)	-(0.0013)	-(3.0999)	-(1.0466)	-(1.3588)	-(1.3443)	-(4.4704)	-(2.2225)	-(4.8694)	(1.7225)	-(1.2129)	-(0.9388)
β_5	0.4351***	0.5534	0.2744**	0.5904***	-0.0338***	0.4730***	0.5815***	0.5503	0.6033***	0.6250**	0.6705***	0.8015***	0.6478***	0.0027	0.7099***	-0.0262*	0.5084***	0.4764***
	(3.6475)	(0.5363)	(2.4093)	(4.4381)	-(3.0594)	(2.7125)	(6.6731)	(0.8649)	(6.0545)	(2.3202)	(4.6390)	(5.9026)	(7.9633)	(0.1287)	(7.1086)	-(1.7500)	(3.0307)	(3.6227)

Z-statistics in parentheses; ***=1% significance, **=5% significance, *=10% significance. [&] singular covariance coefficients are not unique.

Tab. 43. *Estimation Results of GARCH(1,1) model for traditional CDO spreads (actual, transformed and Johnson Fit adjusted spreads) – LIBOR at first differences.*

	Mortgage-Backed Securities (MBS)											
	MAAA3		MAAA3_L		MAAA3_AD_L		MAAA5		MAAA5_L		MAAA5_AD_L	
	BHHH	M	BHHH	M	BHHH[&]	M	BHHH	M	BHHH[&]	M[&]	BHHH	M
α_0	0.6957*	-0.2128	0.0648	-0.0107	0.5348***	0.2316*	0.1188	0.2213	0.0256*	0.0283	2.1303***	1.5572***
	(1.8789)	-(0.8552)	(1.1690)	-(0.1381)	(2.5633)	(1.6494)	(0.2290)	(0.4193)	(1.6860)	(1.0146)	(6.3509)	(5.3027)
$\alpha_{1,1}$	-0.0299*	0.0138	-0.0200	0.0038	-0.1828**	-0.0748	0.2504	0.0805	-0.0057	-0.0094	-0.6812***	-0.5001***
	-(1.9276)	(1.0007)	-(1.1498)	(0.1725)	-(2.4703)	-(1.5936)	(1.2238)	(0.3420)	-(1.2629)	-(0.9509)	-(6.2183)	-(5.2584)
$\alpha_{1,2}$	-0.0604***	-0.0368***	-0.0274	-0.0125	-0.2256***	-0.1189***	-0.0052	-0.0021	-0.0204***	-0.0236**	-0.7325***	-0.5222***
	-(4.0029)	-(2.8427)	-(1.6163)	-(0.5712)	-(2.6568)	-(2.6805)	-(0.6008)	-(0.2496)	-(4.9925)	-(2.4034)	-(6.8095)	-(5.4146)
$\alpha_{2,1}$	7.3730***	0.3402	1.0977***	0.0413	1.4318	0.0244	-0.0464***	-0.0417***	0.1197	-0.0415	2.0532	0.2156
	(3.6070)	(0.2681)	(2.7006)	(0.0404)	(0.8512)	(0.0332)	-(5.0098)	-(4.5036)	(0.7985)	-(0.2552)	(1.2231)	(0.2065)
$\alpha_{2,2}$	-2.7031	-0.9292	-0.4855	-0.1552	-0.6449	-0.4362	-2.0158*	0.0567	-0.3930*	-0.4621	-3.4029***	-3.4593***
	-(0.8587)	-(0.3338)	-(0.5967)	-(0.1834)	-(0.6854)	-(0.5801)	-(1.7796)	(0.0531)	-(1.7680)	-(1.2727)	-(3.5324)	-(4.3524)
α_3	-1.5082	-0.5373	-18.3664	0.0015	5.9111	0.3255	0.0000	0.0000	2.7644	12.8894	-0.8505	0.1480
	-(1.4477)	-(0.5407)	-(1.2266)	(0.0000)	(0.9384)	(0.1759)	(0.0000)	(0.0000)	(0.2942)	(0.7370)	-(0.4761)	(1.1015)
β_0	0.0794*	0.0523	0.0016*	0.0006***	0.0043	0.0062	0.0000	0.0000	0.0004***	0.0002***	-0.0432	0.0015
	(1.8114)	(0.5130)	(1.8936)	(6.2346)	(0.2351)	(0.1694)	(0.0000)	(0.0000)	(53.2556)	(3.9080)	-(1.0739)	(0.0404)
β_1	0.0091	0.0114	0.0532	-0.0090	0.2535	0.7420	0.0472	0.0741	-0.1274	-0.0097	0.3087**	1.1233***
	(0.1088)	(0.3710)	(0.5191)	-(0.4440)	(0.8003)	(0.4465)	(0.4403)	(0.7038)	-(0.9836)	-(0.1956)	(2.0863)	(3.1385)
β_2	0.5378	-0.0629**	0.4983	-0.0209	-0.3176	-0.7731	-0.0304	-0.0279	-0.4370	0.0032	0.4484	-0.0755
	(1.1829)	-(2.0783)	(0.9361)	-(0.3928)	-(0.9157)	-(0.4581)	-(0.8052)	-(0.4207)	-(1.4432)	(0.0110)	(1.1253)	-(0.1319)
β_3	-0.0031*	-0.0007	-0.0005*	-0.0002***	-0.0006	-0.0011	-0.6187	-0.3699	-0.0001***	0.0000	0.0145	0.0001
	-(1.6449)	-(0.1849)	-(1.7743)	-(6.9541)	-(0.0929)	-(0.0895)	-(0.4865)	-(0.2027)	-(12.3141)	-(0.6519)	(1.1208)	(0.0116)
β_4	-0.4114	-0.6510	-0.0040	-0.0074***	-0.0003	-0.0677*	0.4912**	0.5339	-0.0065*	-0.0090*	-0.0720	-0.1149***
	-(0.4403)	-(0.7741)	-(0.2277)	-(2.6771)	-(0.0051)	-(1.6378)	(2.0016)	(1.2200)	-(1.6449)	-(1.8953)	-(0.8909)	-(2.8773)
β_5	0.5592***	0.5156	0.3149*	0.4751**	0.4093	-0.0283	-0.6850***	-0.5010*	0.9944***	0.5492	0.2605*	-0.0195
	(3.5889)	(0.9115)	(1.8783)	(2.3788)	(1.3163)	-(0.3605)	-(2.6283)	-(1.9144)	(4.6450)	(1.3707)	(1.7464)	-(1.2926)
	MA7		MA7_L		MA7_AD_L		MBBB7		MBBB7_L		MBBB7_AD_L	
	BHHH	M	BHHH	M[&]	BHHH	M[&]	BHHH	M	BHHH	M[&]	BHHH	M
α_0	-1.1642	-0.5196	0.0144	0.0009	0.0515	0.0245	2.8840	-0.2653	-0.0384	-0.0455	2.3855***	-0.5993***
	-(1.4948)	-(1.1046)	(0.7256)	(0.0193)	(0.1996)	(0.1144)	(0.5617)	-(0.1044)	-(0.1847)	-(0.2241)	(4.0927)	-(14.8031)
$\alpha_{1,1}$	0.0170	0.0075	0.0116	-0.0043	-0.0122	-0.0059	-0.0157	0.0138	0.0110	0.0098	-0.4828***	-0.6014***
	(1.3488)	(1.1033)	(0.5827)	-(0.0952)	-(0.1973)	-(0.1144)	-(0.3543)	(0.8346)	(0.2469)	(0.2283)	-(4.0894)	-(14.8182)
$\alpha_{1,2}$	-0.0040	-0.0123*	0.1227	0.0000	-0.0178	-0.0115	-0.0491	-0.0149	0.0059	0.0050	-0.5015***	-0.2156
	-(0.3356)	-(1.9457)	(1.1794)	(0.0000)	-(0.2875)	-(0.2229)	-(1.1019)	-(1.0194)	(0.1338)	(0.1171)	-(4.2517)	-(1.2432)
$\alpha_{2,1}$	6.8531**	3.0618	-0.0403	-0.0001	0.7260	0.4869	4.4225	-0.0301	0.3038	-0.1120	-1.1507	-0.1725*
	(2.5022)	(1.4271)	-(0.4286)	-(0.0001)	(0.9759)	(1.2174)	(0.3253)	-(0.0033)	(0.3802)	-(0.1307)	-(0.5924)	-(1.8021)
$\alpha_{2,2}$	-6.9857	-5.2354	0.0000	0.0000	-0.6688**	-0.6939***	-0.3839	-0.2074	-0.0617	-0.0524	-0.7079*	0.0000
	-(1.5038)	-(1.3076)	(0.0000)	(0.0000)	-(2.4369)	-(3.0943)	-(0.0300)	-(0.0161)	-(0.0806)	-(0.1383)	-(1.6821)	(0.0000)
α_3	-0.3496	-0.2204	-0.0568	-0.0027	-26.8013	-30.2562	0.0927	-0.0626	-20.8092	4.6995	0.6263	2.9657***
	-(1.4412)	-(0.6846)	-(0.6800)	-(0.0142)	-(0.9588)	-(0.6955)	(0.7440)	-(0.7903)	-(0.4024)	(0.1439)	(0.9345)	(14.7673)
β_0	0.8997***	0.1552	0.0560	0.1500	0.0009***	0.0007	-15.3932	5.1587	-0.0005*	-0.0013***	-0.1892	0.7880***
	(15.0398)	(0.7541)	(1.3212)	(0.8243)	(28.4730)	(1.0046)	-(1.5272)	(0.3515)	-(1.8374)	-(9.9610)	-(1.4652)	(5.6708)
β_1	0.1038	0.3452	0.1834	0.0500	0.1363	0.0762	0.0329	0.0010	0.0225	0.1152	-0.0070	-0.5056***
	(1.1806)	(0.6705)	(1.5569)	(0.1091)	(0.8727)	(0.5797)	(0.3800)	(0.0109)	(0.2811)	(1.4374)	-(0.1052)	-(3.4664)
β_2	0.3949*	2.0668**	0.6331***	0.5999***	-0.2383	0.0507	-0.0275	-0.1203***	-0.0082	0.0316	1.3879**	0.1516***
	(1.7001)	(2.0921)	(6.2818)	(3.7642)	-(0.7476)	(0.1372)	-(0.2015)	-(2.7599)	-(0.0450)	(0.1075)	(2.0063)	(3.2581)
β_3	-0.0125***	-0.0009	0.0000	0.0000	-0.0002***	-0.0002	0.1361	0.0000	0.0001**	0.0003***	0.0395	0.0000
	-(1770.81)	-(0.3045)	(0.0000)	(0.0000)	-(23.4736)	-(0.9566)	(1.5791)	(0.0004)	(2.3875)	(10.5667)	(1.5088)	(0.0000)
β_4	-2.7159	-1.2876	-0.0001***	0.0000	-0.0033***	-0.0032***	-46.0344**	-0.3574	-0.0083	-0.0038***	0.0976***	-0.0009***
	-(1.4138)	-(1.2432)	-(48.0315)	-(0.3251)	-(4.0140)	-(4.1013)	-(2.3497)	-(0.0035)	-(1.2745)	-(2.9474)	(3.9777)	-(26.6370)
β_5	0.4571***	-0.0547	-0.0013***	-0.0024**	0.7180***	0.5792**	0.5122***	0.5494	0.6573***	0.5963***	-0.0162	0.0005
	(2.9391)	-(1.3602)	-(5.9347)	-(2.1766)	(6.8271)	(2.2639)	(4.0929)	(0.7472)	(2.6673)	(7.6506)	-(0.1770)	(0.7430)

Z-statistics in parentheses; ***=1% significance, **=5% significance, *=10% significance. [&] singular covariance coefficients are not unique.

Tab. 44. *Estimation Results of GARCH(1,1) model MBS spreads (actual, transformed and Johnson Fit adjusted spreads) – LIBOR at first differences.*

	Pfandbriefe																	
	PAAA3		PAAA3_L		PAAA3_AD_L		PAAA5		PAAA5_L		PAAA5_AD_L		PAAA7		PAAA7_L		PAAA7_AD_L	
	BHHH[&]	M	BHHH	M	BHHH	M	BHHH	M	BHHH	M	BHHH[&]	M	BHHH	M	BHHH	M	BHHH	M
α_0	4.5513***	5.6343**	0.5429	0.6141***	0.6466**	0.9528***	-0.8757	-0.0421	-0.0376	-0.0378	0.2456	-0.0298	0.2407	0.8810	0.3565	0.1193*	0.1436*	0.1854*
	(3.3969)	(2.5078)	(1.5640)	(4.6451)	(2.0686)	(3.0310)	-(0.9609)	-(0.0653)	-(0.4130)	-(0.4745)	(1.5503)	-(0.2136)	(0.3498)	(1.3723)	(1.5510)	(1.9337)	(1.7794)	(1.7381)
$\alpha_{1,1}$	-0.2044***	-0.2226*	-0.1694	-0.2000***	-0.1954*	-0.3058***	0.0795**	0.0189	0.0230	0.0202	-0.0512	0.0262	0.0438*	0.0209	-0.0783	-0.0193	-0.0317	-0.0339
	-(3.0234)	-(1.8070)	-(1.4601)	-(4.6567)	-(1.8981)	-(2.9253)	(2.0655)	(0.5398)	(0.7973)	(0.7725)	-(1.0806)	(0.5746)	(1.7265)	(0.9192)	-(1.2991)	-(1.1243)	-(1.3121)	-(1.2202)
$\alpha_{1,2}$	-0.3256***	-0.3238***	-0.2133*	-0.2268***	-0.2328**	-0.3331***	-0.0438	-0.1040***	-0.0141	-0.0152	-0.0891*	-0.0118	-0.0473*	-0.0698***	-0.1069*	-0.0447***	-0.0632***	-0.0637**
	-(4.6571)	-(2.9230)	-(1.8363)	-(5.3691)	-(2.2827)	-(3.2500)	-(1.2452)	-(3.2538)	-(0.4969)	-(0.6021)	-(1.9260)	-(0.2768)	-(1.9685)	-(3.5111)	-(1.7644)	-(2.7144)	-(2.6532)	-(2.3190)
$\alpha_{2,1}$	6.4384	9.4402	1.9844	0.7331	-2.8504*	0.3296	3.2729	-1.3795	0.0006	-0.5939	-0.9247	-0.4692	-5.1516	-5.8705	-0.7777	-1.2712	-2.7918***	-2.3784*
	(0.9704)	(1.4484)	(0.9168)	(0.5743)	-(1.6531)	(0.3034)	(0.4073)	-(0.3241)	(0.0005)	-(0.7015)	-(0.5431)	-(0.3023)	-(0.6784)	-(1.0138)	-(0.5775)	-(1.2549)	-(2.6031)	-(1.8177)
$\alpha_{2,2}$	-10.6560*	-4.9765	-2.2307	-2.2567***	0.2487	-0.2304	1.0301	3.9858*	0.4105	0.7705*	-1.6499	-0.0087	-0.6495	-6.3677	-1.4791*	-1.0521	-0.6465***	-0.1273
	-(1.9043)	-(0.4748)	-(1.1635)	-(4.9899)	(0.1668)	-(0.2640)	(0.1980)	(1.7260)	(0.5685)	(1.9067)	-(0.9689)	-(0.0075)	-(0.2848)	-(1.4851)	-(1.6625)	-(1.4043)	-(3.2229)	-(0.1882)
α_3	-0.1792*	-0.2756***	-5.4912*	-5.8886	-7.9308*	-8.8594**	0.1442	0.5381***	6.2790	10.1118**	-9.4603*	0.0943	-0.1121	-0.1375	-22.9699	-7.3764	6.8546*	-8.9689
	-(1.9417)	-(4.0149)	-(1.7575)	-(0.7796)	-(1.8327)	-(1.9770)	(1.0683)	(2.9712)	(1.3663)	(2.1555)	-(1.9187)	(0.0185)	-(0.6157)	-(0.8895)	-(1.5915)	-(1.0597)	(1.9447)	-(0.4953)
β_0	3.7387***	2.1333	0.0204	0.0190***	0.0295***	0.0205	1.1119***	0.2832	0.0033**	0.0014	0.0145***	0.0034***	-0.0294	0.2193	0.0090***	0.0040***	0.0052	0.0032
	(3.2557)	(0.5282)	(1.4537)	(3.3434)	(4.8383)	(1.5404)	(3.8610)	(0.8658)	(1.9999)	(0.4616)	(61.6143)	(3.0839)	-(0.1135)	(1.1010)	(3.1027)	(20.0363)	(1.1709)	(0.4735)
β_1	0.1603**	0.0496***	0.1331**	0.2025	0.1006*	0.0021	-0.0556	-0.0725*	-0.0864*	-0.0821**	0.0518**	-0.0362	-0.0663	-0.0266	0.1432	0.1665	0.4051***	0.2566
	(2.0746)	(3.4596)	(2.0639)	(0.9894)	(1.7348)	(0.0153)	-(1.3389)	-(1.8391)	-(1.6775)	-(1.9861)	(2.1670)	-(0.9539)	-(0.9620)	-(0.3430)	(0.8560)	(1.1739)	(3.2857)	(0.7780)
β_2	-0.8337***	-1.0851***	-0.4667**	0.9820	-0.1881	0.5556*	-0.0314	0.0863	0.1273	0.3038**	-0.2147	-0.1020	0.1083	0.0551	-0.0600	0.0612	-0.3755***	-0.1729
	-(2.6019)	-(3.7494)	-(2.1599)	(0.9413)	-(0.5438)	(1.8718)	-(0.3754)	(1.2097)	(1.3129)	(2.0930)	-(1.3852)	-(0.7059)	(0.6288)	(0.3807)	-(0.6102)	(0.3655)	-(3.1800)	-(0.4375)
β_3	-0.1730***	-0.0033	-0.0067	-0.0061***	-0.0098***	-0.0068	-0.0376***	-0.0001	-0.0009*	-0.0001	-0.0042***	-0.0011***	0.0023	-0.0072	-0.0024***	-0.0011***	-0.0006	-0.0004
	-(3.3687)	-(0.0152)	-(1.4561)	-(3.3725)	-(5.0589)	-(1.5721)	-(3.4088)	-(0.0054)	-(1.8242)	-(0.1437)	-(123.903)	-(2.8746)	(0.2301)	-(1.0470)	-(3.0972)	-(118.658)	-(0.5019)	-(0.2118)
β_4	-18.6581**	1.5632	-0.1379	-0.0533	-0.0974**	-0.0541**	-14.5482***	-10.3230***	-0.0827**	-0.0941**	-0.1010	-0.0848***	-5.5926*	-8.2869***	-0.0400**	-0.0635***	0.0297***	0.0286
	-(2.1055)	(0.0721)	-(1.1530)	-(1.1452)	-(2.1245)	-(2.2270)	-(2.8745)	-(2.6079)	-(2.3092)	-(2.3559)	-(1.2116)	-(2.6255)	-(1.6512)	-(3.2629)	-(2.0893)	-(3.7936)	(3.3916)	(1.6265)
β_5	0.6907***	0.5878***	0.6838**	0.0840	0.6548***	0.6085***	0.8650***	0.7896***	0.7998***	0.4894***	0.6171***	1.0095***	0.9232***	0.9176***	0.3777*	0.5733***	-0.4841***	-0.0229
	(10.5717)	(3.1351)	(8.6818)	(0.6759)	(6.3602)	(2.9404)	(10.9277)	(5.3276)	(7.4708)	(3.2640)	(5.7479)	(11.9213)	(9.0558)	(20.9413)	(1.8807)	(4.1402)	-(3.1267)	-(0.0311)

Z-statistics in parentheses; ***=1% significance, **=5% significance, *=10% significance. [&] singular covariance coefficients are not unique.

Tab. 45. *Estimation Results of GARCH(1,1) model for Pfandbrief spreads (actual, transformed and Johnson Fit adjusted spreads) – LIBOR at first differences.*

	Collateralised Debt Obligations (CDO), synthetic																	
	CSAAA3		CSAAA3_L		CSAAA3_AD_L		CSA5		CSA5_L		CSA5_AD_L		CSBBB7		CSBBB7_L		CSBBB7_AD_L	
	BHHH	M	BHHH[&]	M[&]	BHHH	M[&]	BHHH	M	BHHH	M	BHHH	M	BHHH	M	BHHH	M	BHHH	M
α_0	-0.9165	0.2938	-0.1324***	-0.0309	-0.1941**	-0.0442	2.2535**	-1.7213	0.0312	0.0932	0.1842	0.1719	-2.5155	-10.0061**	0.1166	-0.0603	-0.0167	0.0034
	-(1.1546)	(0.6168)	-(2.5725)	-(0.5400)	-(2.2929)	-(0.5708)	(2.2964)	-(0.3864)	(0.3236)	(1.0101)	(0.7698)	(0.7167)	-(0.4893)	-(2.2299)	(0.4786)	-(0.6537)	-(0.1937)	(0.0210)
$\alpha_{1,1}$	0.0932	-0.0036	0.0942	0.0090	-0.2280*	0.0214	0.0089	0.0465	-0.1363	-0.0174	-0.2984**	-0.0638	0.0996	0.0577	0.0605	0.0250	-0.0463	-0.0244
	(1.3416)	-(0.1569)	(1.2065)	(0.2281)	-(1.7833)	(0.6529)	(0.3267)	(0.6184)	-(1.4109)	-(0.1577)	-(2.0652)	-(0.5323)	(0.7414)	(0.4924)	(0.2000)	(0.3713)	-(0.9307)	-(0.1925)
$\alpha_{1,2}$	0.0426	-0.0356	0.0859	0.0043	-0.2445*	-0.0049	-0.0085	0.0571	-0.1417	-0.0206	-0.3017**	-0.0657	0.1006	0.0381	0.0591	0.0238	-0.0478	-0.0274
	(0.6193)	-(1.7404)	(1.0998)	(0.1102)	-(1.9301)	-(0.1417)	-(0.2896)	(0.7670)	-(1.4666)	-(0.1877)	-(2.0735)	-(0.5589)	(0.7720)	(0.3711)	(0.1955)	(0.3526)	-(0.9654)	-(0.2178)
$\alpha_{2,1}$	-0.0771	-0.0010	-0.0616	-0.0027	0.2855**	-0.0116	-0.0158	-0.0501	0.1349	-0.0022	0.2665*	0.0345	-0.1042	-0.0062	-0.0858	-0.0159	0.0533	0.0253
	-(1.0911)	-(0.0475)	-(0.8089)	-(0.0824)	(2.1343)	-(0.2903)	-(0.5349)	-(0.8052)	(1.5537)	-(0.0213)	(1.7713)	(0.3893)	-(0.7455)	-(0.0428)	-(0.2631)	-(0.2549)	(0.9765)	(0.2368)
$\alpha_{2,2}$	-0.0799	-0.0121	-0.0663	-0.0046	0.2776**	-0.0152	-0.0389	-0.0782	0.1320	-0.0055	0.2588*	0.0300	-0.1411	-0.0267	-0.0877	-0.0213	0.0464	0.0210
	-(1.1389)	-(0.6143)	-(0.8798)	-(0.1436)	(2.0965)	-(0.3821)	-(1.3789)	-(1.3135)	(1.5347)	-(0.0540)	(1.7211)	(0.3448)	-(1.0020)	-(0.2061)	-(0.2702)	-(0.3409)	(0.8531)	(0.1968)
$\alpha_{3,1}$	-8.6818	-0.0361	0.7767	0.3594	-2.3231**	0.7941	-36.963**	0.8871	-1.3951**	0.1148	-1.1604	-0.4630	-9.6551	-3.7598	-0.8035	0.0798	-0.5769	-0.2904
	-(1.1016)	-(0.0042)	(1.0292)	(0.4149)	-(2.2330)	(0.5694)	-(1.9946)	(0.0599)	-(1.9881)	(0.1362)	-(1.0842)	-(0.3714)	-(0.2014)	-(0.0548)	-(0.3670)	(0.1360)	-(1.0068)	-(0.3569)
$\alpha_{3,2}$	-1.5302	-0.4673	-1.1494	-2.1324*	-0.8871	-2.3778	-3.8433	-38.8050*	0.1550	-1.2040	0.2274	-0.7047	-49.882*	-57.964***	-0.2410	-1.0439*	-0.0673	-0.5853
	-(0.1570)	-(0.1324)	-(1.1088)	-(1.9028)	-(0.8393)	-(1.6223)	-(0.4329)	-(1.7889)	(0.2950)	-(1.6164)	(0.2838)	-(0.7130)	-(1.9097)	-(4.2393)	-(0.2295)	-(1.7309)	-(0.1306)	-(1.1260)
α_4	0.3009	0.0699	7.9678**	4.7340	0.7800	2.1554	0.0551**	0.0737	-1.7372	5.7496	0.2279	-3.7926	0.0652*	0.0131	31.8975	11.9746	0.4265	3.2328
	(1.4414)	(0.9777)	(2.0938)	(0.6688)	(0.2096)	(0.7992)	(2.0155)	(1.0558)	-(0.2508)	(0.3945)	(0.0419)	-(0.4530)	(1.8584)	(0.5207)	(1.3500)	(0.7368)	(0.0569)	(0.3829)
β_0	-0.7249	2.3338	-0.0030***	0.0015***	-0.0076	0.0039***	-5.4397	17.2733	0.0024	0.0010*	-0.0141*	0.0026***	-63.123***	54.2793	-0.0025***	0.0008	-0.0066*	0.0015*
	-(0.9379)	(0.1199)	-(15.3516)	(4.7983)	-(1.1494)	(4.2016)	-(0.8084)	(0.5118)	(1.3603)	(2.0924)	-(1.7285)	(3.8374)	-(3.5708)	(0.6481)	-(4.1777)	(1.3472)	-(1.9590)	(1.7703)
β_1	-0.0459	-0.0247	-0.0362	-0.0351	0.0298*	-0.0451**	-0.0269	-0.0610	0.1350	-0.0407	0.0228	-0.0312	-0.0104	0.0142	-0.0337**	-0.0352	0.0012	-0.0275
	-(2.1557)	-(0.2435)	-(0.8413)	-(1.0654)	(1.6543)	-(2.1877)	-(0.7562)	-(1.6127)	(1.3389)	-(1.5852)	(0.8507)	-(0.6901)	-(0.1846)	(1.3114)	-(2.1938)	-(0.5579)	(0.0622)	-(0.2434)
β_2	0.3352	0.0718	0.0241	0.2346	0.2483	-0.0640	1.5260**	0.2235	1.9004*	0.0790	1.3710	-0.0117	0.1807	1.8008	-0.0738	0.0279	2.2296*	0.0825
	(1.5264)	(0.0080)	(0.2251)	(0.8227)	(1.5919)	-(1.1462)	(2.2651)	(0.6975)	(1.7805)	(0.3097)	(0.8863)	-(0.0031)	(0.2688)	(1.3264)	-(0.3139)	(0.0882)	(1.9109)	(0.0985)
β_3	0.0440*	-0.0041	0.0010***	-0.0002***	0.0031**	-0.0002	0.0665*	0.0025	-0.0004	0.0000	0.0032*	-0.0001	0.3442***	0.0127	0.0005***	0.0000	0.0012**	0.0000
	(1.8460)	-(0.0241)	(35.2391)	-(5.1066)	(2.1357)	-(0.2586)	(1.6480)	(0.0137)	-(0.9729)	-(0.7362)	(1.8286)	-(0.0778)	(3.3357)	(0.0331)	(4.5434)	-(0.4545)	(2.0343)	-(0.1515)
β_4	-25.6427***	-0.6181	-0.0808	-0.0336	-0.1694*	-0.0722	-102.26***	-6.2214	-0.0185	-0.0126	-0.0541**	-0.0104	-319.12**	-0.2916	-0.0037	-0.0115	-0.0103**	0.0272**
	-(2.7195)	-(0.0058)	-(1.5893)	-(0.4713)	-(1.7845)	-(0.3417)	-(3.1820)	-(0.0528)	-(0.5432)	-(0.1794)	-(2.3442)	-(0.1621)	-(1.9810)	-(0.0026)	-(0.5354)	-(0.6625)	-(2.1798)	(2.2919)
β_5	0.6252***	0.5246	0.7877***	0.4460	-0.1030	0.4582	0.1958	0.4839	0.0789	0.4430	0.7313**	0.4833	0.1388	-0.1558	0.9408**	0.5031	0.0973*	0.5069
	(3.6110)	(0.6490)	(2.9751)	(1.5773)	-(1.4103)	(1.5705)	(0.4217)	(1.0430)	(0.5713)	(1.1050)	(2.3745)	(0.8760)	(0.6636)	-(1.3625)	(2.2960)	(1.1034)	(1.7637)	(0.9299)
β_6	-0.1654	0.0350	-0.1527	-0.0753	-0.1824	-0.0333	0.2734	0.0027	0.0642	-0.0593	-0.4457*	-0.0087	0.5519	-0.0967	-0.1518	0.0274	0.2711***	0.0171
	-(1.2913)	(0.0203)	-(0.6984)	-(0.5117)	-(1.1124)	-(0.0884)	(1.3089)	(0.0069)	(0.2196)	-(0.1360)	-(1.6526)	-(0.0091)	(1.6252)	-(0.8681)	-(0.3456)	(0.0656)	(3.3183)	(0.0371)

Z-statistics in parentheses; ***=1% significance, **=5% significance, *=10% significance. [&] singular covariance coefficients are not unique.

Tab. 46. *Estimation Results of GARCH(2,1) model for synthetic CDO spreads (actual, transformed and Johnson Fit adjusted spreads) – LIBOR at first differences.*

	Collateralised Debt Obligations (CDO), traditional																	
	CTAAA3		CTAAA3_L		CTAAA3_AD_L		CTA5		CTA5_L		CTA5_AD_L		CTBBB7		CTBBB7_L		CTBBB7_AD_L	
	BHHH	M	BHHH	M	BHHH	M	BHHH	M	BHHH	M	BHHH	M	BHHH	M	BHHH[&]	M[&]	BHHH	M
α_0	0.5430	-0.4539	0.0538	0.0580	-0.0711	-0.1511	4.5026***	0.5589	0.1967**	0.1119	0.0039	0.0135	2.3518	-14.1340**	0.2097	0.0869	0.0153	0.1471
	(1.4804)	-(1.2954)	(0 7175)	(1.3260)	-(0.3454)	-(1.3905)	(2.9976)	(0.2013)	(2.2218)	(1.0451)	(0.0236)	(0.0414)	(0.2379)	-(2.3485)	(1.3148)	(0.3895)	(0.1018)	(0.9631)
$\alpha_{1,1}$	0.0700	0.0581	0.0466***	0.0610	0.2259	0.1746***	0.2073	0.0000	0.1469	0.0211	-0.0746	0.0432	0.0558	0.0498	0.0100	0.0092	-0.0900	-0.0147
	(0 8979)	(1 1600)	(2.5578)	(0.4476)	(1 1915)	(12.5770)	(1.4428)	(0.0006)	(1.1641)	(0 2203)	-(0.4776)	(0.0857)	(0.3846)	(0.2118)	(0.0771)	(0.0460)	-(0.6335)	-(0.0966)
$\alpha_{1,2}$	0.0066	-0.0305	0.0292	0.0397	0.2021	0.1540***	-0.1642	-0.0396	0.1337	0.0089	-0.0880	0.0240	0.0229	0.0219	0.0057	0.0014	-0.0994	-0.0234
	(0.0861)	-(0.6323)	(1.5923)	(0.2921)	(1.0934)	(7.8951)	-(0.6184)	-(0.2788)	(1.0478)	(0.0940)	-(0.5682)	(0.0478)	(0.1583)	(0.0968)	(0.0439)	(0.0069)	-(0.7013)	-(0.1579)
$\alpha_{2,1}$	-0.0847	-0.0448	-0.0622***	-0.0806	-0.2067	-0.1339***	-0.2560*	-0.0057	-0.1901	-0.0387	0.0735	-0.0459	-0.0660	0.0312	-0.0506	-0.0263	0.0897	-0.0090
	-(1.1411)	-(0.9529)	-(5.9446)	-(0.6168)	-(1.1435)	-(3.2232)	-(1.7226)	-(0.0878)	-(1.5091)	-(0.4382)	(0.4669)	-(0.0892)	-(0.5316)	(0.1323)	-(0.4781)	-(0.1464)	(0.7016)	-(0.0545)
$\alpha_{2,2}$	-0.0800	-0.0387	-0.0623***	-0.0781	-0.2052	-0.1308***	0.0225	-0.0396	-0.1936	-0.0408	0.0728	-0.0409	-0.0766	0.0222	-0.0523	-0.0299	0.0874	-0.0132
	-(1.1632)	-(0.8919)	-(4.7800)	-(0.6110)	-(1.1624)	-(3.0491)	(0.0834)	-(0.2259)	-(1.5429)	-(0 4688)	(0 4702)	-(0.0805)	-(0 6383)	(0.0969)	-(0.4978)	-(0.1681)	(0.6910)	-(0 0822)
$\alpha_{3,1}$	-0.9176	1.8798	-0.5188	0.5116	-0.3280	-0.0972	-33.649**	-0.1030	-0.6267	-0.7414	-1.2032	-0.4383	4.9368	-11.1842	-0.3600	0.0860	-0.1281	0.0217
	-(0.3975)	(0.9088)	-(0.7411)	(1.1446)	-(0.6096)	-(0.0486)	-(2.3165)	-(0.0087)	-(0.9621)	-(1 5933)	-(1.4918)	-(0.0971)	(0.3770)	-(0.6177)	-(1.2232)	(0.1951)	-(0.2707)	(0.0161)
$\alpha_{3,2}$	-1.6029	-5.9203	0.1107	-1.0346*	-0.2005	-0.7562***	14.1711	-0.0873	-0.0835	0.1896	0.1939	-0.0588	-14.575	-34.088***	-0.2130	-0.2398	-0.7577*	-0.4926**
	-(0.3795)	-(1.0670)	(0.1789)	-(1.7861)	-(0.3205)	-(2.9754)	(1.3258)	-(0.0161)	(0 1511)	(0 5003)	(0.6755)	-(0.0197)	-(1.1142)	(3.9812)	-(0.6076)	-(0.7736)	-(1.6755)	(2.0810)
α_4	0.1487	0.0900	19.1670	16.6260	12.8721*	21.5064	0.0953***	0.0626	8.4844*	-7.2260	5.1810	1.3884	0.0481*	0.0063	19.587**	21.7091	-9.0672	-18.5734
	(0.5408)	(0.1790)	(0.7738)	(1.3497)	(1.9185)	(1.2530)	(2.9038)	(0.9471)	(1.8492)	-(0 7766)	(1.4333)	(0.0874)	(1 8822)	(0.7410)	(2.2591)	(1.4091)	-(1.4917)	-(0.7312)
β_0	-0.7087**	-0.0129	-0.0014*	0.0004***	0.0046	0.0080***	-5.7895***	9.8934	0.0011	0.0014	0.0073**	0.0011	-46.2602	9.6684	-0.0063***	0.0004***	0.0010	0.0007
	-(2.3097)	-(0.0520)	-(1.6487)	(11.8742)	(0.9898)	(78.5940)	-(2.9919)	(0.2622)	(0.3128)	(1.5677)	(2.1316)	(0.8562)	-(1.4040)	(0.3226)	-(974.4171)	(17.2726)	(0.6655)	(0.6005)
β_1	-0.0090	-0.0088	-0.0154	0.0943	-0.0379	-0.0085	0.0088	0.0765	0.0290	-0.0442	0.0697	0.1183	0.0477	0.4386**	-0.0443	0.1492	0.1278*	-0.0031
	-(0.5409)	-(0.7781)	-(1.2847)	(0.9127)	-(0.7699)	-(0.3343)	(0.1683)	(0.6601)	(0.5438)	-(0.5682)	(0.6178)	(0.6493)	(0.3633)	(2.1146)	-(0.4887)	(0.9129)	(1.7007)	-(0.0779)
β_2	-0.0624	0.2628	0.0561	0.0138	0.3330*	0.0409	0.1979	-0.1610	-0.0747	-0.0894	-0.4589	0.0411	-0.0223	0.5234	-0.0204	-0.0468	-0.0173	0.1101
	-(1.1222)	(1.0833)	(0.3677)	(0.0851)	(1.7967)	(0.4737)	(0.7773)	-(0.8604)	-(0.2559)	-(0 7293)	-(1.2328)	(0.0329)	-(0.1531)	(0.4515)	-(0.1716)	-(0.3371)	-(0.1446)	(0.5658)
β_3	0.0291**	0.0067	0.0005**	-0.0001**	-0.0012	-0.0022***	0.0902***	-0.0103	-0.0001	-0.0000***	-0.0015**	-0.0001	0.2832	-0.0366	0.0012***	-0.0000***	-0.0002	-0.0001
	(2.3004)	(0.7310)	(2.0442)	-(2.0003)	-(0.9524)	(-3.5E+100)	(2.7234)	-(0.0377)	-(0.2050)	-(3.2597)	-(2.1090)	-4.59E-01	(1.5441)	-(0.2165)	(229.8929)	-(2.8298)	-(0.6121)	-(0.3680)
β_4	-3.3265*	-4.7877**	-0.0150***	-0.0189	-0.0207	-0.0040	-94.1082	-0.1115	-0.0414*	-0.0307	-0.0195	-0.0655*	-177.78***	-17.0316	-0.0146***	-0.0181	-0.0011	0.0072
	-(1.9242)	-(2.2182)	-(13.2959)	-(1.0586)	-(1.1276)	-(1.5119)	-(1.5295)	-(0.0012)	-(1.8376)	-(0 8788)	-(1.5034)	-(1.6491)	-(3.3661)	-(0.5769)	-(4.2345)	-(0.9606)	-(0.4139)	(1.0416)
β_5	0.7944***	0.2463*	0.7934**	0.4061*	0.7336	0.6902***	0.7230*	0.4937	0.7548	0.4840	0.2800	0.5425	0.7744***	0.4296***	0.7962**	0.5136	1.3411***	0.5740
	(11.6847)	(1.7195)	(2.4652)	(1.8718)	(1.5417)	(3.5883)	(1.8462)	(0.8703)	(1.5717)	(1.2484)	(0.9502)	(0.9115)	(3.8011)	(3.0916)	(2.1840)	(1.4533)	(10.4099)	(0.4566)
β_6	-0.3648***	-0.0273	-0.2865	-0.0634	-0.2123	-0.4029*	-0.0189	0.0058	-0.0583	-0.0055	0.4933*	0.0661	-0.1591	-0.1613***	-0.0420	0.0241	-0.5758***	0.0856
	-(7.6867)	-(0.3320)	-(1.0575)	-(0.4970)	-(0.7268)	-(2.0172)	-(0.0535)	(0.0069)	-(0.1592)	-(0.0149)	(1.8763)	(0.1381)	-(1.1039)	-(2.7255)	-(0.1288)	(0.0663)	-(7.2270)	(0.0695)

Z-statistics in parentheses; ***=1% significance, **=5% significance, *=10% significance. [$] singular covariance coefficients are not unique.

Tab. 47. *Estimation Results of GARCH(2,1) model for traditional CDO spreads (actual, transformed and Johnson Fit adjusted spreads) – LIBOR at first differences.*

	Mortgage-Backed Securities (MBS)											
	MAAA3		MAAA3_L		MAAA3_AD_L		MAAA5		MAAA5_L		MAAA5_AD_L	
	BHHH	M	BHHH	M	BHHH	M	BHHH	M	BHHH[&]	M	BHHH	M
α_0	0.4868	-0.0750	0.0487	0.0236	0.7483***	0.2823	0.0326	0.4856***	0.0116	0.0300	-1.6262	-0.1207
	(1.4767)	-(0.3392)	(0.9501)	(0.3234)	(2.6615)	(1.5964)	(0.1545)	(2.6935)	(0.3066)	(0.7335)	-(0.7829)	-(0.1135)
$\alpha_{1,1}$	-0.2381***	0.0136	-0.1495	0.0080	-0.2049	-0.0953	-0.0303	-0.1264*	-0.0149	-0.1024	1.6073***	1.0435**
	-(3.0717)	(0.1124)	-(1.1178)	(0.0458)	-(1.4412)	-(1.2999)	-(0.3493)	-(1.8244)	-(0.1763)	-(1.0181)	(4.3718)	(2.3521)
$\alpha_{1,2}$	-0.2548***	-0.0278	-0.1534	-0.0088	-0.2450*	-0.1353*	-0.0728	-0.1646**	-0.0263	-0.1139	-0.7933***	-0.6072***
	-(3.3754)	-(0.2411)	-(1.1587)	-(0.0512)	-(1.6944)	-(1.9106)	-(0.8364)	-(2.4143)	-(0.3136)	-(1.1365)	-(7.7255)	-(4.3501)
$\alpha_{2,1}$	0.2152***	-0.0083	0.1356	-0.0155	0.0962	0.0139	0.0327	0.1158	0.0146	0.0957	-0.8251***	-0.6140***
	(2.9187)	-(0.0697)	(1.0646)	-(0.0872)	(0.9082)	(0.1459)	(0.3678)	(1.6256)	(0.1681)	(0.8742)	-(8.4767)	-(4.3868)
$\alpha_{2,2}$	0.2073***	-0.0136	0.1320	-0.0158	0.0835	-0.0026	0.0290	0.1092	0.0104	0.0918	0.2909***	0.2728*
	(2.9598)	-(0.1214)	(1.0413)	-(0.0894)	(0.8642)	-(0.0296)	(0.3409)	(1.6237)	(0.1213)	(0.8516)	(2.6656)	(1.7937)
$\alpha_{3,1}$	2.0166	2.2738	0.7417	0.0022	0.3298	0.1252	0.2501	-3.5663**	-0.0489	-0.1724	0.2565**	0.2544*
	(1.6228)	(1.3987)	(1.5300)	(0.0024)	(0.2270)	(0.1385)	(0.1561)	-(1.9597)	-(0.1689)	-(0.4186)	(2.3743)	(1.7039)
$\alpha_{3,2}$	-1.6992	-2.8867	-0.2391	-0.0327	0.3130	-1.0085	-0.2271	-4.4025**	-0.2763	-0.5382	1.9604	1.4554
	-(0.5220)	-(0.7886)	-(1.1792)	-(0.0634)	(0.2928)	-(1.2501)	-(0.1873)	-(2.1325)	-(0.9146)	-(1.0361)	(1.1445)	(0.8466)
α_4	-0.6969	-0.4942	-19.7467	0.0002	-91.6566**	-8.6834	0.4942	-1.4640	-3.6681	-15.7246	0.0000	0.0000
	-(0.9236)	-(0.3528)	-(0.9195)	(0.0000)	-(2.4194)	-(1.0686)	(0.6547)	-(0.9583)	-(0.2571)	-(0.2989)	(0.0000)	(0.0000)
β_0	0.0291	0.0879	0.0008***	0.0005***	-0.0006	0.0027	0.0815	0.0750***	0.0009	0.0002	0.0000	0.0000
	(0.3447)	(0.5682)	(2.5783)	(11.3812)	-(1.4493)	(0.1442)	(0.6551)	(3.2862)	(1.3664)	(0.3004)	(0.0000)	(0.0000)
β_1	0.0083	0.0477	0.0102	0.0583	-0.0253	0.1481	0.0176	-0.0513	0.0769	-0.0483	-0.0339	0.0027
	(0.1271)	(0.8018)	(0.6555)	(0.4606)	-(1.5675)	(1.0146)	(0.3896)	-(1.5606)	(1.3180)	-(1.1521)	-(1.5271)	(0.1715)
β_2	0.5859	-0.1469*	0.3948**	0.0162	0.0306*	-0.1951	-0.6433	-0.2954	0.6448	0.0485	0.1296***	0.6075*
	(0.9548)	-(1.6633)	(2.2961)	(0.0909)	(1.7999)	-(1.2501)	-(1.1001)	-(1.6101)	(1.3051)	(0.1226)	(2.6631)	(1.6990)
β_3	-0.0003	-0.0007	-0.0003**	-0.0001***	0.0005***	0.0008	0.0012	-0.0015***	-0.0003	0.0000	-0.0025	-0.0790
	-(0.0728)	-(0.1532)	-(2.1579)	-(10.9828)	(137.7558)	(0.1289)	(0.2001)	-(992.1363)	-(1.3095)	-(0.1064)	-(0.0637)	-(1.4169)
β_4	-0.2974	-0.3033	-0.0030**	-0.0103***	0.0027	-0.0689***	-0.6431	-0.9197*	-0.0103**	-0.0061	-0.4234***	-0.1507***
	-(0.2314)	-(0.1346)	-(2.2788)	-(2.9805)	(0.6919)	-(3.2289)	-(0.6700)	-(1.7239)	-(2.0965)	-(1.1734)	-(3.7514)	-(2.9736)
β_5	0.2639	0.4439	0.3088	0.4876**	-0.0485	-0.2361	0.6863**	0.5408*	0.1079	0.4639	0.4127*	0.3203
	(1.1269)	(0.4652)	(1.1145)	(2.3001)	-(0.5703)	-(1.4119)	(2.0262)	(1.8115)	(0.5449)	(0.7449)	(1.6400)	(0.5344)
β_6	0.0329	-0.0515	0.0255	-0.0152	0.8832***	-0.3478*	-0.4743	0.1056	0.2556	-0.0208	0.9811***	0.5588***
	(0.2233)	-(0.1475)	(0.1001)	-(0.0917)	(10.2092)	-(1.8147)	-(0.9223)	(1.1288)	(1.2991)	-(0.0660)	(6.6004)	(5.2719)

	MA7		MA7_L		MA7_AD_L		MBBB7		MBBB7_L		MBBB7_AD_L	
	BHHH	M	BHHH	M	BHHH	M	BHHH[&]	M	BHHH[&]	M	BHHH[&]	M
α_0	-0.9301	-0.2115	-0.0178	-0.0058	0.0043	-0.0040	-2.2637	0.5382	-0.0513	-0.0527	1.7863	0.0268
	-(0.8507)	-(0.4410)	-(1.1152)	-(0.0866)	(0.1731)	-(0.0668)	-(1.0429)	(0.3135)	-(0.1848)	-(0.4567)	(0.9309)	(0.0430)
$\alpha_{1,1}$	0.0345	0.0140	0.02915***	0.0004	-0.0119***	0.0006	-0.2040	-0.1435	-0.0432	-0.1132	-0.0591	-0.0017
	(0.2179)	(0.1197)	(12.6285)	(0.0038)	-(12.1498)	(0.0080)	-(1.5270)	-(1.0108)	-(0.3209)	-(0.6897)	-(0.1525)	-(0.0085)
$\alpha_{1,2}$	0.0186	-0.0068	0.0267***	-0.0067	-0.0148***	-0.0055	-0.2286*	-0.1603	-0.0485	-0.1185	-0.0713	-0.0059
	(0.1198)	-(0.0594)	(15.0188)	-(0.0636)	-(7.6477)	-(0.0714)	-(1.7242)	-(1.1478)	-(0.3616)	-(0.7234)	-(0.1847)	-(0.0293)
$\alpha_{2,1}$	-0.0174	-0.0143	-0.0242***	-0.0003	0.0119***	0.0005	0.2249*	0.1503	0.0550	0.1290	-0.3025	-0.0034
	-(0.1172)	-(0.1249)	-(28.7970)	-(0.0025)	(19.3590)	(0.0075)	(1.8199)	(1.1184)	(0.3198)	(0.7471)	-(1.1710)	-(0.0122)
$\alpha_{2,2}$	-0.0224	-0.0145	-0.0239***	0.0022	0.0118***	0.0005	0.2090*	0.1344	0.0537	0.1257	-0.3058	-0.0061
	-(0.1544)	-(0.1285)	-(18.9327)	(0.0216)	(5.6825)	(0.0076)	(1.7490)	(1.0234)	(0.3140)	(0.7337)	-(1.1971)	-(0.0217)
$\alpha_{3,1}$	6.9869**	3.1172	0.0808	-0.0180	0.3231	-0.0074	-7.9981	4.4998	0.1012	-0.0782	3.6380**	-0.0835
	(2.3613)	(0.9171)	(0.1412)	-(0.0838)	(1.2862)	-(0.0390)	-(0.3395)	(0.3548)	(0.1722)	-(0.1499)	(1.9859)	-(0.0392)
$\alpha_{3,2}$	-4.8158	-4.3490	-0.0146	-0.1029	-0.1718	-0.1433	0.3639	-16.2003*	-0.1714	-0.0780	-0.1605	-0.0736
	-(0.9748)	-(0.9302)	-(0.0786)	-(0.2481)	-(0.6157)	-(0.2331)	(0.0205)	-(1.7174)	-(0.4113)	-(0.1075)	-(1.4074)	-(0.0241)
α_4	-0.4758	0.5215	-9.1387	-0.0002	-21.7732	-0.0004	0.0533	-0.0867	3.9314	-24.6576**	-0.3115	0.0337
	-(1.0619)	(0.5208)	-(0.4066)	(0.0000)	-(0.4504)	(0.0000)	(1.1261)	-(0.5840)	(0.0948)	-(1.9580)	-(0.1282)	(0.0128)
β_0	0.5091	0.3177**	0.0003*	0.0001***	0.0008***	0.0002***	-8.3230***	4.4075	-0.0087***	0.0002***	0.0532***	0.0040***
	(0.6283)	(2.4539)	(1.9260)	(4.8379)	(3.2880)	(10.0610)	-(14.2803)	(1.2129)	(-210.751)	(5.8307)	(156.066)	(3.5354)
β_1	0.0236	0.0558	0.0742	0.0248	0.0451	0.0533	0.1302	-0.0226	-0.0316	0.0956**	0.4824	0.3536***
	(0.7820)	(0.6513)	(0.6613)	(0.5742)	(0.8101)	(0.6000)	(0.8044)	-(0.4012)	-(0.8059)	(2.0534)	(0.8159)	(2.7346)
β_2	0.2685	-0.1158	0.1088	0.0370	0.1704	0.0318	-0.3392**	-0.0954*	0.0918	0.0496	-0.0527	0.1931
	(0.8045)	-(0.9611)	(0.5027)	(0.1141)	(0.6360)	(0.1245)	-(2.3207)	-(1.8458)	(0.7531)	(0.3588)	-(0.0398)	(0.8957)
β_3	-0.0067	-0.0026***	-0.0001***	0.0000	-0.0002***	0.0000	0.0730***	-0.0023	0.0019***	0.0000	-0.0106***	-0.0006***
	-(0.5486)	-(4165.675)	(-2E+100)	-(1.7157)	(-4.8E+100)	-(1.1969)	(4313.608)	-(0.0665)	(813.599)	-(0.8242)	-(2599.17)	-(3.2588)
β_4	-2.7396	-2.4292	-0.0009**	-0.0039	-0.0033**	-0.0069	-41.9922	-77.9337***	-0.0107***	-0.0124	0.0100	-0.0690
	-(1.1673)	-(1.1972)	-(2.2344)	-(0.4196)	-(2.3655)	-(0.3842)	-(1.0841)	-(2.7831)	-(2.8585)	-(0.6994)	(0.6090)	-(1.3080)
β_5	0.5926**	0.3404	0.4849	0.4734	0.5189	0.4690	0.8758***	0.4494	-0.3147*	0.5066	0.0962	0.3881
	(2.0470)	(1.6048)	(0.6386)	(0.8454)	(0.9904)	(0.7719)	(4.2615)	(1.5093)	-(1.9235)	(1.1924)	(0.3807)	(1.1547)
β_6	-0.0375	-0.0750	0.1050	-0.0348	0.0754	-0.0417	-0.1714	-0.0018	0.0207	0.0196	0.0758	0.0251
	-(0.1409)	-(0.4041)	(0.1962)	-(0.0797)	(0.2325)	-(0.0906)	-(1.0514)	-(0.0071)	(0.0734)	(0.0685)	(1.2080)	(0.1222)

Z-statistics in parentheses; ***=1% significance, **=5% significance, *=10% significance. [&] singular covariance coefficients are not unique.

Tab. 48. *Estimation Results of GARCH(2,1) model for MBS spreads (actual, transformed and Johnson Fit adjusted spreads) – LIBOR at first differences.*

	Pfandbriefe																	
	PAAA3		PAAA3_L		PAAA3_AD_L		PAAA5		PAAA5_L		PAAA5_AD_L		PAAA7		PAAA7_L		PAAA7_AD_L	
	BHHH	M	BHHH	M	BHHH&	M	BHHH	M	BHHH	M	BHHH&	M	BHHH&	M	BHHH	M	BHHH	M
α_0	-0.2647	-0.1451	-0.0521	-0.0134	-0.2188	0.0111	-0.3758	0.0890	-0.0255	-0.0706	-0.0398	-0.0206	0.8504	0.7241*	0.0871	0.0314	0.0285	0.1354
	-(0.2174)	-(0.0801)	-(0.3110)	-(0.0626)	-(0.7491)	(0.0528)	-(0.5092)	(0.1116)	-(0.2553)	-(0.8890)	-(0.3241)	-(0.2341)	(1.4492)	(1.7590)	(1.2126)	(0.6284)	(0.2953)	(1.5318)
$\alpha_{1,1}$	-0.4041***	-0.0200	-0.3629***	0.0171	-0.4586***	-0.4860***	-0.0843	0.0665	-0.1878**	-0.2283***	-0.2253***	0.0139	-0.4118***	-0.2762***	-0.4454***	-0.4144***	-0.3051***	-0.3609***
	-(3.4403)	-(0.0874)	-(3.1673)	(0.1115)	-(4.0932)	-(4.3664)	-(0.7856)	(0.4314)	-(2.3724)	-(3.6545)	-(2.6311)	(0.1200)	-(5.0326)	-(4.4457)	-(6.1585)	-(5.9506)	-(3.3119)	-(4.6788)
$\alpha_{1,2}$	-0.4676***	-0.1121	-0.3882***	-0.0168	-0.4894***	-0.5101***	-0.1744*	-0.0446	-0.2157***	-0.2558***	-0.2547***	-0.0139	-0.4663***	-0.3355***	-0.4614***	-0.4318***	-0.3224***	-0.3756***
	-(4.3169)	-(0.5103)	-(3.5065)	-(0.1108)	-(4.5011)	-(4.7338)	-(1.6906)	-(0.3004)	-(2.7872)	-(4.1992)	-(3.0509)	-(0.1214)	-(5.9511)	-(5.6461)	-(6.4872)	-(6.3006)	-(3.5524)	-(4.9805)
$\alpha_{2,1}$	0.4477***	0.0879	0.3913***	0.0078	0.5510***	0.5004***	0.1786	0.0284	0.2177***	0.2706***	0.2611***	0.0119	0.4634***	0.2933***	0.4416***	0.4259***	0.3102***	0.3366***
	(4.6573)	(0.7298)	(4.3343)	(0.0603)	(6.1349)	(6.3623)	(1.6183)	(0.1757)	(2.6406)	(3.9818)	(3.1786)	(0.1045)	(5.6037)	(4.7038)	(6.4452)	(5.9969)	(3.5725)	(5.1403)
$\alpha_{2,2}$	0.3947***	0.0438	0.3752***	-0.0074	0.5246***	0.4689***	0.1221	-0.0087	0.2047***	0.2507***	0.24649***	-0.0040	0.3909***	0.2371***	0.4183***	0.4057***	0.2904***	0.3184***
	(4.3111)	(0.4326)	(4.2064)	-(0.0599)	(5.9729)	(6.1266)	(1.2185)	-(0.0639)	(2.5709)	(3.8036)	(3.1068)	-(0.0361)	(5.2543)	(4.1295)	(6.2584)	(5.8479)	(3.4543)	(5.0485)
$\alpha_{3,1}$	10.3354	3.0072	2.3453	0.7539	-0.2003	0.3079	-0.3055	0.2739	0.0833	-0.0182	-0.2845	0.3500	-11.6693**	-6.5375	-1.7284**	-1.7950***	-1.8068*	-2.5797**
	(1.5855)	(0.9293)	(1.5090)	(0.5364)	-(0.1315)	(0.1598)	-(0.0885)	(0.0273)	(0.0636)	-(0.0207)	-(0.2127)	(0.7107)	-(2.2211)	-(1.3905)	-(2.0663)	-(2.5874)	-(1.8651)	-(2.4691)
$\alpha_{3,2}$	-5.6915*	-3.1671	-1.1432**	-0.0077	0.5323	-0.0839	-4.0858	0.2218	-0.4698	-0.0344	-1.1240	-0.0154	-1.4411	0.1250	-0.1108	-0.1863	-0.2118	-0.1203
	-(1.6577)	-(0.7661)	-(2.0308)	-(0.0050)	(0.5655)	-(0.1245)	-(0.6747)	(0.0223)	-(0.6641)	-(0.0709)	-(1.0119)	-(0.0435)	-(0.2899)	(0.0714)	-(0.2285)	-(0.2628)	-(0.9151)	-(0.1970)
α_4	0.0050	-0.1540	0.2491	-0.7786	3.0892	0.9344	-0.2438	-0.2997	-6.5642	0.0121	-4.2735	-1.2837	-0.5257	0.3724**	-8.7588	-8.3737	7.5425	-2.9003
	(0.0408)	-(0.3832)	(0.0931)	-(0.1243)	(0.4628)	(0.1599)	-(0.8731)	-(1.3737)	-(1.1551)	(0.0014)	-(0.9724)	-(0.5465)	-(1.3467)	(2.0032)	-(1.0964)	-(0.8609)	(0.8112)	-(0.5882)
β_0	3.0869	0.7277	0.0171	0.0027***	0.0209*	0.0015	1.3128	0.9882	0.0070**	0.0029	0.0075	0.0025	0.4995	0.0089	0.0033***	0.0025**	0.0024	0.0005
	(1.0649)	(0.3410)	(1.3231)	(3.0660)	(1.6838)	(0.0765)	(0.7960)	(0.8082)	(2.2042)	(0.8467)	(1.5993)	(0.3627)	(1.4067)	(0.4569)	(2.7087)	(2.4549)	(1.2444)	(1.1164)
β_1	0.0226	0.0604	0.0247	0.0454	-0.0322	-0.0573	0.3667	0.0626**	-0.0045	-0.0665	0.0550	0.4921	0.0489	-0.1162**	0.2369*	0.2832*	-0.1270	-0.1868**
	(0.3781)	(0.9067)	(0.5131)	(0.2668)	-(0.5628)	-(0.5971)	(0.9260)	(1.9620)	-(0.0869)	-(0.7354)	(0.8001)	(1.0731)	(0.3887)	-(2.1407)	(1.7862)	(1.7705)	-(1.1408)	-(2.2866)
β_2	0.7875*	-0.3590	0.8903***	-0.0551	-0.0145	0.0530	-0.1054	-0.2871***	0.4026	-0.0837	0.3333	0.0509	-0.1771	0.0837	0.0295	0.0912	0.2854**	0.3425
	(1.7649)	-(1.0415)	(2.5254)	-(0.1660)	-(0.1021)	(0.1586)	-(0.2634)	-(2.6410)	(1.4262)	-(0.3693)	(1.5247)	(0.1197)	-(1.0588)	(1.6276)	(0.1612)	(0.4485)	(2.1324)	(1.5198)
β_3	-0.1521	-0.0169	-0.0057	-0.0002***	-0.0065	-0.0001	0.0103	0.0011	-0.0018*	-0.0010	-0.0017	-0.0001	-0.0072	0.0019**	-0.0009***	-0.0006*	-0.0006	-0.0001
	-(1.0161)	-(0.1537)	-(1.3141)	-(13.7999)	-(1.5382)	-(0.0190)	(0.1858)	(0.0345)	-(1.8896)	-(0.7933)	-(1.1372)	-(0.0493)	-(0.5039)	(2.3657)	-(2.8210)	-(1.9142)	-(1.1927)	-(0.9043)
β_4	-8.5958	-11.5618	-0.0774	-0.1672	-0.1137	-0.0462	-14.9679	-1.8951	-0.0500	-0.0578	-0.1478**	-0.1289*	-6.9851**	-2.3354***	-0.0198*	-0.0441***	-0.0090	-0.0172
	-(0.9231)	-(1.1107)	-(1.1688)	-(0.6662)	-(1.2618)	-(0.3343)	-(1.5099)	-(0.0977)	-(1.5620)	-(1.2503)	-(2.3356)	-(1.9683)	-(2.4832)	-(3.0917)	-(1.7287)	-(3.7841)	-(1.3377)	-(1.3658)
β_5	0.3031	0.5662***	0.1451	0.4813	0.6591**	0.5085*	-0.1980	0.5130	0.6829***	0.5658	0.3350	-0.0237	-0.0118	1.6075***	0.4965	0.0816	0.8466**	0.9862**
	(0.4112)	(6.0261)	(0.3199)	(1.2279)	(2.1626)	(1.8351)	-(1.3601)	(1.0814)	(2.9924)	(1.3850)	(1.0985)	-(0.1976)	-(0.0293)	(22.0634)	(1.2375)	(0.9049)	(2.4569)	(2.4277)
β_6	0.0570	0.1016	0.1557	-0.0551	-0.2124	0.0057	-0.0455	0.0376	-0.4480*	0.4708	-0.2247**	-0.0637*	0.6824***	-0.6173***	0.0002	0.0621	-0.1936	0.0033
	(0.1090)	(1.0347)	(0.4741)	-(0.1795)	-(0.6722)	(0.0086)	-(0.7414)	(0.0894)	-(1.8475)	(1.3557)	-(2.2530)	-(1.7333)	(3.9131)	-(7.3964)	(0.0005)	(0.3075)	-(0.5809)	(0.0089)

Z-statistics in parentheses; ***=1% significance, **=5% significance, *=10% significance. & singular covariance coefficients are not unique.

Tab. 49. *Estimation Results of GARCH(2,1) model for Pfandbrief spreads (actual, transformed and Johnson Fit adjusted spreads) – LIBOR at first differences.*

	Collateralised Debt Obligations (CDO), synthetic					
	CSAAA3		CSAAA3_L		CSAAA3_AD_L	
	BHHH[&]	M	BHHH	M	BHHH	M
Wald-test H_0: $\alpha_{1,1}=\alpha_{1,2}$ (t-stat.)	46.2651***	18.0171***	23.7990***	0.3587	7.5655***	5.4546**
(p-value)	0.0000	0.0001	0.0000	0.5509	0.0074	0.0220
Wald-test H_0: $\alpha_{1,1}+\alpha_{1,2}=0$ (t-stat.)	1.9190	3.0870*	0.1977	0.0008	6.0161**	0.7126
(p-value)	0.1698	0.0827	0.6578	0.9779	0.0164	0.4011
LB-Q Statistic (lags)	0.2871 (1)	0.0078 (1)	0.3356 (1)	0.4916 (1)	0.0494 (1)	0.0684 (1)
(p-value)	0.5920	0.9290	0.5620	0.4830	0.8240	0.7940
LB^2-Q Statistic (lags)	0.0413 (1)	0.0744 (1)	0.0617 (1)	0.0189 (1)	0.0909 (1)	0.0802 (1)
(p-value)	0.8390	0.7850	0.8040	0.8910	0.7630	0.7770
Jarque-Bera	9674.84***	843.07***	7103.24***	4277.12***	2206.44***	3691.25***
(p-value)	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
	Collateralised Debt Obligations (CDO), synthetic					
	CSA5		CSA5_L		CSA5_AD_L	
	BHHH	M	BHHH	M	BHHH	M
Wald-test H_0: $\alpha_{1,1}=\alpha_{1,2}$ (t-stat.)	24.3937***	26.7143***	12.4572***	1.0132	23.8282***	0.2490
(p-value)	0.0000	0.0000	0.0007	0.3171	0.0000	0.6192
Wald-test H_0: $\alpha_{1,1}+\alpha_{1,2}=0$ (t-stat.)	0.0577	3.0030*	0.4695	0.2230	712.6768***	0.0574
(p-value)	0.8107	0.0869	0.4952	0.6380	0.0000	0.8113
LB-Q Statistic (lags)	1.3587 (1)	0.0194 (1)	1.5633 (1)	0.6237 (1)	0.3783 (1)	0.1861 (1)
(p-value)	0.2440	0.8890	0.2110	0.4300	0.5380	0.6660
LB^2-Q Statistic (lags)	0.0665 (1)	0.0694 (1)	0.0042 (1)	0.0429 (1)	0.0692 (1)	0.0602 (1)
(p-value)	0.7960	0.7920	0.9480	0.8360	0.7930	0.8060
Jarque-Bera	1368.03***	1551.56***	4496.75***	1826.39***	3449.73***	3778.63***
(p-value)	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
	Collateralised Debt Obligations (CDO), synthetic					
	CSBBB7		CSBBB7_L		CSBBB7_AD_L	
	BHHH	M	BHHH	M	BHHH	M
Wald-test H_0: $\alpha_{1,1}=\alpha_{1,2}$ (t-stat.)	20.3832***	17.3294***	1.1270	1.0254	49.3522***	1.4367
(p-value)	0.0000	0.0001	0.2916	0.3142	0.0000	0.2342
Wald-test H_0: $\alpha_{1,1}+\alpha_{1,2}=0$ (t-stat.)	5.1587**	1.4015	0.4525	0.0416	2.3971	0.0172
(p-value)	0.0258	0.2399	0.5031	0.8389	0.1255	0.8959
LB-Q Statistic (lags)	0.9405 (1)	0.1060 (1)	0.2041 (1)	0.0580 (1)	0.1617 (1)	0.0911 (1)
(p-value)	0.3320	0.7450	0.6510	0.8100	0.6880	0.7630
LB^2-Q Statistic (lags)	0.0177 (1)	0.0361 (1)	0.0660 (1)	0.0837 (1)	0.0352 (1)	0.0300 (1)
(p-value)	0.8940	0.8490	0.7970	0.7720	0.8510	0.8620
Jarque-Bera	3991.63***	5024.83***	2772.27***	2887.26***	6709.17***	10758.22***
(p-value)	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000

***=1% significance, **=5% significance, *=10% significance. *NA* indicates that no results could be generated by the statistics software due to data overflow. [&] singular covariance coefficients are not unique.

Tab. 50. *Coefficient and residual tests of GARCH(1,1) model for synthetic CDO spreads (actual, transformed and Johnson Fit adjusted spreads) – LIBOR at first differences.*

	Collateralised Debt Obligations (CDO), traditional					
	CTAAA3		CTAAA3_L		CTAAA3_AD_L	
	BHHH	M	BHHH	M	BHHH	M
Wald-test H_0: $\alpha_{1,1}=\alpha_{1,2}$ (t-stat.)	51.6935***	23.4591***	51.4759***	131.45***	38.1184***	140.2872***
(p-value)	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Wald-test H_0: $\alpha_{1,1}+\alpha_{1,2}=0$ (t-stat.)	9.2297***	0.9380	11.4216***	3.9703*	19.2352***	10.2301***
(p-value)	0.0032	0.3357	0.0011	0.0497	0.0000	0.0020
LB-Q Statistic (lags)	1.4963 (1)	0.2653 (1)	0.0008 (1)	0.1393 (1)	0.1069 (1)	0.0477 (1)
(p-value)	0.2210	0.6070	0.9780	0.7090	0.7440	0.8270
LB^2-Q Statistic (lags)	0.0035 (1)	0.0066 (1)	0.0242 (1)	0.0096 (1)	0.0128 (1)	0.1410 (1)
(p-value)	0.9530	0.9350	0.8760	0.9220	0.9100	0.7070
Jarque-Bera	9296.42***	4659.05***	11614.09***	6383.01***	234.93***	491.24***
(p-value)	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
	Collateralised Debt Obligations (CDO), traditional					
	CTA5		CTA5_L		CTA5_AD_L	
	BHHH	M	BHHH	M	BHHH	M
Wald-test H_0: $\alpha_{1,1}=\alpha_{1,2}$ (t-stat.)	13.5305***	2.9658*	15.4555***	1.2995	24.9706***	8.7777***
(p-value)	0.0004	0.0889	0.000177	0.2577	0.0000	0.0040
Wald-test H_0: $\alpha_{1,1}+\alpha_{1,2}=0$ (t-stat.)	18.8959***	0.5829	10.7137***	1.1444	0.1244	0.6170
(p-value)	0.0000	0.4474	0.0016	0.2879	0.7252	0.4345
LB-Q Statistic (lags)	1.1044 (1)	0.2088 (1)	1.1044 (1)	0.3136 (1)	7.1395 (3)	1.7519 (1)
(p-value)	0.2930	0.6480	0.2930	0.5750	0.0680	0.1860
LB^2-Q Statistic (lags)	0.0857 (1)	0.1558 (1)	0.0741 (1)	0.0953 (1)	0.1359 (1)	0.1062 (1)
(p-value)	0.7700	0.6930	0.7850	0.7580	0.7120	0.7440
Jarque-Bera	1160.85***	1335.47***	1994.70***	1845.7030***	5771.945***	4166.91***
(p-value)	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
	Collateralised Debt Obligations (CDO), traditional					
	CTBBB7		CTBBB7_L		CTBBB7_AD_L	
	BHHH	M	BHHH[&]	M	BHHH[&]	M
Wald-test H_0: $\alpha_{1,1}=\alpha_{1,2}$ (t-stat.)	12.5383***	0.6570	11.1996***	18.1293***	28.3589***	2.9836***
(p-value)	0.0007	0.4200	0.0012	0.0001	0.0000	0.0000
Wald-test H_0: $\alpha_{1,1}+\alpha_{1,2}=0$ (t-stat.)	0.2748	0.1139	13.9502***	-0.2427	0.9676	0.3817
(p-value)	0.6016	0.7366	0.0003	0.6236	0.3282	0.5384
LB-Q Statistic (lags)	1.8484 (1)	0.0468 (1)	0.6019 (1)	0.0006 (1)	0.2840 (1)	0.3129 (1)
(p-value)	0.1740	0.8290	0.4380	0.9810	0.5940	0.5760
LB^2-Q Statistic (lags)	0.0091 (1)	0.0512 (1)	0.0120 (1)	0.0118 (1)	0.0457 (1)	0.0014 (1)
(p-value)	0.9240	0.8210	0.9130	0.9140	0.8310	0.9700
Jarque-Bera	1381.52***	1705.50***	1349.01***	1156.71***	3197.54***	149.09***
(p-value)	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000

***=1% significance, **=5% significance, *=10% significance. *NA* indicates that no results could be generated by the statistics software due to data overflow. [&] singular covariance coefficients are not unique.

Tab. 51. *Coefficient and residual tests of GARCH(1,1) model for traditional CDO spreads (actual, transformed and Johnson Fit adjusted spreads) – LIBOR at first differences.*

	Mortgage-Backed Securities (MBS)											
	MAAA3		MAAA3_L		MAAA3_AD_L		MAAA5		MAAA5_L		MAAA5_AD_L	
	BHHH	M	BHHH	M	BHHH	M	BHHH	M	BHHH[§]	M[§]	BHHH	M
Wald-test H_0: $\alpha_{1,1}=\alpha_{1,2}$ (t-stat.)	51.6257***	66.6042***	14.7224***	80.0245***	3.1593*	114.4901***	150.5251***	291.1307***	15.9830***	66.1914***	16.0829***	18.1481***
(p-value)	0.0000	0.0000	0.0002	0.0000	0.0792	0.0000	0.0000	0.0000	0.0001	0.0000	0.0001	0.0001
Wald-test H_0: $\alpha_{1,1}+\alpha_{1,2}=0$ (t-stat.)	8.8757***	0.7818	1.9116	0.0395	2.3547	4.5068**	8.5931***	6.2005**	0.0038	0.7207	42.5402***	28.5036***
(p-value)	0.0038	0.3792	0.1706	0.8430	0.1288	0.0368	0.0044	0.0148	0.9511	0.3984	0.0000	0.0000
LB-Q Statistic (lags)	2.7276 (1)	1.3907 (1)	0.0026 (1)	1.6504 (1)	0.0403 (1)	0.0029 (1)	0.5881 (1)	0.4457 (1)	0.5825 (1)	0.3414 (1)	0.0015 (1)	0.3397 (1)
(p-value)	0.0990	0.2380	0.9590	0.1990	0.8410	0.9570	0.4430	0.5040	0.4450	0.5590	0.9690	0.5600
LB^2-Q Statistic (lags)	0.2811 (1)	0.0286 (1)	0.5351 (1)	0.1462 (1)	0.3496 (1)	0.0105 (1)	0.0100 (1)	0.0007 (1)	0.0093 (1)	0.0172 (1)	145.5700 (1)	0.0697 (1)
(p-value)	0.5960	0.8660	0.4640	0.7020	0.5540	0.9180	0.9200	0.9800	0.9230	0.8960	0.0000	0.7920
Jarque-Bera	1638.7350***	3236.1840***	1023.56***	1689.1530***	371.94***	365.36***	2315.29***	1346.21***	1035.26***	3470.21***	10.9757***	133.1563***
(p-value)	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0041	0.0000

	Mortgage-Backed Securities (MBS)											
	MA7		MA7_L		MA7_AD_L		MBBB7		MBBB7_L		MBBB7_AD_L	
	BHHH	M	BHHH	M[&]	BHHH	M[&]	BHHH	M	BHHH	M[&]	BHHH	M
Wald-test H_0: $\alpha_{1,1}=\alpha_{1,2}$ (t-stat.)	48.7051***	49.6932***	32.5483***	21.5544***	19.4155***	35.4487***	70.1703***	46.9081***	12.9539***	11.8526***	20.1336***	20.5709***
(p-value)	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0005	0.0009	0.0000	0.0000
Wald-test H_0: $\alpha_{1,1}+\alpha_{1,2}=0$ (t-stat.)	0.4663***	0.0876	0.4277	0.0014	0.0587	0.0284	0.5324	0.0015	0.0364	0.0300	17.3983***	219.3632***
(p-value)	0.4967	0.7680	0.5150	0.9698	0.8091	0.8665	0.4677	0.9697	0.8492	0.8630	0.0001	0.0000
LB-Q Statistic (lags)	0.3859 (1)	0.0081 (1)	1.0488 (1)	0.0086 (1)	0.9923 (1)	0.2815 (1)	0.6734 (1)	0.0392 (1)	0.0031 (1)	0.1009 (1)	0.1718 (1)	31.0600 (20)
(p-value)	0.5340	0.9280	0.3060	0.9260	0.3190	0.5960	0.4120	0.8430	0.9560	0.7510	0.6790	0.0540
LB^2-Q Statistic (lags)	0.0142 (1)	0.0183 (1)	0.0007 (1)	0.0165 (1)	0.0311 (1)	0.0125 (1)	0.0389 (1)	0.0148 (1)	0.0523 (1)	0.0339 (1)	7.1737 (3)	24.2910 (15)
(p-value)	0.9050	0.8920	0.9790	0.8980	0.8600	0.9110	0.8440	0.9030	0.8190	0.8540	0.0670	0.0600
Jarque-Bera	10549.54***	17874.59***	11612.55***	20155.39***	5119.85***	5102.31***	3973.24***	4171.32***	3318.68***	3470.21***	714.69***	121.25***
(p-value)	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000

***=1% significance, **=5% significance, *=10% significance. *NA* indicates that no results could be generated by the statistics software due to data overflow. [&] singular covariance coefficients are not unique.

Tab. 52. *Coefficient and residual tests of GARCH(1,1) model for MBS spreads (actual, transformed and Johnson Fit adjusted spreads) – LIBOR at first differences.*

	Pfandbriefe					
	PAAA3		PAAA3_L		PAAA3_AD_L	
	BHHH[&]	M	BHHH	M	BHHH	M
Wald-test H_0: $\alpha_{1,1}=\alpha_{1,2}$ (t-stat.)	129.1306***	39.2609***	137.0914***	31.2007***	79.7204***	55.8482***
(p-value)	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Wald-test H_0: $\alpha_{1,1}+\alpha_{1,2}=0$ (t-stat.)	14.9376***	5.4647**	2.7176	25.1790***	4.3676**	9.5255***
(p-value)	0.0002	0.0219	0.1031	0.0000	0.0398	0.0028
LB-Q Statistic (lags)	0.2412 (1)	0.29 (1)	NA (-)	1.1659 (1)	0.0100 (1)	4.9298 (2)
(p-value)	0.6230	0.5900	NA	0.2800	0.9200	0.0850
LB^2-Q Statistic (lags)	0.3751 (1)	0.0015 (1)	NA(-)	0.5587 (1)	0.0341 (1)	0.0362 (1)
(p-value)	0.5400	0.9690	NA	0.4550	0.8540	0.8490
Jarque-Bera	1989.2060***	2858.43***	NA	1524.71***	139.52***	59.8124***
(p-value)	0.0000	0.0000	NA	0.0000	0.0000	0.0000

	Pfandbriefe					
	PAAA5		PAAA5_L		PAAA5_AD_L	
	BHHH	M	BHHH	M	BHHH[&]	M
Wald-test H_0: $\alpha_{1,1}=\alpha_{1,2}$ (t-stat.)	121.6456***	160.1546***	153.8805***	154.8126***	180.2684***	44.5311***
(p-value)	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Wald-test H_0: $\alpha_{1,1}+\alpha_{1,2}=0$ (t-stat.)	0.1603	1.6396	0.0244	0.0094	1.0605	0.0268
(p-value)	0.6900	0.2040	0.8763	0.9230	0.3062	0.8705
LB-Q Statistic (lags)	1.5474 (1)	0.4631 (1)	0.0220 (1)	0.0672 (1)	0.6945 (1)	1.7015 (1)
(p-value)	0.2140	0.4960	0.8820	0.7960	0.4050	0.1920
LB^2-Q Statistic (lags)	0.1922 (1)	0.0074 (1)	0.0084 (1)	0.1190 (1)	0.0007 (1)	1.9691 (1)
(p-value)	0.6610	0.9310	0.9270	0.7300	0.9790	0.1610
Jarque-Bera	1148.99***	1316.86***	283.75***	634.57***	1263.37***	477.41***
(p-value)	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000

	Pfandbriefe					
	PAAA7		PAAA7_L		PAAA7_AD_L	
	BHHH	M	BHHH	M	BHHH	M
Wald-test H_0: $\alpha_{1,1}=\alpha_{1,2}$ (t-stat.)	130.3716***	116.3700***	119.8820***	131.1770***	150.47***	72.2650***
(p-value)	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Wald-test H_0: $\alpha_{1,1}+\alpha_{1,2}=0$ (t-stat.)	0.0050	1.3709	2.3491	3.6318*	3.9212*	3.1330*
(p-value)	0.9439	0.2451	0.1293	0.0602	0.0511	0.0805
LB-Q Statistic (lags)	0.1702 (1)	1.1656 (1)	NA (-)	0.9328 (1)	0.5066 (1)	0.2286 (1)
(p-value)	0.6800	0.2800	NA	0.3340	0.4770	0.6330
LB^2-Q Statistic (lags)	0.3457 (1)	1.2690 (1)	NA (-)	0.5513 (1)	8.4929 (4)	0.2203 (1)
(p-value)	0.5570	0.2600	NA	0.4580	0.0750	0.6390
Jarque-Bera	102.26***	11.76***	NA	10.15***	1.4125	1.8746
(p-value)	0.0000	0.0028	NA	0.0063	0.4935	0.3917

***=1% significance, **=5% significance, *=10% significance. *NA* indicates that no results could be generated by the statistics software due to data overflow. [&] singular covariance coefficients are not unique.

Tab. 53. *Coefficient and residual tests of GARCH(1,1) model for Pfandbrief spreads (actual, transformed and Johnson Fit adjusted spreads) – LIBOR at first differences.*

	Collateralised Debt Obligations (CDO), synthetic					
	CSAAA3		CSAAA3_L		CSAAA3_AD_L	
	BHHH	M	BHHH[&]	M[&]	BHHH	M[&]
Wald-test H_0: $\alpha_{1,1}=\alpha_{1,2}$ (t-stat.)	9.1476***	49.0537***	2.2721	4.2153**	2.7887*	0.1793
(p-value)	0.0034	0.0000	0.1359	0.0435	0.0990	0.6731
Wald-test H_0: $\alpha_{1,1}+\alpha_{1,2}=0$ (t-stat.)	0.9792	0.8159	1.3313	0.0287	3.4511*	0.0002
(p-value)	0.3255	0.3692	0.2522	0.8658	0.0671	0.9895
Wald-test H_0: $\alpha_{2,1}=\alpha_{2,2}$ (t-stat.)	0.0361	2.1791	0.9019	1.8848	10.0836***	0.0026
(p-value)	0.8498	0.1440	0.3453	0.1738	0.0022	0.9594
Wald-test H_0: $\alpha_{2,1}+\alpha_{2,2}=0$ (t-stat.)	1.2564	0.1052	0.7133	0.0127	4.4756*	0.0003
(p-value)	0.2659	0.7465	0.4010	0.9105	0.0377	0.9873
LB-Q Statistic (lags)	1.1351 (1)	0.3066 (1)	0.7078 (1)	0.0251 (1)	0.8522 (1)	0.0000 (1)
(p-value)	0.2870	0.5800	0.4000	0.8740	0.3560	0.9950
LB^2-Q Statistic (lags)	0.0697 (1)	0.0665 (1)	0.0578 (1)	0.0004 (1)	0.0411 (1)	0.0907 (1)
(p-value)	0.7920	0.7960	0.8100	0.9840	0.8390	0.7630
Jarque-Bera	3764.22***	4169.84***	4614.09***	2062.80***	444.50***	1479.40***
(p-value)	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000

	Collateralised Debt Obligations (CDO), synthetic					
	CSA5		CSA5_L		CSA5_AD_L	
	BHHH	M	BHHH	M	BHHH	M
Wald-test H_0: $\alpha_{1,1}=\alpha_{1,2}$ (t-stat.)	2.8538*	5.9786**	9.1380***	8.2931***	6.7854**	0.0081
(p-value)	0.0952	0.0168	0.0034	0.0052	0.0110	0.9286
Wald-test H_0: $\alpha_{1,1}+\alpha_{1,2}=0$ (t-stat.)	0.0001	0.1706	2.0701	0.0082	1.8470	0.0708
(p-value)	0.9944	0.6807	0.1543	0.9280	0.1781	0.7908
Wald-test H_0: $\alpha_{2,1}=\alpha_{2,2}$ (t-stat.)	13.5211***	2.3582	3.9763**	0.4491	0.7065	0.0031
(p-value)	0.0004	0.1287	0.0497	0.5048	0.4032	0.9557
Wald-test H_0: $\alpha_{2,1}+\alpha_{2,2}=0$ (t-stat.)	0.9063	0.5624	2.3848	0.0043	2.1695	0.0125
(p-value)	0.3441	0.4556	0.1266	0.9478	0.1448	0.9112
LB-Q Statistic (lags)	0.3237 (1)	0.0551 (1)	0.0599 (1)	0.1783 (1)	2.8715 (1)	0.0011 (1)
(p-value)	0.5690	0.8140	0.8070	0.6730	0.0900	0.9730
LB^2-Q Statistic (lags)	0.2919 (1)	0.0648 (1)	0.0404 (1)	0.043 (1)	0.2253 (1)	0.0365 (1)
(p-value)	0.5890	0.7990	0.8410	0.8360	0.6350	0.8480
Jarque-Bera	742.78***	1494.31***	3920.82***	1184.47***	2343.01***	4101.14***
(p-value)	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000

	Collateralised Debt Obligations (CDO), synthetic					
	CSBBB7		CSBBB7_L		CSBBB7_AD_L	
	BHHH	M	BHHH	M	BHHH	M
Wald-test H_0: $\alpha_{1,1}=\alpha_{1,2}$ (t-stat.)	0.0056	1.3355	0.0854	0.0719	0.0338	0.0237
(p-value)	0.9405	0.2514	0.7709	0.7893	0.8546	0.8780
Wald-test H_0: $\alpha_{1,1}+\alpha_{1,2}=0$ (t-stat.)	0.5736	0.1902	0.0391	0.0081	17.2446***	0.0019
(p-value)	0.4511	0.6640	0.8437	0.9286	0.0001	0.9652
Wald-test H_0: $\alpha_{2,1}=\alpha_{2,2}$ (t-stat.)	11.0249***	1.4186	0.1937	0.1022	0.8336	0.0620
(p-value)	0.0014	0.2373	0.6611	0.7501	0.3641	0.8040
Wald-test H_0: $\alpha_{2,1}+\alpha_{2,2}=0$ (t-stat.)	0.7654	0.0143	0.0711	0.0039	0.0620	0.0019
(p-value)	0.3844	0.9050	0.7904	0.9506	0.8040	0.9658
LB-Q Statistic (lags)	0.5277 (1)	0.0085 (1)	0.3907 (1)	0.9231 (1)	5.6452 (2)	0.0019 (1)
(p-value)	0.4680	0.9270	0.5320	0.3370	0.0590	0.9650
LB^2-Q Statistic (lags)	0.0617 (1)	0.0153 (1)	0.1802 (1)	0.0528 (1)	0.4504 (1)	0.0266 (1)
(p-value)	0.8040	0.9020	0.6710	0.8180	0.5020	0.8700
Jarque-Bera	2046.31***	1717.90***	2722.73***	7203.98***	7155.60***	9634.85***
(p-value)	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000

***=1% significance, **=5% significance, *=10% significance. *NA* indicates that no results could be generated by the statistics software due to data overflow. [&] singular covariance coefficients are not unique.

Tab. 54. *Coefficient and residual tests of GARCH(2,1) model for synthetic CDO spreads (actual, transformed and Johnson Fit adjusted spreads) – LIBOR at first differences.*

	Collateralised Debt Obligations (CDO), traditional					
	CTAAA3		CTAAA3_L		CTAAA3_AD_L	
	BHHH	M	BHHH	M	BHHH	M
Wald-test H_0: $\alpha_{1,1}=\alpha_{1,2}$ (t-stat.)	117.7515***	85.9906***	6.0677**	5.3532**	3.7628*	11.9642***
(p-value)	0.0000	0.0000	0.0160	0.0234	0.0561	0.0009
Wald-test H_0: $\alpha_{1,1}+\alpha_{1,2}=0$ (t-stat.)	0.2472	0.0794	4.4698**	0.0016	104.4335***	0.0500
(p-value)	0.6205	0.7789	0.0377	0.9680	0.0000	0.8236
Wald-test H_0: $\alpha_{2,1}=\alpha_{2,2}$ (t-stat.)	0.4967	1.5472	0.0000	0.0399	0.1002	0.2597
(p-value)	0.4831	0.2173	0.9977	0.8421	0.7524	0.6118
Wald-test H_0: $\alpha_{2,1}+\alpha_{2,2}=0$ (t-stat.)	1.3275	0.8542	29.6054***	0.0149	9.9549***	0.2925
(p-value)	0.2528	0.3582	0.0000	0.9031	0.0023	0.5902
LB-Q Statistic (lags)	0.5066 (1)	0.0613 (1)	0.4119 (1)	0.2989 (1)	10.7930 (5)	0.2555 (1)
(p-value)	0.4770	0.8040	0.5210	0.5850	0.0560	0.6130
LB^2-Q Statistic (lags)	0.0037 (1)	0.0180 (1)	0.0159 (1)	0.0054 (1)	14.7820 (8)	0.0021 (1)
(p-value)	0.9520	0.8930	0.9000	0.9410	0.0640	0.9640
Jarque-Bera	11195.83***	19175.19***	13273.06***	9904.79***	213.67***	696.64***
(p-value)	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000

	Collateralised Debt Obligations (CDO), traditional					
	CTA5		CTA5_L		CTA5_AD_L	
	BHHH	M	BHHH	M	BHHH	M
Wald-test H_0: $\alpha_{1,1}=\alpha_{1,2}$ (t-stat.)	1.4672	0.0527	5.2952**	0.4114	24.9096***	4.6735**
(p-value)	0.2295	0.8191	0.0241	0.5232	0.0000	0.0337
Wald-test H_0: $\alpha_{1,1}+\alpha_{1,2}=0$ (t-stat.)	0.0211	0.0617	1.2230	0.0034	0.2732	0.0045
(p-value)	0.8848	0.8045	0.2722	0.9539	0.6027	0.9469
Wald-test H_0: $\alpha_{2,1}=\alpha_{2,2}$ (t-stat.)	0.8064	0.0278	1.1227	0.0108	0.0658	0.1476
(p-value)	0.3720	0.8679	0.2927	0.9174	0.7983	0.7019
Wald-test H_0: $\alpha_{2,1}+\alpha_{2,2}=0$ (t-stat.)	0.5828	0.0715	2.3289	0.0305	0.2196	0.0072
(p-value)	0.4476	0.7898	0.1311	0.8619	0.6407	0.9326
LB-Q Statistic (lags)	0.0207 (1)	0.0742 (1)	0.2789 (1)	0.7867 (1)	0.0728 (1)	0.0106 (1)
(p-value)	0.8860	0.7850	0.5970	0.3750	0.7870	0.9180
LB^2-Q Statistic (lags)	0.0118 (1)	0.1756 (1)	0.0229 (1)	0.0412 (1)	0.0870 (1)	0.0187 (1)
(p-value)	0.9140	0.6750	0.8800	0.8390	0.7680	0.8910
Jarque-Bera	479.78***	1146.55***	1552.34***	2408.92***	8004.54***	10425.07***
(p-value)	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000

	Collateralised Debt Obligations (CDO), traditional					
	CTBBB7		CTBBB7_L		CTBBB7_AD_L	
	BHHH	M	BHHH[&]	M[&]	BHHH	M
Wald-test H_0: $\alpha_{1,1}=\alpha_{1,2}$ (t-stat.)	5.6831*	4.6951**	1.0248	11.6448***	16.2930***	1.1134
(p-value)	0.0196	0.0333	0.3146	0.0010	0.0001	0.2947
Wald-test H_0: $\alpha_{1,1}+\alpha_{1,2}=0$ (t-stat.)	0.0739	0.0075	0.0798	0.0007	0.4454	0.0161
(p-value)	0.7864	0.9311	0.7783	0.9790	0.5065	0.8993
Wald-test H_0: $\alpha_{2,1}=\alpha_{2,2}$ (t-stat.)	2.6372	0.0009	0.1467	3.7456*	1.7833	0.2469
(p-value)	0.1085	0.9759	0.7028	0.0566	0.1857	0.6207
Wald-test H_0: $\alpha_{2,1}+\alpha_{2,2}=0$ (t-stat.)	0.3412	0.0216	0.0817	0.0247	0.4849	0.0046
(p-value)	0.5608	0.8834	0.7757	0.8755	0.4883	0.9458
LB-Q Statistic (lags)	0.4125 (1)	0.0045 (1)	0.0470 (1)	0.0099 (1)	24.6870 (15)	0.3046 (1)
(p-value)	0.5210	0.9460	0.8280	0.9210	0.0540	0.5810
LB^2-Q Statistic (lags)	2.0083 (1)	0.0762 (1)	0.0715 (1)	0.0098 (1)	5.1869 (2)	0.0124 (1)
(p-value)	0.1560	0.7830	0.7890	0.9210	0.0750	0.9110
Jarque-Bera	1365.94***	1580.87***	3747.04***	753.83***	156.61***	181.45***
(p-value)	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000

***=1% significance, **=5% significance, *=10% significance. *NA* indicates that no results could be generated by the statistics software due to data overflow. [&] singular covariance coefficients are not unique.

Tab. 55. *Coefficient and residual tests of GARCH(2,1) model for traditional CDO spreads (actual, transformed and Johnson Fit adjusted spreads) – LIBOR at first differences.*

	Mortgage-Backed Securities (MBS)											
	MAAA3		MAAA3_L		MAAA3_AD_L		MAAA5		MAAA5_L		MAAA5_AD_L	
	BHHH	M	BHHH	M	BHHH	M	BHHH	M	BHHH[&]	M	BHHH	M
Wald-test H_0: $\alpha_{1,1}=\alpha_{1,2}$ (t-stat.)	14.0474***	28.4184***	1.9952	18.5008***	13.0022***	3.2037*	158.05***	243.7303***	66.1130***	140.7861***	6.2115**	0.7402
(p-value)	0.0003	0.0000	0.1618	0.0000	0.0006	0.0774	0.0000	0.0000	0.0000	0.0000	0.0148	0.3923
Wald-test H_0: $\alpha_{1,1}+\alpha_{1,2}=0$ (t-stat.)	10.3853***	0.0412	1.2955	0.0000	2.4650	0.0024	0.3520	4.4828**	0.0598	1.1603	65.6843***	19.0990***
(p-value)	0.0019	0.8397	0.2586	0.9980	0.1205	0.9607	0.5547	0.0375	0.8074	0.2848	0.0000	0.0000
Wald-test H_0: $\alpha_{2,1}=\alpha_{2,2}$ (t-stat.)	2.4479	0.1167	1.5577	0.0040	1.0149	0.0895	0.5867	2.3217	5.2070**	4.5688**	18.9879***	12.5057***
(p-value)	0.1218	0.7336	0.2158	0.9499	0.3169	0.7656	0.4460	0.1317	0.0253	0.0357	0.0000	0.0007
Wald-test H_0: $\alpha_{2,1}+\alpha_{2,2}=0$ (t-stat.)	8.6410***	0.0000	1.1089	0.0078	0.7886	0.0024	0.1258	2.6399	0.0210	0.7448	6.3620**	3.0602*
(p-value)	0.0043	0.9967	0.2956	0.9299	0.3773	0.9607	0.7238	0.1083	0.8851	0.3908	0.0137	0.0842
LB-Q Statistic (lags)	0.0545 (1)	1.3708 (1)	0.2573 (1)	0.7213 (1)	0.6578 (1)	0.7573 (1)	0.6827 (1)	6.9812 (1)	0.2366 (1)	0.9238 (1)	0.2708 (1)	1.2203 (1)
(p-value)	0.8150	0.2420	0.6120	0.3960	0.4170	0.3840	0.4090	0.0720	0.6270	0.3360	0.6030	0.2690
LB^2-Q Statistic (lags)	0.0545 (1)	0.0133 (1)	0.0008 (1)	0.0013 (1)	0.1050 (1)	0.0244 (1)	0.1165 (1)	0.2955 (1)	0.0370 (1)	0.0001 (1)	98.7080 (8)	0.0091 (1)
(p-value)	0.8150	0.9080	0.9770	0.9710	0.7460	0.8760	0.7330	0.5870	0.8470	0.9930	0.0000	0.9240
Jarque-Bera	4961.71***	4749.15***	1345.78***	2825.98***	112.1410***	102.29***	1332.68***	97.4937***	421.1872***	241.08***	18.8417***	218.43***
(p-value)	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0001	0.0000

	Mortgage-Backed Securities (MBS)											
	MA7		MA7_L		MA7_AD_L		MBBB7		MBBB7_L		MBBB7_AD_L	
	BHHH	M	BHHH	M	BHHH	M	BHHH	M	BHHH	M	BHHH[&]	M
Wald-test H_0: $\alpha_{1,1}=\alpha_{1,2}$ (t-stat.)	16.0644***	54.1040***	0.9503	0.1604	2.6785	0.1464	38.3527***	35.2435***	1.9714	0.9780	3.3301*	0.0681
(p-value)	0.0001	0.0000	0.3327	0.6899	0.1058	0.7031	0.0000	0.0000	0.1643	0.3258	0.0719	0.7949
Wald-test H_0: $\alpha_{1,1}+\alpha_{1,2}=0$ (t-stat.)	0.1276	0.0009	289.1358***	0.0000	115.8702***	0.0000	0.6695	0.1242	0.9869	0.8792	0.0757	0.0004
(p-value)	0.7219	0.9755	0.0000	0.9959	0.0000	0.9997	0.4158	0.7255	0.3236	0.3514	0.7840	0.9850
Wald-test H_0: $\alpha_{2,1}=\alpha_{2,2}$ (t-stat.)	0.0425	0.0027	0.0675	0.0023	0.0047	0.0022	6.3986**	3.5912*	0.740516	1.0438	0.1885	0.029119
(p-value)	0.8373	0.9588	0.7957	0.9615	0.9453	0.9623	0.0135	0.0618	0.3922	0.3101	0.6654	0.8650
Wald-test H_0: $\alpha_{2,1}+\alpha_{2,2}=0$ (t-stat.)	0.0595	0.0161	841.4658***	0.0000	124.1782***	0.0000	0.7052	0.108211	0.8612	1.0907	0.1426	0.0003
(p-value)	0.8080	0.8995	0.0000	0.9975	0.0000	0.9984	0.4036	0.7431	0.3563	0.2996	0.7067	0.9865
LB-Q Statistic (lags)	0.7893 (1)	0.1584 (1)	1.1107 (1)	0.0323 (1)	1.6291 (1)	0.0025 (1)	0.4288 (1)	0.4602 (1)	NA (-)	8.2213 (4)	7.1643 (3)	4.3848 (2)
(p-value)	0.3740	0.6910	0.2920	0.8570	0.2020	0.9600	0.5130	0.4980	NA	0.0840	0.0670	0.1120
LB^2-Q Statistic (lags)	0.0207 (1)	0.003 (1)	0.0139 (1)	0.0165 (1)	0.2007 (1)	0.0146 (1)	0.0229 (1)	0.0411 (1)	NA (-)	0.0008 (1)	1.1795 (1)	0.7806 (1)
(p-value)	0.8860	0.9560	0.9060	0.8980	0.6540	0.9040	0.8800	0.8390	NA	0.9770	0.2770	0.3770
Jarque-Bera	13574.11***	14751.88***	10808.59***	20019.31***	14168.17***	23505.94***	12912.18***	2411.09***	NA	2411.09***	382.03***	1045.63***
(p-value)	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	NA	0.0000	0.0000	0.0000

***=1% significance, **=5% significance, *=10% significance. *NA* indicates that no results could be generated by the statistics software due to data overflow. [&] singular covariance coefficients are not unique.

Tab. 56. *Coefficient and residual tests of GARCH(2,1) model for MBS spreads (actual, transformed and Johnson Fit adjusted spreads) – LIBOR at first differences.*

	Pfandbriefe					
	PAAA3		PAAA3_L		PAAA3_AD_L	
	BHHH	M	BHHH	M	BHHH[&]	M
Wald-test H_0: $\alpha_{1,1}=\alpha_{1,2}$ (t-stat.)	25.9411***	66.1769***	30.0515***	22.9634***	40.9130***	26.2764***
(p-value)	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Wald-test H_0: $\alpha_{1,1}+\alpha_{1,2}=0$ (t-stat.)	14.9274***	0.0870	11.1170***	0.0024	10.9676***	20.6809***
(p-value)	0.0002	0.7689	0.0013	0.9613	0.0014	0.0000
Wald-test H_0: $\alpha_{2,1}=\alpha_{2,2}$ (t-stat.)	15.6226***	4.2855**	14.1315***	0.0314	44.1682***	81.4127***
(p-value)	0.0002	0.0418	0.0003	0.8599	0.0000	0.0000
Wald-test H_0: $\alpha_{2,1}+\alpha_{2,2}=0$ (t-stat.)	20.2373***	0.353607	18.2490***	0.000611	34.0455***	39.0259***
(p-value)	0.0000	0.5538	0.0001	0.9803	0.0000	0.0000
LB-Q Statistic (lags)	3.3700 (1)	6.4031 (3)	2.8382 (1)	2.2874 (1)	11.4420 (1)	0.3812 (1)
(p-value)	0.0660	0.0940	0.0920	0.1300	0.0010	0.5370
LB^2-Q Statistic (lags)	0.3998 (1)	0.1084 (1)	0.6363 (1)	0.0030 (1)	25.6920 (1)	0.1814 (1)
(p-value)	0.5270	0.7420	0.4250	0.9560	0.0000	0.6700
Jarque-Bera	4483.14***	4776.23***	2649.86***	1871.34***	667.74***	638.28***
(p-value)	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000

	Pfandbriefe					
	PAAA5		PAAA5_L		PAAA5_AD_L	
	BHHH	M	BHHH	M	BHHH[&]	M
Wald-test H_0: $\alpha_{1,1}=\alpha_{1,2}$ (t-stat.)	83.3926***	112.9865***	92.8332***	98.6260***	95.7934***	19.9111***
(p-value)	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Wald-test H_0: $\alpha_{1,1}+\alpha_{1,2}=0$ (t-stat.)	0.5652	0.0052	2.6263	0.0000	0.5399	0.7550
(p-value)	0.4545	0.9425	0.1092	0.9998	0.4647	0.3876
Wald-test H_0: $\alpha_{2,1}=\alpha_{2,2}$ (t-stat.)	9.5896***	1.842273	6.4145**	0.00314	14.0902***	6.3326**
(p-value)	0.0027	0.1787	0.0134	0.9555	0.0003	0.0139
Wald-test H_0: $\alpha_{2,1}+\alpha_{2,2}=0$ (t-stat.)	0.8319	0.004338	1.547299	0.0000261	0.652934	1.69031
(p-value)	0.3646	0.9477	0.2173	0.9959	0.4216	0.1974
LB-Q Statistic (lags)	0.3635 (1)	0.8217 (1)	1.1426 (1)	0.1458 (1)	0.2058 (1)	8.0446 (4)
(p-value)	0.5470	0.3650	0.2850	0.7030	0.6500	0.0900
LB^2-Q Statistic (lags)	0.0365 (1)	0.0021 (1)	0.0894 (1)	0.0038 (1)	0.0301 (1)	1.5583 (1)
(p-value)	0.8480	0.9630	0.7650	0.9510	0.8620	0.2120
Jarque-Bera	2237.18***	1105.09***	546.21***	251.70***	1799.2100***	1233.82***
(p-value)	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000

	Pfandbriefe					
	PAAA7		PAAA7_L		PAAA7_AD_L	
	BHHH[&]	M	BHHH	M	BHHH	M
Wald-test H_0: $\alpha_{1,1}=\alpha_{1,2}$ (t-stat.)	52.4371***	113.2866***	55.0310***	92.1496***	52.2577***	13.6369***
(p-value)	0.0000	0.0000	0.0000	0.0000	0.0000	0.0004
Wald-test H_0: $\alpha_{1,1}+\alpha_{1,2}=0$ (t-stat.)	28.9154***	25.3665***	39.9667***	37.5099***	11.7751***	23.3220***
(p-value)	0.0000	0.0000	0.0000	0.0000	0.0010	0.0000
Wald-test H_0: $\alpha_{2,1}=\alpha_{2,2}$ (t-stat.)	66.1212***	67.1582***	93.3045***	88.4765***	35.8244***	17.6272***
(p-value)	0.0000	0.0000	0.0000	0.0000	0.0000	0.0001
Wald-test H_0: $\alpha_{2,1}+\alpha_{2,2}=0$ (t-stat.)	25.7835***	19.6427***	40.3666***	35.0885***	12.3520***	25.9819***
(p-value)	0.0000	0.0000	0.0000	0.0000	0.0007	0.0000
LB-Q Statistic (lags)	1.2895 (1)	1.3956 (1)	2.1350 (1)	0.2643 (1)	0.1635 (1)	0.0508 (1)
(p-value)	0.2560	0.2370	0.1440	0.6070	0.6860	0.8220
LB^2-Q Statistic (lags)	0.0142 (1)	0.2844 (1)	2.3081 (1)	0.2311 (1)	0.1961 (1)	0.0555 (1)
(p-value)	0.9050	0.5940	0.1290	0.6310	0.6580	0.8140
Jarque-Bera	5935.17**	137.0564***	0.36	2.91	0.91	30.06***
(p-value)	0.0000	0.0000	0.8347	0.2328	0.6344	0.0000

***=1% significance, **=5% significance, *=10% significance. *NA* indicates that no results could be generated by the statistics software due to data overflow. [&] singular covariance coefficients are not unique.

Tab. 57. *Coefficient and residual tests of GARCH(2,1) model for Pfandbrief spreads (actual, transformed and Johnson Fit adjusted spreads) – LIBOR at first differences.*

CHAPTER V: "SECURITY ISSUANCE AND INVESTOR INFORMATION"

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1 ABSTRACT

Although the commoditisation of illiquid asset exposures through securitisation facilitates the disciplining effect of capital markets on risk management, private information about securitised debt and complex transaction structures could impair fair market valuation. In a simple issue design model without intermediaries we maximise issuer proceeds over a positive measure of issue quality, where a *direct revelation mechanism* (DRM) by profitable informed investors engages endogenous price discovery through auction-style allocation preference as a continuous function of perceived issue quality. We derive an optimal allocation schedule for maximum issuer payoffs under different pricing regimes if asymmetric information requires underpricing. In particular, we study how the incidence of uninformed investors at varying levels of valuation uncertainty and their function of clearing the market effect profitable informed investment. We find that the issuer optimises own payoffs at each valuation irrespective of the applicable pricing mechanism by awarding informed investors the lowest possible allocation (and attendant underpricing) that still guarantees profitable informed investment. Under uniform pricing, the composition of the investor pool ensures that informed investors appropriate higher profit than uninformed types. Any reservation utility by issuers lowers both the probability of information disclosure by informed investors and the scope of issuers to curtail profit taking by informed investment.

Keywords: asset securitisation, security design, security issue, direct revelation mechanism, asymmetric information, auction model, asset securitisation, reservation utility

JEL Classification: D82, G12, G14, G23

2 INTRODUCTION

Asset securitisation refers to the growing tendency of substituting capital markets for intermediaries in channelling external funds to efficient uses of economic activity. Recently it has been touted as a viable and expedient risk management and refinancing method. It allows issuers to convert existing or future cash flows from pooled asset exposures ("reference portfolio") into marketable debt securities as commoditised structured claims, which blend default risk and asset pricing features of securitised assets (mostly mortgages, consumer debt, trade receivables and corporate loans) and the merchantability of fixed income securities. Secured debt, such as asset-backed securities (ABS), registers as a safer claim than unsecured debt under the pecking order theory (Myers, 1977; Leland, 1998), mainly because it derives its value from repayment on a scrutinisable asset portfolio insulated from overall issuer performance. At the same time, the inherent asset transformation of securitisation challenges the traditional value proposition of financial intermediation by separating asset origination and risk management as two distinctive components in external finance. Despite its efficiency-enhancing effect as a diversified source of liquid funds, securitisation falls short of mitigating incomplete capital allocation in financial markets. The complex nature of securitisation engenders valuation uncertainty and possible non-verifiability of trading motives due to imperfect information dissemination. Asymmetric information between issuers and investors suggests that issuers have superior information about the true asset value, so that investors in securitised assets would reasonably command external price discounting to compensate for *ex ante* moral hazard as regards the deliberate misrepresentation of securitised asset quality and adverse selection by rational investor expectations à la Akerlof (1970).[1] Issuers usually retain the most junior claim in a transaction *(credit enhancement)* as *ex ante* reservation utility to mitigate these agency costs of asymmetric information (DeMarzo and Duffie, 1997).

In this chapter, we present a general issue design, which demonstrates how valuation uncertainty and credit enhancement might affect both the incentive structure of investors and issuer payoff of security issuance. A low incidence of informed investors suggests an auction-style allocation mechanism with price discounting ("underpricing") as a feasible model design for the optimal choice of pricing and allocation under valuation uncertainty. Our proposed model introduces a new argument for optimal security issuance under asymmetric information without intermediaries in keeping with the "winner's curse" problem. Although our framework of optimal security issuance relies on the conventional allocation-based argument of IPO underpricing due to asymmetric information between issuers and investors in keeping with the "winner's curse" problem (Rock, 1986), our simple one-period approach goes beyond the rationing of uninformed investors as the

[1] Rational investors would expect to be offered only poor deals in securitisation markets under asymmetric information. If the investment choice is conditional on the level of investor information, uninformed investors assume to partake in a disproportionately large number of poor transactions once better informed investors have picked off most if not all profitable deals. Asymmetric information might also arise from (i) incentives of biased loan selection at the time the asset composition of the portfolio is determined (*ex ante* moral hazard) and (ii) reduced monitoring of asset exposure after securitisation (*ex post* moral hazard). See Jobst (2003) for a detailed review of the information economics of asset securitisation.

main determinant of underpricing. In a general auction-style design, we maximise issuer payoffs conditional on price discounting needed to guarantee profitable informed investment over a positive measure of issue quality for a given degree of valuation uncertainty about securitised assets. As opposed to Rock (1986), where underpricing compensates uninformed investors for being rationed by informed demand across all states of profitable investment, we explain underpricing to be jointly determined by both an auction-style share allocation to informed investors and the degree of uninformed investment associated with valuation uncertainty. It is not the rationing of uninformed investors, but the allocation preference by informed investors, which guides our thinking about underpricing and how it relates to the optimisation problem of issuer proceeds. We treat the level of allocation as a strategic choice variable, which allows issuers to extract information about the actual quality of the security issue through revealed allocation preference by informed investors in a *direct revelation mechanism* (DRM).[2] DRM endogenises price discovery in an auction-style allocation preference as a continuous function of perceived issue quality. Informed investors accept some allocation as a continuous function of their beliefs about the actual issue valuation and reveal their valuation to uninformed investors only if a known price-quantity schedule implies profitable investment.[3] The acceptance set of profitable informed investment qualifies an optimal allocation schedule for maximum issuer payoffs at varying degrees of valuation uncertainty and different pricing regimes. Issuers maximise issue payoffs at a positive measure of issue quality for an allocation that ensures participation by informed investors. The price discovery of actual issue quality conditional on some acceptance set of informed investors allows issuers to price the residual allocation to uninformed investors to clear the market. In particular, we study how the incidence of uninformed investors at varying levels of valuation uncertainty affects the utility from informed investment if the offering price is set to be either the same for both types of investors (uniform pricing) or higher for

[2] Due to private information informed investors have superior knowledge about the actual quality of the security issue, whose valuation uncertainty is indicated by the precision measure of the private signal received by informed investors.

[3] The option value of informed investment increases (decreases) the higher (lower) the valuation uncertainty and the lower (higher) the precision of investor beliefs, which implies that more investors become informed as information gathering about the true value of the transaction becomes more profitable. An increase in the number of informed investors raises the rational expectation of uniformed investors to be allocated shares in a disproportionately large number of unprofitable (bad) deals ("winner's curse dilemma"). Uninformed investors will require sufficient underpricing to compensate for *ex ante* valuation uncertainty ("*ex ante* uncertainty hypothesis") as agency cost of adverse selection. Also informed investors would only commit to profitable, underpriced investments. If the size of the overall investor pool is kept unchanged, the altered composition of the investor pool due to a larger share of informed investors at higher valuation uncertainty changes the prices both types of investors would be prepared to pay. The degree of underpricing associated with valuation uncertainty depends on the applicable pricing scheme (uniform pricing vs. discriminatory pricing). Uniform pricing induces informed investors to require higher underpricing as more informed investors in the investor pool reduce the individual net payoff of each informed investor relative to the payoff of uninformed investors. Discriminatory pricing schemes would be sustainable at lower levels of underpricing as valuation uncertainty increases.

uninformed investors (discriminatory pricing). The residual allocation to uninformed investors and the incentive of informed investors to subscribe to DRM at any issue quality – as long as some allocation yields positive payoff – curtail the ability of informed investors to optimise own payoffs from disclosing their beliefs under the profitability condition of DRM. Under uniform pricing, the incidence of investor types associated with the degree of valuation uncertainty further conditions the propensity of informed investors to participate. As an extension to the existing underpricing paradigm, we add credit enhancement to the model as some reservation utility in the form of fractional investor repayment, which sanctions the scope of profitable informed investment.[4]

We find that issuers maximise own payoffs and derive an optimal solution to the design problem if their allocation to informed investors remains large enough to elicit "truth telling" in return for profitable investment, irrespective of the pricing regime (uniform or discriminatory). A higher allocation to informed investors means that a larger portion of the transaction is subject to underpricing, which in turn reduces overall issue payoffs. The presence of an unknown number of uninformed investors only matters as a participation constraint of optimal allocation under uniform pricing, which requires an adjustment of the allocation choice to still guarantee profitable informed investment. Increased uninformed investment demand at lower valuation uncertainty limits the utility of informed investment. Thus, the composition of the investor pool ensures that informed investors[5] appropriate higher relative profit than uninformed types. We find that issuers maximise payoffs under uniform pricing by keeping the actual quality of the transaction, valuation uncertainty and any reservation utility as low as possible. This rule of action establishes an "efficient frontier" of allocation choices, which implies higher individual net payoff from informed investment relative to uninformed investment.

The rest of the chapter is structured as follows. The chapter begins with a review of the literature, linking stylised facts about asset securitisation with information processing under asymmetric information in matters pertinent to efficient security issuance in securitisation markets. In the next sections we present a simple issue design model without intermediaries, where a *direct revelation mechanism* (DRM) determines the optimal allocation choice for maximum issuer payoffs at varying degrees of valuation uncertainty and different pricing regimes – assuming asymmetric information requires "winner's curse"-type underpricing and uninformed investment demand clears the market. With information processing by informed investors taking a critical role in security issuance, we first

[4] If issuers retain some reservation utility the resultant fractional repayment increases demands on the minimum issue quality.

[5] Informed investors can infer valuation uncertainty and the incidence of uninformed investment from the precision of their private signal, which qualifies the allocation schedule of profitable investment.

derive an acceptance set of profitable informed investment, which prescribes an optimal allocation schedule for a perceived issue quality. We then determine expected issuer proceeds if informed investors maximise their payoffs within this acceptance set according to a fixed price-quantity schedule. In particular, we study how the incidence of uninformed investors at varying levels of valuation uncertainty impacts the utility from informed investment under uniform pricing conditions. Subsequently, we introduce endogenous price discovery through auction-style allocation preference as a continuous function of perceived issue quality (in keeping with a fixed price-quantity schedule) within the acceptance set of profitable informed investment to derive maximum issuer net payoffs. Finally, we provide a numerical illustration of the relationship between perceived issue quality and net issuer proceeds contingent on the degree of valuation uncertainty (see section 6). The chapter concludes with a summary of significant findings and recommendations.

3 LITERATURE REVIEW AND EMPIRICAL REASONING

The design problem of security issuance under asymmetric information and valuation uncertainty has been extensively studied in past research on the underwriting process and investor behaviour in stock markets.[6] However, so far the well-understood economic rationale behind the alignment of asset pricing and share allocation choices to investor incentives has not been transposed into related areas of external finance, such as asset securitisation. Asset securitisation represents a cost-efficient and flexible structured finance instrument to convert illiquid present or future asset claims of varying maturity and quality into tradable debt securities by re-packaging and diversifying receivables into securitisable asset portfolios (*liquidity transformation* and *asset diversification*).[7] Transactions typically involve reference portfolios of one or more (fairly illiquid) asset exposures, from which stratified positions (or tranches) with different seniority are created, reflecting different degrees of investment risk.[8] The existing literature in securitisation primarily focuses on the implications of potential agency costs arising from adverse selection and moral hazard sanctioned by capital market investors.

[6] See Welch and Ritter (2002) for a recent overview of the literature in this regard.
[7] Asset securitisation initially started as a way of depository institutions, non-bank finance companies and other corporations to explore new sources of asset funding either through moving assets off their balance sheet or raising cash by borrowing against balance sheet assets ("liquifying"). In the meantime, securitisation goes a long way in advancing two main objectives: (i) to curtail balance sheet growth and realise certain accounting objectives and balance sheet patterns, and/or (ii) to reduce economic cost of capital as a proportion of asset exposure and ease regulatory capital requirements (by lower bad debt provisions) to manage risk more efficiently. Most commonly, a balanced mix of both objectives and further operational and strategic considerations determine the type of securitisation – traditional or synthetic – in the way issuers envisage securitisation as a method to shed excessive asset exposures.
[8] These positions may take the form of fully/partially funded asset-backed securities or unfunded derivatives.

In securitisation, issuers and/or investors tend to retain some of the securitised asset exposure and/or provide other means of structural support to build investor confidence in the quality of their security issue. Frequently, such risk sharing agreement between issuers and investors comes in the form of an equity-like claim[9] on the expected losses of the securitised assets in the effort to limit agency costs of asymmetric information due to inherent valuation uncertainty.[10] These information problems associated with the lack of external verifiability of securitised assets and the risk-sharing arrangements between issuers and investors are common considerations in existing security design models. We reconcile existing approaches to model the information structure of investors and partial asset retention by issuers as crucial elements to security issuance under asymmetric information. In order to specify (i) information processing of informed investors as "truth tellers" in an auction-style allocation choice under asymmetric information and (ii) how valuation uncertainty affects the degree of underpricing, we amalgamate previous findings from (i) economic models with multiple equilibrium outcomes from information processing and coordination games, (ii) security design model of debt contracts with partial repayment and (iii) auction-style solutions to IPO mechanisms. In order to determine how informed investors process private information we resort to the concept of adjusted investor beliefs in a coordination game setting proposed by Morris and Shin (2000) in the context of bank runs, where the discrepancy between the indeterminacy of beliefs and the objective assessment could lead to suboptimal economic outcomes.[11] In particular, we adopt the definition of a precision measure of private signals to specify informed investment decisions as a basis of a *direct revelation mechanism* (DRM). Second, we borrow the optimal design of lending contracts with partial repayment from Inderst and Müller (2002) in order to derive the first-best condition of optimal informed investment if a reservation utility associated with *credit enhancement* reduces expected payoffs from investment. This approach is in stark contrast to many erroneous accounts in the literature,

[9] The structural risk sharing arrangement between issuers and investors through subordination, which concentrates most default loss in the most junior tranche, also entails leveraged investment due to the difference of tranche sizes across different levels of seniority. Tranches with little or no subordination are more affected by the mean and volatility of default losses (expected and unexpected losses) (Gibson, 2004), i.e. their ratio of relative tranche losses to relative portfolio losses is higher than for more senior tranches. So we would expect an ever greater effect of adverse selection from valuation uncertainty on leveraged exposures in securitised asset portfolios. Issuers and investors might also be faced with the prospect of high trading cost (Duffie and Gârleanu, 2001) associated with a small market volume of outstanding issues, liquidity premium to the agency cost from adverse selection.

[10] Early models suggest signalling (DeMarzo and Duffie, 1997; Leland and Pyle, 1977) as a means to curb investor uncertainty, where sellers of a security issues convey the value of the security by their willingness to partake in the risk as they retain a portion of the issue. Riddiough (1997) takes a slightly different twist on risk sharing. He proposes a theoretical model of asset-retention as an effort choice by issuers to mitigate external price discounting as agency cost of rational investor beliefs about superior information[10] about the securitised asset risk held by non-recourse single-purpose entities in conventional securitisation structures.

[11] In their view multiple equilibria assume that economic outcomes result from actions motivated by the beliefs of individuals. However, any indeterminacy of beliefs, although these beliefs themselves are rationale and consistent with fundamental economic features, yields quite different states of affairs, which might not be perfectly in a nod to what would be deemed appropriate judging by the underlying information to start with.

which regard credit enhancement as a signalling device[12] Finally, we resort to the rich literature about IPO underpricing (Malakhov, 2003; Welch and Ritter, 2002; Myerson, 1981) of corporate share issues as the theoretical basis for the specification of an *optimal security auction* under asymmetric information with maximum issuer payoffs. We rule out all but asymmetric information from the list of researched explanations for IPO underpricing,[13] as most of the legal and strategic considerations of alternative explanatory approaches do not apply to securitisation.[14] Asymmetric information models suggest a positive correlation between *ex ante* valuation uncertainty and underpricing. The "winner's curse" problem is one of the asymmetric information models,[15] whose economic reasoning for IPO underpricing seems to be most in tune with empirical observations about the workings of securitisation markets. The "winner's curse" problem postulated by Rock (1986) implies that asymmetric information about the actual issue quality entails adverse selection of investor as regards share allocation, where informed investors benefit from better information.[16] Since the information

[12] Since credit enhancement compensates for the rating shortfall between the rating quality and the desired rating quality of the transaction (as a completely discretionary choice), the level of credit enhancement cannot increase information transparency as a signalling device.

[13] In classical IPO models issuers offer new shares at a selling price below fair market value ("underpricing") due to one or more of the following factors: (i) asymmetric information, (ii) institutional and systemic constraints, (iii) strategic considerations, and (iv) ownership and control. However, individual characteristics of national stock markets and disparate statutory regulations limit how these factors might actually explain the reasons for discounted IPOs. Besides asymmetric information other main reasons for underpricing are defined as: (i) legal risk of violations against securities laws ("lawsuit hypothesis"), price support and book building as a mechanism of information revelation could explain high levels of underpricing as investors require significant compensation for systemic uncertainty and institutional constraints by means of underpricing; (ii) pricing and/or explicit rationing bias give rise to restrictions on ownership and control; (iii) strategic considerations ("manager's strategic underpricing explanation"), where underpricing occurs as an agency cost that results from strategic considerations by managers to benefit from higher expected shareholding value at lock-up expiration if underpricing creates an information momentum, which shifts the demand curve for the issued shares outwards (Aggarwal et al., 2002). Hence, managers trade-off substantial underpricing against a maximisation of personal wealth when they have their first opportunity to sell shares.

[14] Although a good part of securitisation deals are sold via private placements especially uniform pricing of securitised claims leaves asymmetric information as a probable explanation for the workings of securitisation issuance.

[15] Other asymmetric information models of IPO underpricing include signalling models (Welch, 1989 and 1996) and principal agent models about the significance of underwriting services (Jenkinson and Ljunqvist, 2001). In signalling models good issuers use discounting to signal actual valuation as a means to achieve separation from bad issuers under information asymmetry between issuers and investors. A noisier environment with high uncertainty increases the extent of underpricing needed for separation. Allen and Faulhaber (1989), Michaely and Shaw (1994) as well as Welch (1989 and 1996) find that the signalling hypothesis explains the empirical pattern of underpricing behaviour. Second, in principal-agent models greater valuation uncertainty puts a premium on the underwriting services (Jenkinson and Ljunqvist, 2001), where higher underwriting (agency) cost conditional on uncertainty entails higher levels of underpricing. Nonetheless, this situation can only occur if competition in the underwriting line and/or difficulties in placing shares with investors accords underwriters sufficient market power to seek information rents from issuers. Third, the *ex ante* hypothesis problem developed by Ritter (1984) as well as Beatty and Ritter (1986) explains a discounted offering price as compensation for the investment risk of uninformed investors, whose rational expectation would suggest disproportionately high shares in poor transactions when informed investors shy away placing their bids.

[16] Since informed investors condition their decision to request some allocation on positive payoff, this allocative benefit results in underpricing and increases in valuation uncertainty. Hence, the benefit from

advantage of informed investors carries higher gross payoffs as the degree of valuation uncertainty rises, higher informed investment demand in the composition of the investor pool entails a higher degree of underpricing (to maintain the participation incentive of investors). Hence, higher gross payoffs from informed investment exacerbate the "winner's curse" problem. Uninformed investors would rationally believe that they receive a disproportionately high allocation of transactions of poor quality.[17]

It is commonplace to argue that securitisation markets are notorious for weak information disclosure about underlying reference portfolios, intricate auditing standards and legal uncertainty surrounding the estimation of expected investor return and the complex enforcement of restrictive covenants and redemption criteria. These contingencies and information constraints impede efficient asset pricing and hinder full understanding of the fundamental risk involved in securitisation transactions.[18] Low market liquidity of securitisation instruments suggests substantial valuation uncertainty.[19] In the presence of disintegrated capital markets, the low degree of informed investment could provide grounds for discounted offerings to compensate for investment risk. So, the adaptation of asymmetric information models of IPO pricing has intuitive appeal. Moreover, participants in securitisation markets[20] learn about allocation rates, which award all agents regardless of their size the same chance of placing a successful bid. Consequently, the "winner's curse" problem seems a plausible cause to underpricing of securitisation transactions.

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generating private information production is similar to investment in a call option on the IPO with the offering price as strike price and the valuation of the issue as the underlying asset price. The call option reflects the degree of underpricing. As the option value increases with uncertainty about the underlying valuation, more investors become informed.

[17] Some empirical studies confirming the winner's curse problem on the basis of allocation rates of IPO issues include Koh and Walter (1989), Levis (1990), Keloharju (1993) as well as Amihud et al. (2003).

[18] See also Rutledge (2004) on the frequently decried absence of widespread standardisation in securitisation markets.

[19] Substantial liquidity risk and rent seeking from information advantage has confined most investment in securitisation markets to "buy-and-hold" strategies by large and well-informed institutional investors, insurance companies, banks and other financial institutions; yet evidence about the degree of uninformed investment remains inconclusive for loss of empirical observations.

[20] The securitisation market consists of two types of investors: individual investors and institutional investors. While the majority of investors, which mostly invest in high-volume issue tranches with high seniority (such as big insurance companies), could be regarded as uninformed, the small portion of institutional and private investors function is informed and invests in junior and riskier. As senior tranches outweigh lower rated tranches by far in notional volume, uninformed investor claim a sizeable part of investment demand in securitisation markets.

4 MODEL

We tender a security (issue) design model, where a single monopolistic issuer of securitised claims maximises his proceeds through an optimal allocation that is incentive compatible with informed investment demand. The model describes a simplified issuing process in a simplified securitisation market consisting of one issuer without endowment[21] and two discrete types of investors, with competition limited to investors only. The issuer offers securitised claims to outside investors at some selling price after having sounded out the perceived issue quality by taking initial quantity orders from sophisticated investors on the basis of a commonly understood pricing scheme. The total number of claims is set to unity. We distinguish between two discrete types of buyers: informed investors I (e.g. large institutional investors, banks, hedge fund managers) and uninformed investors $\theta \in \Psi = \left[1, \bar{\theta}\right]$ (e.g. retail investors), whose types are defined by nature *ex ante* as measures of informed and uninformed demand. Informed investors act as quasi-market makers and price setters during initial placement, before uninformed investors clear the market after price discovery by informed types. The probability of being an informed or uninformed investor is proportional to the incidence of types, where $I/(I+\theta)$ is the probability of being informed. The distribution of uninformed investment θ and the total number of informed investors I is common knowledge. Informed investors have sufficient funds to buy the entire transaction (or as much as available). The same applies to the total number of uninformed investors. In keeping with Rock (1986) we assume uniform informed investment, where each informed investor can be allocated more than one share (i.e. varying quantity orders). Uninformed investors can only buy at most one share each and have sufficient funds to buy the entire issue at any valuation irrespective of the offering price. If informed investors decide to buy (at some pricing schedule based on allocation), we anticipate rationing of uninformed investors in the sense of the "winner's curse" adverse selection problem in Rock (1986).[22] All agents in the model are assumed to be risk-neutral. The issue valuation r is a random variable $r \sim N\left(\tilde{r}, \alpha^{-1}\right)$ with precision α. The issuer does not know the realisation of uninformed investment θ and offers the transaction with promised repayment $c(r) \in C = [0,1]$ to informed investors $i \in I$ at a fixed price-quantity schedule. Informed investors learn about the actual valuation by gathering precise but not perfect information about the quality of the issue before they tender a

[21] i.e. funds generated from the issue accrue irrespective of other assets the issuer might hold on his books.
[22] See also section 3 for a brief review of the rationale of underpricing in the context of initial public offerings of stocks (IPO).

bid.[23] They observe the realisation of valuation r as a i.i.d. private (and costless)[24] noisy signal $\varsigma = r + \varepsilon$, where $\varepsilon \sim N(0, \beta^{-1})$ and $f(\varsigma) = \exp\left[-(\varsigma - r)^2 / (2\beta^{-2})\right] / \left(\sqrt{2\pi}\beta^{-1}\right)$. Due to perfect information sharing all informed investors form uniform beliefs about the actual issue valuation on aggregate; however, we rule out information extraction by means of simple cross-reporting (Crémer and McLean, 1988).[25] Informed investors adjust their beliefs ς about realisation r with non-decreasing contractual repayment $c(r)$ to the weighted measure[26] $s = (\alpha \tilde{r} + \beta \varsigma)/(\alpha + \beta)$ with $s \in S \equiv [0,1]$.[27] They have an incentive to participate only if the noisy signal ς of private information is sufficiently accurate, so that precision measure $\gamma = \left(\alpha^2 (\alpha + \beta)\right) / \beta(\alpha + 2\beta)$ of the private signal received by informed investors satisfies $\gamma \leq 2\pi$ (see section 5.2). The precision also indicates the degree of valuation uncertainty.

Our design problem maximises issuer payoffs contingent on an efficient rule of action, which prescribes a particular allocation preference of informed investors with belief s to obtain positive payoffs for a given price-quantity schedule. Informed investors request some allocation $0 \leq q(s) \leq 1$ if and only if the fixed price-quantity schedule of general property $p(s) = q(s)^a$ $(0 \leq a \leq 1)$ implied

[23] This superior capability of interpreting the investment risk of securitised exposures in a more informative way could be interpreted in several ways. Informed investment by large brokerage firms or other financial institutions with expert knowledge, either within or outside the issuer's industry, could stem from their own expertise in originating and monitoring credit risk and structured risk (i.e. market and asset liquidity, interest and currency volatility as well as organisational risk of asymmetric information in lending relationships), such as credit risk analysis (Boot and Thakor, 2000). Similarly, Inderst and Müller (2002) suggest that also gathering new information about macroeconomic facts, such as market growth and product demand, effecting the outcome of issue performance might help improve the accuracy of risk assessment. Both arguments indicate that informed investors are able to extract private information about the actual issue quality and update their beliefs accordingly.

[24] Inderst and Müller (2002) point out two prime inefficiencies associated with the information production through noisy signals: (i) misclassification of the actual valuation r, so that the action of informed investment after observing signal s would constitute either overpriced investment or forgone profitable investment; and (ii) mismatch of actual efforts taken by informed investors and required effort level for appropriate risk analysis (Manove et al., 2001). In order to remedy these inefficiencies, for simplicity we consider (i) the information content of the signal fixed and (ii) the effort of risk analysis essentially costless (instead of the proposition of a marginal cost associated with the signal).

[25] In contrast, uninformed investors behave quasi-atomistically, so their allocation implies forgone informed investment, given sufficient availability of investment funds by both categories of investors.

[26] Assuming that uncertainty about the valuation r would otherwise eliminate private signals ς unless they were sufficiently precise, informed investors adjust their subjective beliefs ς about the expected returns by the degree of perceived accuracy of private information.

[27] The acceptance set of adjusted beliefs for profitable informed investment is adapted from the work by Morris and Shin (2000) on the indeterminacy of beliefs as a source of co-ordination failure. Their model of bank runs is based on a Bayes Nash equilibrium of an imperfect information game. In our case, we treat each realisation of perceived valuation as a continuum of varying investment decisions by informed investors in a one-shot game.

by an auction-style allocation preference as a continuous function of perceived issue quality yields profitable investment $E(c(r)|s) > p(s)$, where $0 \leq \underline{r} < p(s)$ and $\underline{\theta} > \overline{r}$. The acceptance set of allocation choices associated with profitable informed investment formalises a *direct revelation mechanism* (DRM). The issuer allocates the residual portion of the transaction to uninformed investors at the same (i.e. uniform) or a higher (i.e. discriminate) offering price. Uninformed investors are unaware of the realisation of both *r* and θ. If the uniformed price is still lower than fair market price, passive uninformed investment demand clears the market.[28] We attribute no additional function to uninformed investors. If informed investors do not appropriate any profit for a given issue quality, they refrain from disclosing information about actual issue quality through an acceptable allocation level. Without allocation to informed investors, everybody receives zero payoffs.[29] Hence, our issue design model relies on efficient allocation as the only strategic choice variable to (i) maximise issuer payoffs under optimal information extraction from informed investors and (ii) ensure their as price setters of uninformed investment demand.[30]

5 OPTIMAL ISSUING PROCESS AND ALLOCATION

Our basic model framework of optimal security issuance relies on the conventional allocation-based argument of IPO underpricing due to asymmetric information between issuers and investors in keeping with the "winner's curse" problem (Rock, 1986). However, our approach goes beyond the rationing of uninformed investors as the main determinant of underpricing. In a general auction-style design, we maximise issuer proceeds conditional on price discounting needed to guarantee profitable informed investment over a positive measure of issue quality for a given degree of valuation uncertainty about securitised assets reflected in the composition of the investor pool. In extension to

[28] This issue process requires waiting to be the dominant strategy of uninformed investors if the appellation of being informed is limited only to those investors who can adjust their beliefs about actual issue quality based on the realisation of signal ς. So no uninformed can pretend to be informed by definition.

[29] Since any allocation of claims will only take place if informed investors decide to participate, all poor transactions are singled out through this direct revelation mechanism, and, hence, have no effect on the optimal allocation and pricing schedule of the issuing process. This implies that issuers would not be able to solicit any investment demand unless a true market valuation (as some "seal of approval") has been sought from informed investors. Ruling out investment in poor securitisation transactions with a negative signal denies any partial or full issuance prior to risk assessment (with the resultant formation of investor beliefs) and indirect information disclosure through informed investment demand. In this case the offering price would need to be regarded as a sunk cost, so that the investment choice of informed investors could be solved trivially for the first best outcome without repayment playing a role. Hence, we confine the feasible states of issuing a securitisation transaction to a continuous range of positive measures of issue quality with positive signals only. Hence, we confine the feasible states of issuing a securitisation transaction to a continuous range of positive measures of issue quality with positive signals only.

[30] Only the proportion of informed investment is common knowledge, and both types of investors have sufficient funds on aggregate to theoretically buy the entire transaction.

the "winner's curse" problem, we derive a sustainable equilibrium solution for an optimal issuing process with endogenous price discovery, in which the allocation choice satisfies informed investment demand as a continuous function of perceived issue quality. At the same time, issuers are able to extract maximum surplus from informed investors in a *direct revelation mechanism* (DRM).

Before we present an auction-style allocation choice to derive maximum issuer payoffs under uniform and discriminatory pricing, we solve the optimisation problem of informed investors within an efficient acceptance set of adjusted beliefs about actual issue quality (see section 5.2), which prescribes a profile of profitable allocation choices at a fixed price-quantity schedule. We firs derive expected issuer returns under uniform and discriminatory pricing if informed investors were granted optimal allocation (see section 5.3). Then we introduce an auction-style allocation preference as a continuous function of perceived issue quality within the acceptance set of profitable informed investment, which allows issuers to maximise own payoffs by extracting information surplus from price discovery through DRM by informed investors (Malakhov, 2003; Myerson, 1981) (see section 5.4). Let us now revisit the fundamental rationale of the Rock IPO model, before we derive the acceptance set of optimal informed investment and an allocation schedule under DRM, which maximises profitable informed investment at a fixed price-quantity schedule.

5.1 The Rock (1986) model revisited

The aforementioned *ex ante* rationing problem of uninformed investors for an issuing process of "good deals" at a fixed price offering equates to the widely known "winner's curse" problem of IPOs in equity markets. According to Rock (1986), less privileged investors are crowded out by investors with superior information about the true value of the issue, who would only invest if shares priced at their expected value or lower, else they withdraw from the market in response to an observed bad quality of the IPO shares. This argument explains why issuers would need to discount uniform offering price below fair market value in order to compensate uniformed investors for a "lemons problem" (Akerlof, 1970) of share allocation. Most shares allocated to uninformed issuers are "overpriced" compared to shares desired by informed investors. So underpricing accommodates the rational expectation that a disproportionately large share of "bad deals" are allocated to uninformed investment demand. Uninformed investors receive a full allocation of all shares only for overpriced issues (with informed investment being limited to "good deals"). A simplified version of the Rock model in Biais et al. (2002) conveys the essence of the "winner's curse" dilemma of issuers.[31,32]

[31] In line with Rock (1986) an issuer offers a total number of shares at uniform price p, where all informed investors (with individually varying quantity orders) demand at most I shares, whilst each of θ uninformed

5.2 Optimisation problem of informed investors

Since price discovery in our DRM is contingent on profitable informed investment, we first derive the acceptance set of allocation choices that generate positive net payoffs at a fixed price-quantity schedule for eligible (i.e. sufficiently precise) beliefs about actual issue quality. At this stage we represent uniform informed investment demand by *one* informed investor. Informed investor belief s about the true issue quality is associated with an absolutely continuous distribution function $G_s(r)$ of valuation $r \in \mathrm{R}$ with positive conditional density $g_s(r) > 0$ continuous in the interior of S, where $g_{s'}(r)/g_s(r)$ strictly increases for all $r \in \mathrm{R}$, given any pair of signals $(s, s') \in \Omega(s)$ with $s' > s$ [*Monotone Likelihood Ratio Property* (MLRP)]. The conditional and unconditional expected return of the issue at valuation r is defined as $\mu_s = \int_{\mathrm{R}} r g_s(r) dr$ and $\int_S f(s) g_s(r) ds$ respectively. Given a repayment contract[33] $c(r)$ with $f(c) > 0$, we re-specify expected investor return as

$$u_s(r) = \int_{\mathrm{R}} c(r) g_s(r) dr. \tag{1}$$

buyers are allocated at most one share. This assumption reflects allocative benefits associated with better information about the actual issue quality, where only individual allocation of shares to uninformed investors matters to model an optimal allocation schedule in the presence of investor rationing. Informed investors request I shares on aggregate if the IPO is a "good deal", i.e. the market valuation v of the issue is larger than the offering price p. If $v < p$ informed investors abstain from investing and leave all shares to uninformed investors. Consequently, higher overall informed demand and associated rationing of investors for "good deals" results in a "winner's curse problem" – uninformed investors receive a disproportionately large amount of shares in "bad deals" if their bids are successful. Hence, uninformed investors would expect a "price discount" proportional to the rationing rate, so that $\pi_U = E[\tau(v - p)] > 0$, where the rationing rate $\tau = 1/(I + \theta)$ if $v > p$, else $\tau = 1/\theta$. Since the covariance of τ and v is positive, it follows that $E(v) > p$.

[32] Note that the participation incentive of informed investors to engage in information production represents a call option on the actual value of the IPO, which they will only exercise (by requesting shares in the IPO) if the underlying expected value exceeds the offering price (as strike price). The value of the option held by informed investors increases with valuation uncertainty. More investors become informed as higher information asymmetry between issuers and investors increases the option value, which exacerbates the "winner's curse problem". Higher uncertainty also implies that a declining fraction of uninformed investors suffers from higher chances of being allocated a disproportionately large amount of shares in "bad deals". Empirical evidence of IPOs suggests that the degree of asymmetry seems to be correlated with the size of the issue. The larger the issue the higher the chances of professional management and transparency, so more information about the true valuation reduces the degree of asymmetric information.

[33] Fractional repayment arises if issuers retain some expected return ("first loss provision"/"credit enhancement") as a positive effort choice to guarantee residual claims over and above full payment on issued securities. We follow the credit decision approach by Maskin and Tirole (1990 and 1992) in modelling the specification of the overall repayment level to investors.

If the noisy signal ς is deemed to be sufficiently precise, informed investors would only request an allocation $0 \le q(s) \le 1$ as a continuous function of updated investor beliefs s, where the associated offering price implies positive payoff for $p(s) \le u_s(r)$, which is binding at the optimum.[34] In order to devise a rule of action for optimal informed investment, we need to specify a lower bound of informed investor belief s with associated conditional investor payoff $u_s(r)$ to yield profitable investment.

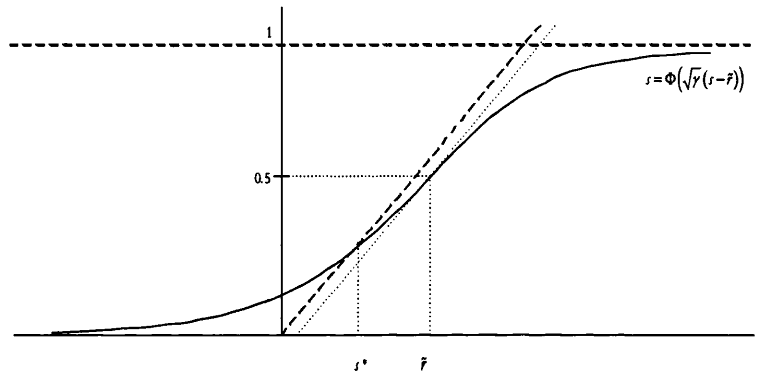

Fig 1. *Cumulative distribution function of updated investor beliefs.*

Informed investors adjust their beliefs about the realisation r with contractual repayment $c(r)$ to the weighted measure $s = (\alpha\tilde{r} + \beta\varsigma)/(\alpha + \beta)$ with $s \in S \equiv [0,1]$ upon observing noisy signal ς. The distribution functions $F(s)$ and $F(\varsigma)$ with $f(s) > 0$ and $f(\varsigma) > 0$ are absolutely continuous and common knowledge. Informed investors consider ς sufficiently accurate only if precision measure $\gamma = (\alpha^2(\alpha+\beta))/\beta(\alpha+2\beta)$ of (weighted) signal s is small enough to satisfy $\gamma \le 2\pi$ and meet the critical value $s^* = \Phi\left(\sqrt{\gamma}(s^* - \tilde{r})\right)$, where $\Phi(.)$ denotes a standard normal distribution.[35] Higher precision (at a low γ) reflects lower valuation uncertainty of informed investor belief s about the realisation of r. The critical level s^* (see Fig. 1) is obtained at the intersection of $\Phi(.)$ with the 45

[34] This specification restricts the specification of repayment in Inderst and Müller (2002), where informed investment maximise gross payoff for a menu $m \in M$ of possible repayment contracts $c_m(r) \in C$, to a single repayment contract. In keeping with Innes (1990) as well as Marzo and Duffie (1999) we assume that repayment is non-decreasing in investment returns. In lending relationships borrowers could realise *ex post* arbitrage gains by borrowing cash to boost expected future cash flows and qualify for some lending criteria if contractual repayment generated from an investment project was to decrease over some subset of realised project payoffs (Innes, 1990).

[35] In this set-up we ignore the co-ordination problem of several agents in Morris and Shin (2000).

degree line, which divides the indeterminate region $[0,1]$ around its mid point. The critical level s^* diverges to the left of expected $\tilde{r}$ the less precise the signal. Conversely, if the signal becomes less noisy, s^* approximates $\tilde{r}$ at $\Phi(.) = 0.5$. As noise becomes negligible in the limit, the curve of $\Phi(.)$ flattens out, and γ and s^* tend to zero and 0.5 respectively. Once signal $s > s^*$ passes muster as sufficiently precise private information, informed investors consider a profitable allocation level that satisfies $u_s(r) \geq p(s)$. At s^* the utility of private information from noisy signal ς is zero and non-random. The expectation of *r* is only conditional on s^*, which is s^* itself. Since noise β of signal ς is independent of *r*, informed investor are uniformly indifferent at s^* in expectation of valuation *r*.

Since all eligible signals $s > s^* \in S$ of sufficient precision belong to the absolutely continuous distribution function $G_s(r)$ and each allocation level is subject to a fixed price-quantity schedule with the general property $p(s) = q(s)^a \quad (0 \leq a \leq 1)$, by monotonicity we obtain an optimisation problem with a simple crossing property and an unconstrained maximum. Provided that informed investors only disclose their private information if their allocation generates positive net payoff, we define two cases of the relationship between (implied) offering price and expected investment return: $u_s(r) < p(s)$ and $u_s(r) \geq p(s)$, which rules out the trivial case of either positive or negative signals for all levels of adjusted investor beliefs s about valuation $r \in \mathrm{R}$. Since we assume the margin of indifference to divulge private information to be a zero-probability event, we include the case $u_s(r) = p(s)$ of zero payoffs from informed investment in the acceptance set as boundary condition. Note that the repayment level restricts the acceptance set of profitable informed investment.[36]

Lemma. *The acceptance set of informed investors for repayment c(r) is defined by* $\Omega(s) \equiv \{ s \in S \,|\, s \geq s^* \wedge s \geq \underline{s} \text{ s.t. } u_s(r) \geq p(s) \} \subseteq S$ *with cut-off signal* $\underline{s} \in [0,1]$ *with zero profit from informed investment at* $u_{\underline{s}}(r) = p(\underline{s})$. *Unless* $u_s(r) < p(s)$ *with* $\underline{s} = 1$, $\underline{s} \geq s^*$ *is unique and informed investment occurs for all* $s \geq \underline{s} \geq s^* > 0$.

[36] With full repayment (i.e. no restriction on conditional return from valuation *r* by some repayment contract), we would need to distinguish the less restrictive conditions $\mu_s < p(s)$ and $\mu_s > p(s)$. This consideration reflects the repayment choice in securitisation – the lower the quality of securitised assets, the higher the level of required credit support as reservation utility and the lower repayment from the realised portfolio value as higher expected default reduces expected returns from the securitised asset pool.

Based on Lemma, we can derive the net payoff from optimal informed investment for allocation choice $q(s)$ and conditional return $u_s(r)$ with $g_s(r)>0$ for each belief s within the acceptance set $\Omega(s)$. Informed investors derive the first best solution of their optimisation problem by requesting allocation $0 \leq q_I(s) \leq 1$ for payment of offering price $p_I(s)$, which maximises the concave objective function

$$U(s)_I = \max_{q(s)} \int_{\Omega(s)} q_I(s)\left(u_s(r) - p_I(s)\right) f(s)\, ds, \tag{2}$$

where the optimal allocation choice $q_I^*(s) = \sqrt[a]{u_s(r)/(a+1)}$ implies $p_I^*(s) = q_I^*(s)^a = u_s(r)/(a+1)$ under the general property of a fixed price-quantity schedule. Note that non-decreasing repayment $c(r)$ yields surplus $\int_{\Omega(s)} q_I^*(s)\left(\mu_s - u_s(r)\right) f(s)\, ds$ as reservation utility from $\int_{\Omega(s)} q_I^*(s)\left(\mu_s - p_I^*(s)\right) f(s)\, ds$ before repayment at valuation r. Since informed investors optimise net payoff $U(s) \geq 0$ over acceptance set $\Omega(s)$ the probability of profitable informed investment for all eligible private signals is illustrated as the area indicated by $\Pr\left[U(s) \geq 0\right]$ for $s > s^*$ in Fig. 2 as the subset of distribution function $F(c(r))$ and $F(s)$ of expected conditional return and adjusted belief. Hence, this probability measure reflects the chances of private information about the actual issue to be sufficiently accurate for consideration of profitable investment within acceptance set $\Omega(s)$ in Lemma. We will revisit this interim observation at a later stage of our analysis (see section 5.4) when we were to represent issuer payoff over the entire range of $r \in [0,1]$.

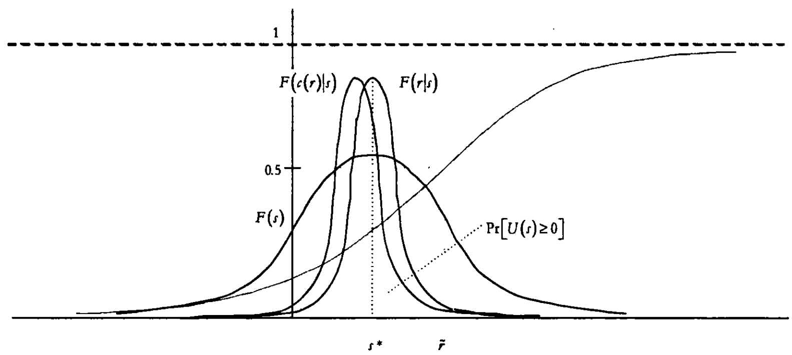

Fig 2. *Probability of profitable informed investment given updated investor belief.*

5.3 Issuer payoffs under optimal informed investment

For illustrative purposes, we first determine issuer payoffs for our issue design problem with price discovery of first-best informed investment at optimal allocation $q_I^*(s)$ within the acceptance set under *uniform* and *discriminatory* pricing,[37] with informed investors acting as price setters for uninformed investment demand. Under *uniform* pricing, both informed and uninformed investors pay the same offering price, which creates straightforward incentive compatibility. All investors obtain positive payoff with certainty, with uninformed investors being rationed at a rate of $\tau = 1/\left(q_I^*(s)+\theta\right)$. With total issue volume set to unity, complete allocation at uniform price $p_I^*(s)$ generates issuer payoff

$$E(\Pi)_U = \int_{\Omega(s)} p_I^*(s) f(s)\,ds = \int_{\Omega(s)} \left(u_s(r)/(a+1)\right) f(s)\,ds \underset{a\to 0}{=} \int_{\Omega(s)} u_s(r) f(s)\,ds\,, \tag{3}$$

where informed investors obtain $U(s)_I$ in (2). Since the remainder, $1-q_I^*(s)$, is tendered to uninformed investors at the same offering price to clear the market, they each receive expected net payoff

$$U(s)_U = \frac{1}{\theta}\int_{\Omega(s)} \left(1-q_I^*(s)\right)\left(u_s(r)-p_I^*(s)\right) f(s)\,ds\,. \tag{4}$$

Issuers can increase their expected issue payoff $E(\Pi)_U$ through a minimum allocation of claims at a slightly discounted offering price within acceptance set $\Omega(s)$. A low value of $u_s(r)$ further limits the absolute measure of underpricing. However, uniform pricing could weaken incentives of informed investors to engage in price discovery for an efficient allocation choice, as net payoff $U(s)_I$ of informed investors might even be smaller than individual payoff $U(s)_U$ of uninformed investors at high valuation uncertainty. If $\left(1-q_I^*(s)\right)/\theta \geq q_I^*(s) \Leftrightarrow \theta \leq \left(1-q_I^*(s)\right)/q_I^*(s)$ informed

[37] Note that by restricting ourselves to solving the design problem for maximum informed investor payoff, we deliberately disregard valuation uncertainty and the associated composition of the investment demand as a determinant of the optimal allocation choice by the issuer to achieve a sustainable equilibrium outcome.

investors[38] may choose to misrepresent their type for a given expected conditional return $u_s(r)$. Only a high incidence of uninformed investors associated with low valuation uncertainty preserves informed investment demand for efficient allocation choices in $\Omega(s)$ under uniform pricing.

Note that higher valuation uncertainty is reflected in lower precision (i.e. a high γ measure, see section 5.2) of informed investor belief s about the realisation of r, which decreases acceptance set $\Omega(s)$ of Lemma. If $U(s)_I$ were to be kept constant, a higher allocation $q_I^*(s)$ associated with a smaller range of profitable allocation choices leaves a smaller residual allocation $1-q_I^*(s)$ to uninformed investors θ. Since uninformed investors are limited to one share each, higher rationing at lower $\tau = 1/\left(q_I^*(s)+\theta\right)$ leaves a smaller number of uninformed investors θ in the investor pool, who might possibly claim $U(s)_U \geq U(s)_I$.[39]

Proposition 1 [Valuation uncertainty and acceptance set]. *Lower valuation uncertainty increases the acceptance set $\Omega(s)$ and decreases both the optimal allocation to informed investors and underpricing. Lower (higher) valuation uncertainty also implies a higher (lower) incidence of uninformed investors.*

Proposition 2 [Uniform pricing]. *Under uniform pricing the issuer extracts most informed investor surplus by keeping the perceived valuation and valuation uncertainty as low as possible within acceptance set $\Omega(s)$ according to Proposition 1, while preventing misrepresentation by informed investors.*

Alternatively, issuers might have discretion in tendering the residual allocation to uninformed investors at an offering price higher than the offering price $p_I^*(s)$ implied by a first-best allocation to informed investors. Since both types of investors act independently, *discriminatory* pricing allows the issuer to extract more surplus from investors, while eliminating the danger of misrepresentation by informed investors. Discriminatory pricing can satisfy the incentive compatibility constraint $U(s)_I \geq U(s)_U$ invariant to the incidence of uninformed investors. The issuer allocates the

[38] For the determination of this threshold of uninformed investment demand, we maintain the assumption of uniform informed investment behaviour, such that our comparative statics are only influenced by the number of informed investors in relation to positive net payoffs from investment.

[39] At the same time, we could also argue this aspect from the perspective of underpricing in line with the IPO underpricing model by Rock (1986). Valuation uncertainty represents an (implicit) "outside option", where uninformed issuers would expect higher underpricing associated with a higher rationing rate for higher levels of valuation uncertainty, which increases the option value. Lower valuation uncertainty implies higher levels of

proportion $0 \leq q_I^*(s) \leq 1$ of the issue to informed investors at price $p_I^*(s)$. The remainder $q_U(s) \leq 1 - q_I^*(s)$ is offered to uninformed investors to clear the market. The maximum offering price $p_U(s)$ the issuer can charge to uninformed investors is

$$p_U^*(s) = \max\left\{ p_I^*(s), u_s(r) - \frac{q_I^*(s)}{q_U(s)}\left(u_s(r) - p_I^*(s)\right)\theta\eta \right\}, \tag{5}$$

which solves inequality

$$\eta U(s)_I \geq U(s)_U \Leftrightarrow \eta \int_{\Omega(s)} q_I^*(s)\left(u_s(r) - p_I^*(s)\right) f(s)\,ds \geq \frac{1}{\theta}\int_{\Omega(s)} q_U(s)\left(u_s(r) - p_U(s)\right) f(s)\,ds, \tag{6}$$

where fraction $0 < \eta \leq 1$ denotes the multiple of the payoff received by all informed investors at allocation $q_I^*(s)$ to the maximum net payoff of each uninformed investor at allocation $q_U(s) \leq 1 - q_I^*(s)$. The measure η becomes binding if informed investors expect η-times higher informed payoff than individual uninformed investment payoff, which requires $\partial\theta/\partial\eta = -1$. Thus, expected issuer payoff under discriminatory pricing would be

$$E(\Pi)_D = \int_{\Omega(s)} p_I^*(s) f(s)\,ds + \int_{\Omega(s)} q_U(s)\left(p_U^*(s) - p_I^*(s)\right) f(s)\,ds \underset{\substack{a \to 0,\\ q_U(s) = 1 - q_I^*(s)}}{=} \int_{\Omega(s)} u_s(r) f(s)\,ds \tag{7}$$

Proof of equation (7). *See Appendix.*

Since $p_U^*(s) \geq p_I^*(s)$, the issuer could extract more surplus from uninformed investors, so that expected issuer gross payoffs under discriminatory pricing satisfies

$$E(\Pi)_D \geq E(\Pi)_U \Leftrightarrow \int_{\Omega(s)} \underbrace{\left[(1+a) - \sqrt[a]{\frac{u_s(r)}{1+a}}\left(2 + a(1 - \theta\eta)\right)\right]}_{\geq 1} u_s(r) f(s)\,ds \geq \int_{\Omega(s)} u_s(r) f(s)\,ds, \tag{8}$$

within the range for all $0 \leq a \leq 0$. Only in the limit of $a \to 0$, when the selling price equals unity, would issuers be indifferent between both pricing regimes.

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market information about the true issue quality and lower discounting of the uniform offering price as

Proposition 3 [Discriminatory pricing]. *Discriminatory pricing allows issuers to charge uninformed investors a higher offering price than informed investors to achieve separation. Higher relative payoff of informed investors (regardless of the degree of uninformed investment demand by Proposition 1) completely eliminates the incentive of misrepresentation. The issuer extracts most informed investor surplus by keeping the valuation as low as possible within acceptance set* $\Omega(s)$.

5.4 Optimal allocation for maximum issuer payoffs

The ability of issuers to achieve complete allocation within acceptance set $\Omega(s)$ of profitable informed investment under different pricing regimes indicates the importance of the incidence of investor types in our issue design problem. However, the residual allocation to uninformed investors and the incentive of informed investors to participate in DRM at any issue quality – as long as some allocation yields positive payoff – curtail the ability of informed investors to optimise own payoffs by disclosing their beliefs. So far, we have not recognised the allocation level as a strategic choice variable of issuers. In the following section we derive the conditions for maximum expected issuer payoffs in an auction-style issuing process under uniform and discriminatory pricing, where the issuer's allocation choice satisfies the acceptance set $\Omega(s)$. In line with the general notion of a fixed price-quantity schedule in the previous section, we now derive the offering price from an auction-style allocation choice of informed investors as a continuous function of adjusted beliefs about the actual issue quality. We also assume multiple informed investors to compare individual investor payoffs similar to our approach in section 5.3.

Under *discriminatory* pricing issuers discount their allocation to informed investors and solve the allocation choice for optimal (gross) payoffs by offering the residual allocation to uninformed investors at a fair (market) price. This implies zero net payoffs from uninformed investment while completely denying informed investors incentives of misrepresenting themselves as uninformed types. Since the issue mechanism depends on the participation of informed investors for an allocation choice within the acceptance set $\Omega(s)$, the issuer chooses to discount the issue for $p(s) < u_s(r)$ at unit offering price $p(s)/q(s)$ and acceptable allocation $0 \leq q(s) \leq 1$ according to

uninformed investors would assume lower chances of being outsmarted by informed investors.

the fixed price-quantity schedule.[40] In extension to the previous section, we model the allocation choice as a continuos function of investor beliefs about the true issue quality to represent the fixed price-quantity schedule. The remainder $1-q(s)$ is tendered to all uninformed investors at the offering price $p(s)=u_s(r)$, so that

$$\begin{aligned} E(\Pi)_D &= \max_{p(s),q(s)} \int_{\Omega(s)} \left(\frac{p(s)}{q(s)} q(s) + u_s(r)\left(1-q(s)\right) \right) f(s)\,ds \\ &= \max_{p(s),q(s)} \int_{\Omega(s)} \left(p(s) + u_s(r)\left(1-q(s)\right)\right) f(s)\,ds. \end{aligned} \tag{9}$$

Under *uniform* pricing the issuer offers the same selling price to both types of investors at individual allocation rates of $q(s)/I$ and $\left(1-q(s)\right)/\theta$ respectively to maximise expected payoff

$$E(\Pi)_U = \max_{q(s),p(s)} \int_{\Omega(s)} \left(\frac{p(s)}{q(s)} q(s) + \frac{p(s)}{q(s)}\left(1-q(s)\right) \right) f(s)\,ds = \max_{q(s),p(s)} \int_{\Omega(s)} \frac{p(s)}{q(s)} f(s)\,ds. \tag{10}$$ [41]

We solve the above optimisation problem in (9) and (10) for both pricing regimes by means of a DRM auction model adapted from Myerson (1981), where the issuer maximises own payoffs over a positive measure of issue quality through an allocation choice within an acceptance set of profitable informed investment. Each allocation level of the acceptance set relies on a fixed price-quantity schedule implied by an auction-style allocation preference as a continuous function of perceived issue quality. This implies an offering price that satisfies the following participation and incentive constraints:

$$U(s)_I \geq 0 \Leftrightarrow q(s)\left(u_s(r) - \frac{p(s)}{q(s)} \right) = q(s)u_s(r) - p(s) \geq 0 \tag{PC}$$

$$q(s)u_s(r) - p(s) \geq q(\hat{s})u_s(r) - p(\hat{s}) \quad \forall s,\hat{s},r \tag{IC$_1$}$$

[40] The variables $p(s)$ and $q(s)$ are used as shorthand to denote the offering price and the allocation to informed investors. For simplicity we drop the index for the investor type from the notation in the remainder of the chapter, as the allocation to uninformed investors is not a strategic parameter choice and follows from the price-quantity schedule of informed investors.

$$U(s)_I \geq U(s)_U \Leftrightarrow u_s(r)\frac{q(s)}{I} - \frac{p(s)}{q(s)} \geq u_s(r)\frac{1-q(s)}{\theta} - \frac{p(s)}{q(s)}$$

$$\Leftrightarrow q(s) \geq \frac{I(1-q(s))}{\theta} \Leftrightarrow 1 \geq q(s) \geq \frac{I}{I+\theta}, \qquad \text{(IC}_2\text{)}$$

where $g_s(r) > 0$ is strictly continuous. IC₂ applies only to uniform pricing, ensuring that the proposed allocation-based direct information revelation awards informed investors higher individual net payoff.[42] We consider the allocation choice $q(s)$ a continuous function of investor belief $s \in \Omega(s)$. From rewriting IC₁ and PC above (see Proof Theorem 1) we obtain an alternative definition of non-decreasing and absolutely continuous $U(s)_I \geq 0$ with $U'(s)_I = q(s)$

$$U(s)_I = U(\underline{s})_I + \int_{\Omega(s)} q(s) ds. \qquad (11)$$

Combining PC and (11) with $U(\underline{s})_I = 0$ (see Lemma) yields the "allocation-based" offering price

$$p(s) = q(s)u_s(r) - \int_{\Omega(s)} q(s) ds, \qquad (12)$$

Theorem 1 and 2 follow from substituting (12) in equations (9) and (10) respectively.

---

[41] Note that if we wanted to represent issuer payoff over the entire range of $r \in [0,1]$, we would need to adjust our maximisation problem by the probability of informed investment to occur (see section 5.2).

[42] IC_2 implies a higher (lower) allocation to informed investors in response to a higher (lower) number of informed investors relative to the number of informed investors associated with high (low) uncertainty. For efficient price discovery under uniform pricing, knowledge about θ (as a determinant of the allocation schedule) registers as a critical factor. We know from section 4 that only the distribution of uninformed types is commonly known. However, if informed investors could estimate θ valuation uncertainty, issuer payoffs would decrease in the precision of investor knowledge about θ as IC_2 would become more restrictive. The lack of information about the presence of uninformed investors adds inefficiency to the maximisation problem of issuers in Theorem 2 (see section 5.4). Chances are that informed investors would be more inclined to misrepresent themselves under uniform pricing unless they can claim higher net payoffs as they refine their investment decision. Given a precision measure $\gamma \in \Gamma$ from absolutely continuous $F(\gamma)$ with $f(\gamma) > 0$, informed investors might infer the realisation of uninformed investment $\theta \in \Psi \equiv [\underline{\theta}, \overline{\theta}]$ from the accuracy of their noisy signal ς. Conditioning $F(\gamma)$ on $g_\gamma(\theta) > 0$ yields the conditional number of uninformed as $E_\gamma(\theta) = \int_\Psi \theta g_\gamma(\theta) d\theta$, with the unconditional number of uninformed investors $E_\gamma(\theta) = \int_0^{2\pi} f(\gamma) g_\gamma(\theta) d\gamma$. In keeping with MLRP any pair $(\gamma, \gamma') \in \Gamma$ with $\gamma' > \gamma$ the ratio $g_{\gamma'}(\theta)/g_\gamma(\theta)$ is strictly increasing in θ for all $\theta \in \Psi$.

Theorem 1 [Discriminatory pricing]. *The issuer maximises own payoff under discriminatory pricing by solving* $\max_{q(s)} \int_{\Omega(s)} \left(u_s(r) - \int_{\Omega(s)} q(s)\,ds \right) f(s)ds$ *for* $s \in \Omega(s)$, *where* $0 \le q(s) \le 1$ *is non-decreasing.*

Proof of Theorem 1. *See Appendix.*

Theorem 2 [Uniform pricing]. *The issuer maximises own payoff under uniform pricing by solving* $\max_{q(s),p(s)} \int_{\Omega(s)} \left(u_s(r) - \int_{\Omega(s)} q(s)ds \Big/ q(s) \right) f(s)\,ds$ *for* $s \in \Omega(s)$, *where allocation* $q(s) \in \left[I/(I+\theta), 1 \right]$ *is non-decreasing.*

Proof of Theorem 2. *See Appendix.*

The issuer can mitigate underpricing and optimise the proposed issue design at the lowest possible allocation $q(s)$ to informed investors within acceptance set $\Omega(s)$. We now derive the optimal range of allocation choices to maximise issuer payoff, with some underpricing required for profitable participation based on their private information about actual issue quality.

Corollary 1 [Discriminatory pricing]. *Under discriminatory pricing and full allocation the issuer can extract investor surplus only up to* $E(\Pi)_D \equiv \max_{q(s)} \int_{\Omega(s)} \left(u_s(r) - \int_{\Omega(s)} q(s)\,ds \right) f(s)ds \ge \int_{\Omega(s)} u_s(r) f(s)\,ds - \varepsilon$, *which implies allocation* $q_\varepsilon(s) \in \left[\sqrt[3]{6\varepsilon}, 1 \right]$ *to satisfy informed investment demand according to Lemma at discount* $\varepsilon > 0$.

Proof of Corollary 1. *See Appendix.*

Corollary 2 [Uniform pricing]. *Under uniform pricing and full allocation the issuer can extract investor surplus only up to* $E(\Pi)_U \equiv \max_{q(s),p(s)} \int_{\Omega(s)} \left(u_s(r) - \int_{\Omega(s)} q(s)ds \Big/ q(s) \right) f(s)\,ds \ge \int_{\Omega(s)} u_s(r) f(s)\,ds - \varphi$ *s.t.* $1 - q(s) \le \theta/(I+\theta)$, *which implies allocation* $q_\varepsilon(s) \in \left[\sqrt[3]{6I/(I+\theta)}, 1 \right]$ *to satisfy informed investment demand according to Lemma at discount to* $\varphi > 0$.

Proof of Corollary 2. *See Appendix.*

Corollary 1 verifies previous findings about higher sustainability of the proposed issue design under price discrimination, when only little allocation to informed investors suffices to induce price discovery by informed investors through an allocation preference and overall investor surplus ε invariant to uninformed investment demand. *Discriminatory* pricing allows issuers to extract the most investor surplus from informed investors, who might otherwise misrepresent themselves as uninformed types if $p(s) = p_U(s) \leq u_s(r)$ under *uniform* pricing. This case requires a lower (higher) incidence of uninformed investors associated with a higher (lower) valuation uncertainty to coincide with a higher (lower) allocation to informed investors, so that each informed investor receives a higher individual payoff than uninformed investors (IC_2), given overall investor surplus φ. Corollary 2 shows that the optimal rule of action of the issuer in the case of uniform pricing prescribes an allocation choice based primarily on the incidence of types rather than the degree of underpricing (see also section 5.3).

6 DISCUSSION

In the course of the above analysis we saw that the prospect of informed investors to obtain positive payoffs from DRM-based disclosure of their private information about the true issue quality via allocation preference is fundamental to our issue design process. The acceptance set of profitable informed investment qualifies the optimal allocation schedule for maximum issuer payoffs from endogenous price discovery at varying degrees of valuation uncertainty and pricing regimes. Issuers maximise their payoffs over a positive measure of issue quality if the fixed price-quantity schedule implied by an auction-style allocation preference as a continuous function of perceived issue quality yields profitable informed investment. Moreover, a contractually predefined repayment level would restrict the acceptance set of perceived issue quality due to lower payoff to be appropriated by investors. We find that issuers would strictly prefer *discriminatory* over uniform pricing. Issuers can extract most surplus from informed investors as "truth tellers" by offering only marginal positive net payoff ("underpricing") through a certain allocation choice. The residual allocation to uninformed investors and the incentive of informed investors to subscribe to DRM at any issue quality – as long as some allocation yields positive payoff – curtails the ability of informed investors to optimise own payoffs from disclosing their beliefs. So uninformed investment demand implicitly strengthens the position of issuers to maximise their payoffs under any pricing regime. Under *uniform* pricing, price discovery by informed investors is only sustainable if both the incidence of investor types and the allocation choice translate into higher individual profit of each informed investor relative to uninformed investors. Informed investors require higher underpricing under uniform pricing to obtain higher relative payoffs than uninformed investors in return for private information disclosure.[43] Hence, uniform pricing generates (even) lower expected issuer payoffs than discriminatory pricing the higher the valuation uncertainty. Issuers would generally prefer a small (high) allocation to informed (uninformed) investors at low (high) valuation uncertainty to maximise own payoffs under either pricing regime. Again, the presence of uninformed investors, depending on the degree of valuation uncertainty contributes to the optimisation of issuer payoffs. The higher the incidence of uninformed investors, the lower the degree of underpricing due to the profitability constraint of informed investors under uniform pricing.

If we were to rule out price discrimination as a suitable pricing regime due to statutory provisions in securitisation markets, further analysis of our issue design model begs the question how the (strategic) allocation choice conditional on valuation uncertainty changes expected issuer payoffs under uniform pricing. Our preliminary findings in Corollary 1 and 2 suggest that *higher informed investment demand associated with more valuation uncertainty and higher perceived issue quality always reduces issuer payoffs* irrespective of the pricing regime – though the effect is larger under uniform pricing. We consider a numerical solution to illustrate optimal issuer payoffs under uniform pricing at varying allocation levels.

In Fig. 3 we approximate net issuer payoff under uniform pricing in a quasi-closed form solution of Theorem 2, where the allocation choice to informed investors for $U(s)_I{}' = q(s)$ (see section 5.4) is a continuous function of perceived issue quality for all $s \in \Omega(s)$ (see Lemma in section 5.2). We obtain conditional investment return $u_s(r)$ from repayment $c(r)$ at $s \in \Omega(s)$ by assuming the precision measure $\gamma \to 0$ (i.e. belief s becomes noiseless) to model how investor belief s translates into a corresponding realisation r according to MLRP of $G_s(r) > 0$ (see section 5.2). We set the discrete allocation level commensurate with the incidence of investors in accordance with $q(s) > I/(I+\theta)$ of IC$_2$. (see section 5.4) The cut-off signal is assumed to be $q(s) = \underline{s} = \{0.25; 0.5; 0.75\}$ for simplicity. The issuer retains a reservation utility in the form of credit enhancement so that constant repayment $c(r) = 0.9$. For illustrative purposes we also show net issuer payoff for full repayment, $c(r) = r$, at $q(s) = 0.25$ and cut-off signal $\underline{s} = 0.15$ (scaled to conditional expected return $u_s(r)$ on the x-axis of Fig. 3). As we traverse different degrees of

[43] This implies a low option value of informed investment from valuation uncertainty and a high precision of adjusted investor beliefs s at the limit $s \to \tilde{r}$.

valuation uncertainty – proxied by the minimum discrete allocation level $q(s)$ according to Theorem 2 (see section 5.4) – we find that optimal allocation to informed investors as a strategic choice variable to maximise issuer payoffs is contingent upon the valuation of conditional return $u_s(r)$. Once more informed investors participate at higher valuation uncertainty – so that only a high allocation $q(s)$ satisfies IC_2 – higher valuation will engender higher issuer payoff. Conversely, we maximise issuer payoff only if lower issue valuation entails a matching reduction in valuation uncertainty.

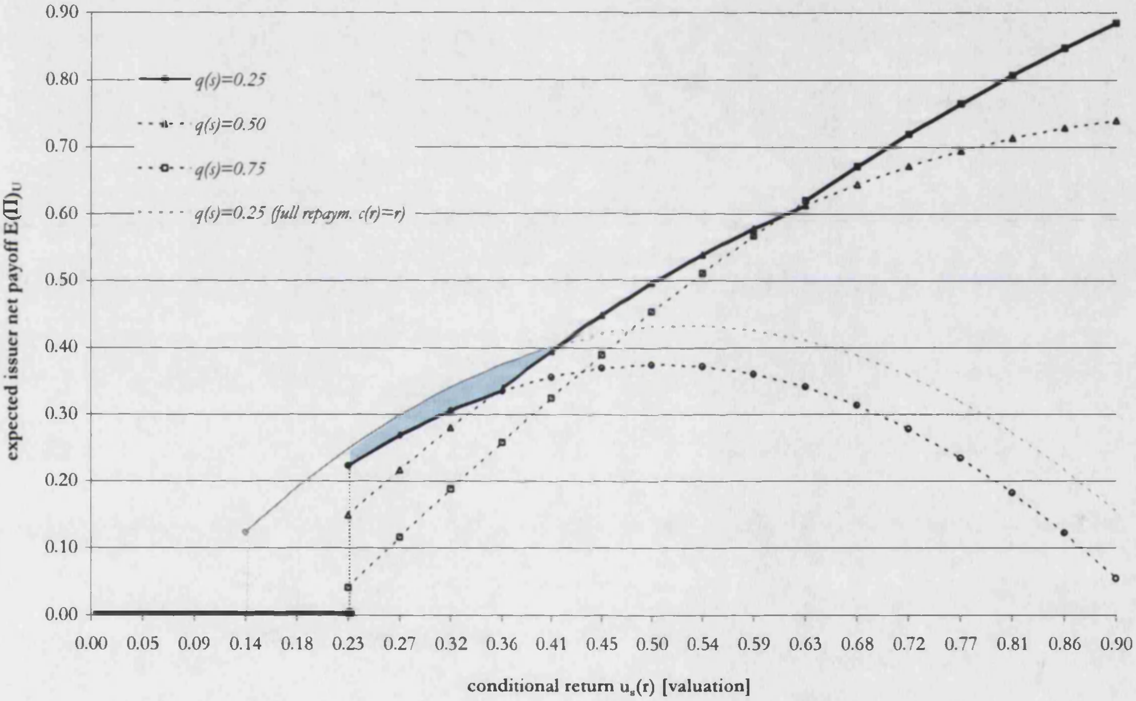

Fig. 3. *Approximated optimal issuer payoffs under uniform pricing at varying levels of valuation uncertainty.*

Fig. 3 represents optimal issue payoffs as an "efficient frontier" of deterministic allocation levels for given conditional expected return for all levels of issuer beliefs about actual issue quality. We derive a positively concave function as solution to the DRM design problem of issue payoffs if valuation uncertainty is continuous. The curvature is induced by continuous allocation preference $\int_{\Omega(s)} q(s)\,ds$ (see Proof of Theorem 1), which drains issuer profits as higher perceived issue quality increases informed investment demand in excess of $q(s)$. This situation follows the basic routine of our model. If the allocation choice is not commensurate to informed investment demand contingent on perceived issue quality, issuers cannot achieve optimal issue payoffs. We also observe that the reservation utility from partial repayment $c(r)$ limits the acceptance set $\Omega(s)$ of eligible perceived issue quality. Fig. 3 also shows the efficiency loss associated with forgone net issue payoffs due to the reservation utility from repayment $c(r)$ as the shaded area between the payoff curves at allocation $q(s)=0.25$ for full repayment r and repayment $c(r)$ respectively.

Both the comparative perspective of both pricing regimes and the graphical representation of issuer payoffs in Fig. 3 reveal two main insights into the mechanics of our model under uniform pricing. First, only high uninformed investment demand associated with low valuation uncertainty allows issuers to satisfy IC_2 at low valuation, while higher valuation uncertainty requires higher valuation for issuer payoff to remain the same. Second, we find that lower expected repayment facilitates higher valuation at lower (valuation) uncertainty to generate the same net issuer payoff.

7 CONCLUSION

Securitisation markets are marred by problems of asymmetric information between market makers with superior knowledge about securitised asset exposures and uninformed investment demand, where issuers frequently sound out a fair market price from sophisticated investors before they issue new securities. The potential effects of this market configuration on price formation, however, have mostly been acknowledged in the academic and professional literature as agency costs of "winner's curse"-type underpricing.

In the course of the above analysis, we addressed this issue in a general allocation-based, auction-style issue design based on price discovery by informed investors. We presented a basic model framework of optimal security issuance in the spirit of the conventional, allocation-based argument of IPO underpricing due to asymmetric information between issuers and investors. However, our approach did not reason underpricing on the grounds of the "winner's curse" problem. Instead of compensating rationed uninformed investors, price discounting in our general issue design ensured profitable informed investment over a positive measure of issue quality to *maximise issuer proceeds*. We formalised a *direct revelation mechanism* (DRM) with a fixed price-quantity schedule, which endogenised price discovery in an auction-style allocation preference as a continuous function of perceived issue quality. Our thinking was mainly guided by sustainable allocation-based price discovery, assuming that a monopolistic issuer can only solicit "truth telling" from informed investors if their allocation choice yields profitable investment. The resultant acceptance set of efficient allocation choices qualified maximum issuer payoffs at varying degrees of valuation uncertainty and pricing regimes.

With uninformed investment demand clearing the market, we studied how the incidence of uninformed investors at varying levels of valuation uncertainty affects the utility of informed investment especially under uniform pricing. Hence, we explored underpricing as jointly determined by profitable allocation by informed investors and the incidence of uninformed investment demand. We also conditioned profitable informed investment on some exogenous repayment level to account for structural support mechanisms in securitisation markets.

We found that – irrespective of the applicable pricing mechanism – the issuer maximises own payoffs at the lowest possible allocation (within the acceptance set of efficient allocation choices) that still implies profitable informed investment. Although discriminatory pricing yields higher issuer payoffs, our evidence suggests that issuers could mitigate forgone net payoffs under uniform pricing by maintaining low valuation uncertainty at moderate levels of issue quality to induce a high presence of uninformed investors. Uninformed investment demand implicitly strengthens the position of issuers to maximise own payoffs, mainly because it lowers the degree of underpricing needed to satisfy the profitability constraint of informed investors. Under uniform pricing, the issuer needs to ensure that the composition of the investor pool allows informed investors to appropriate higher individual profit (than uninformed types). Otherwise, they might be inclined to request no allocation at all (i.e. misrepresent themselves as uninformed investors) due to insufficient profitability from price discovery in DRM. Any reservation utility from partial repayment carried an efficiency loss and required a higher issue valuation. The degree of valuation uncertainty critically mattered only under uniform pricing, where an altered incidence of investor types required an adjustment of the allocation choice to still guarantee profitable informed investment at the highest possible level of issuer payoffs. Since a higher (lower) allocation to informed investors at higher (lower) valuation uncertainty and a lower (higher) incidence of uninformed investors implies higher (lower) underpricing, we would expect the minimisation of valuation uncertainty to be the dominant strategy for each level of valuation at the margin (cf. second moment of payoff curve in Fig. 3). The issuer maximised payoffs under uniform pricing by following an "efficient frontier" of allocation choices across all states of issue quality, where the amount of implied investment induced information disclosure by informed investors as a continuous function of perceived issue valuation. Nonetheless, informed investors never receive an allocation that maximises their own payoffs from investment unless high valuation uncertainty rules out any uninformed investment demand.

Overall this chapter represents a first attempt to reason underpricing on the grounds of a strategic allocation choice by issuers to maximise own payoffs by engaging informed investors in profitable price discovery of actual issue quality. The coincidence of valuation uncertainty and the allocation choice for a certain level of perceived issue quality seems to be a prime consideration for optimal issuer payoffs under asymmetric information. While our approach might be overly parsimonious in many respects, we have restricted our issue design to include the reservation utility from a pre-defined level of repayment as the only element pertinent to securitisation markets. Hence, the general tenor of our model invites a more specialised adaptation of our findings to different asset types and entertains the need for more refined modelling of intricate security design features of asset-backed securities, such as the impact of option clauses, loss subordination and payment structures. Also the possible relaxation of several exogenous assumptions in our model design, such as the repayment level and uniform informed investment, warrants further theoretical investigation.

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9 APPENDIX: PROOFS

Proof of equation (7).

$$
\begin{aligned}
E(\Pi)_D &= \int_{\Omega(s)} p_I^*(s) f(s)\,ds + \int_{\Omega(s)} q_U(s)\left(p_U^*(s) - p_I^*(s)\right) f(s)\,ds \\
&= \int_{\Omega(s)} \left(p_I^*(s) + q_U(s) p_U^*(s) - q_U(s) p_I^*(s)\right) f(s)\,ds \\
&= \int_{\Omega(s)} \left(\left(1 - q_I^*(s)\right)\left(u_s(r) - \frac{q_I^*(s)\left(u_s(r) - p_I^*(s)\right)\theta\eta}{1 - q_I^*(s)} \right) + p_I^*(s) q_I^*(s) \right) f(s)\,ds \quad \left| \begin{array}{l} p_U^*(s) \text{ from } (5) \\ q_U(s) = 1 - q_I^*(s) \end{array} \right. \\
&= \int_{\Omega(s)} \left(u_s(r) - u_s(r) q_I^*(s) + p_I^*(s) q_I^*(s) - q_I^*(s)\left(u_s(r) - p_I^*(s)\right)\theta\eta \right) f(s)\,ds \\
&= \int_{\Omega(s)} \left(u_s(r)\left(1 - q_I^*(s)(1+\theta\eta)\right) + p_I^*(s) q_I^*(s)(1+\theta\eta) \right) f(s)\,ds \\
&= \int_{\Omega(s)} \begin{pmatrix} u_s(r)\left(1 - \sqrt[a]{\dfrac{u_s(r)}{a+1}}(1+\theta\eta)\right) \\ + \left(\dfrac{u_s(r)}{a+1}\right)^{\frac{1+a}{a}}(1+\theta\eta) \end{pmatrix} f(s)\,ds \quad \left| q_I^*(s) = \sqrt[a]{\frac{u_s(r)}{a+1}}, p_I^*(s) = \frac{u_s(r)}{a+1} \right. \\
&= \int_{\Omega(s)} u_s(r)\left((1+a) - \sqrt[a]{\frac{u_s(r)}{1+a}}\left(2 + a(1-\theta\eta)\right) \right) f(s)\,ds \underset{a\to 0}{=} \int_{\Omega(s)} u_s(r) f(s)\,ds.
\end{aligned}
\tag{13}
$$

q.e.d.

Proof of Theorem 1. In keeping with the standard logic of the optimal auction model by Myerson (1981) we can re-write IC and PC in section 5.4 in order to substitute the pricing component of the optimisation problem as an allocation-based profitability constraint. We re-write (IC_1) in terms of $\hat{s}$ and $\hat{r}$ as

$$U(\hat{s})_I \geq 0 \Leftrightarrow q(\hat{s})u_s(r) - p(\hat{s}) \geq q(s)u_s(\hat{r}) - p(s) \quad \forall s, \hat{s}, r, \hat{r}. \tag{IC$_1$'}$$

Combining IC_1' with IC_1 for $U(s)_I - U(\hat{s})_I \geq 0$ yields

$$q(\hat{s}) \leq \frac{U(s)_I - U(\hat{s})_I}{u_s(\hat{r}) - u_s(r)} \leq q(s), \tag{14}$$

which implies $U(s)_I' = q(s)$ for $u_s(\hat{r}) \to u_s(r)$ with continuous $q(s)$. Hence, we can derive $U(s)_I = U(\underline{s})_I + \int_{\Omega(s)} q(s) ds$, where the assessment of cut-off signal $\underline{s}$ yields zero payoff of informed investors set. Combining IC_1 and PC to

$$U(\underline{s})_I + \int_{\Omega(s)} q(s) ds = q(s) u_s(r) - p(s) \geq 0 \tag{15}$$

yields the allocation-based offering price

$$p(s) = q(s) u_s(r) - \int_{\Omega(s)} q(s) ds, \tag{16}$$

where $U(\underline{s})_I = 0$ as optimal mechanism for non-decreasing and absolutely continuous $U(s)_I \geq 0$. Substituting equation (16) into the optimisation problem in (9) yields

$$\begin{aligned} E(\Pi)_D &= \max_{q(s)} \int_{\Omega(s)} \left(p(s) + u_s(r)(1 - q(s))\right) f(s) ds \quad \middle| p(s) = q(s) u_s(r) - \int_{\Omega(s)} q(s) ds \\ &= \max_{q(s)} \int_{\Omega(s)} \left(q(s) u_s(r) - \int_{\Omega(s)} q(s) ds + u_s(r)(1 - q(s))\right) f(s) ds \\ &= \max_{q(s)} \int_{\Omega(s)} \left(u_s(r) - \int_{\Omega(s)} q(s) ds\right) f(s) ds. \end{aligned} \tag{17}$$

q.e.d.

Proof of Theorem 2. Analogous to the Proof of Theorem 1, the optimal price-quantity schedule under uniform pricing hinges only on the continuous allocation $q(s)$ to informed investors for $U(s)_I \geq 0$. We substitute $p(s) = q(s) u_s(r) - \int_{\Omega(s)} q(s) ds$ into the optimisation problem and obtain

$$\begin{aligned} E(\Pi)_D &= \max_{q(s), p(s)} \int_{\Omega(s)} \frac{p(s)}{q(s)} f(s) ds \Leftrightarrow \max_{q(s), p(s)} \int_{\Omega(s)} \frac{q(s) u_s(r) - \int_{\Omega(s)} q(s) ds}{q(s)} f(s) ds \\ &\Leftrightarrow \max_{q(s), p(s)} \int_{\Omega(s)} u_s(r) - \frac{\int_{\Omega(s)} q(s) ds}{q(s)} f(s) ds \end{aligned} \tag{18}$$

s.t. IC_2 to prevent informed investors from misrepresenting their type.

q.e.d.

Proof of Corollary 1. Since $U(s)_I' = q(s)$ for $u_s(\hat{r}) \to u_s(r)$ (see Proof of Theorem 1) of profitability constraint $U(s)_I \geq 0$ for $s \in \Omega(s)$, let us assume that some investor surplus $\varepsilon > 0$ (which implies $u_s(r) > u_{\underline{s}}(r)$ for profitable informed investment in Lemma) as upper bound of "underpricing" involves allocation $q_\varepsilon(s) = A_\varepsilon(u_s(r) - u_{\underline{s}}(r))$ (with $A_\varepsilon \in]0,1]$) so that the issuer appropriates payoff $E(\Pi)_D = \int_{\Omega(s)} \left(u_s(r) - \left(\int_{\Omega(s)} q_\varepsilon(s)\, ds \right) \right) f(s) ds = \int_{\Omega(s)} u_s(r) f(s) ds - \varepsilon$ (see Theorem 1) under discriminatory pricing (see Theorem 1). Issuers minimise the amount of underpricing

$$\int_{\Omega(s)} \left(\int_{\Omega(s)} q(s)\, ds \right) f(s) ds \leq \int_{\Omega(s)} \left(\int_{\Omega(s)} q_\varepsilon(s)\, ds \right) f(s) ds = \frac{A_\varepsilon}{6} \left(u_s(r) - u_{\underline{s}}(r) \right)^3 = \varepsilon, \tag{19}$$

which yields $A_\varepsilon(u_s(r) - u_{\underline{s}}(r)) = q_\varepsilon(s) = \sqrt[3]{6\varepsilon}$ as the optimal allocation schedule for investor surplus $\varepsilon > 0$ with issuer payoff $E(\Pi)_D = \int_{\Omega(s)} u_s(r) f(s) ds - \varepsilon$ under discriminatory pricing and full allocation.

q.e.d.

Proof of Corollary 2. Analogous to the Proof of Corollary 1 we assume that for all $s \in \Omega(s)$ informed investor surplus $\varphi > 0$ is associated with allocation $q_\varphi(s) = A_\varphi(u_s(r) - u_{\underline{s}}(r))$ (with $A_\varphi \in]0,1]$), which entails issuer payoff $E(\Pi)_D = \int_{\Omega(s)} \left(u_s(r) - \left(\int_{\Omega(s)} q_\varphi(s)\, ds \Big/ q_\varphi(s) \right) \right) f(s) ds = \int_{\Omega(s)} u_s(r) f(s) ds - \varphi$ under uniform pricing (see Theorem 2), where issuers minimise the amount of "underpricing"

$$\int_{\Omega(s)} \left(\int_{\Omega(s)} q(s)\, ds \Big/ q(s) \right) f(s) ds \leq \int_{\Omega(s)} \left(\int_{\Omega(s)} q_\varphi(s)\, ds \Big/ q(s) \right) f(s) ds = \varphi. \tag{20}$$

Rewriting L.H.S. of (20) with IC_2 generates inequality

$$\int_{\Omega(s)}\left(\int_{\Omega(s)}q(s)\,ds\Big/q(s)\right)f(s)ds \geq \frac{I}{(I+\theta)}\int_{\Omega(s)}\frac{1}{q(s)}f(s)ds, \tag{21}$$

and rewriting R.H.S. of (20) yields

$$\int_{\Omega(s)}\left(\int_{\Omega(s)}q_\varphi(s)\,ds\Big/q(s)\right)f(s)ds = \frac{A_\varphi}{6}\left(u_s(r)-u_{\underline{s}}(r)\right)^3\int_{\Omega(s)}\frac{1}{q(s)}f(s)ds = \varphi. \tag{22}$$

Combining both equations above generates inequality

$$\frac{I}{(I+\theta)}\int_{\Omega(s)}\frac{1}{q(s)}f(s)ds \leq \frac{A_\varphi}{6}\left(u_s(r)-u_{\underline{s}}(r)\right)^3\int_{\Omega(s)}\frac{1}{q(s)}f(s)ds \Leftrightarrow \frac{6I}{(I+\theta)} \leq A_\varphi\left(u_s(r)-u_{\underline{s}}(r)\right)^3, \tag{23}$$

which yields $A_\varphi\left(u_s(r)-u_{\underline{s}}(r)\right)=q_\varphi(s)=\sqrt[3]{6I/(I+\theta)}$ as the optimal allocation schedule for investor surplus $\varphi>0$ with issuer payoff $E(\Pi)_U = \int_{\Omega(s)}u_s(r)f(s)ds-\varphi$ under uniform pricing and full allocation.

q.e.d.