The London School of Economics and Political Science

Essays in Financial Intermediation

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Declaration

I certify that the thesis I have presented for examination for the PhD degree of the London School of Economics and Political Science is solely my own work other than where I have clearly indicated that it is the work of others (in which case the extent of any work carried out jointly by me and any other person is clearly identified in it).

I declare that my thesis consists of 34,176 words.

To my parents, for without their unconditional love and support I would have never achieved this.

To my late grandmother, who knew I was capable of this before I could even dream it.

Abstract

In the first chapter, "Money markets and borrower transparency: Evidence from the Dodd-Frank Act stress testing policy", I investigate the effect of increased public information disclosure on lending outcomes in money markets. Introduction of the Dodd-Frank Act Stress Testing policy and its mandatory results' disclosure is used as a shock to the availability of information on banks subject to the policy. Using micro data on fund portfolio holdings, I show that funds increase their lending more to transparent relative to non-transparent banks after disclosures. Based on the relationship lending literature, I use the strength of the lending relationships to distinguish between more and less informed funds. Overall, my results are consistent with more information disclosure alleviating information asymmetries between borrowers and less informed lenders in the money markets, allowing banks to expand their borrowing. However, increase in borrowing after the disclosure is conditional on disclosure revealing positive information on the bank, which is in line with the disciplining role that disclosures are to play.

In the second chapter, "Where did the money go? Evidence from money market funds on the portfolio balance channel of QE," I aim to identify the portfolio balance channel as a transmission mechanism of Quantitative Easing (QE). I use micro data on money market fund portfolio holdings to investigate changes in MMF lending decisions and portfolio composition once the third wave of QE3 resulted in the withdrawal of Agency repo securities. My results suggest that QE3 did not induce outflows from the money market industry, but resulted in the increase in uncollateralized lending on behalf of funds with above-median QE3 exposure. My results indicate that this increase in uncollateralized lending remains concentrated within former repo issuing banks.

The third chapter, "If fail, fail less: banks decision on systematic vs. idiosyncratic risk", takes the theoretical approach to investigate the influence of bailout policy, contingent on the aggregate state and a bank's individual characteristics, on the banks' choice between systematic and idiosyncratic risk. The regulator who implements the 'fail less' bailout policy i.e. prefers to bail out the banks with higher asset values in failure is introduced in the 'too many to fail' paradigm. Results imply that once the bank's bailout probability, conditional on the regulator's intervention, depends on its value in failure, banks invest in the uncorrelated project more often. Therefore, this reduces the herding pressure of the 'too many to fail' guarantees as well as the occurence of the systemic banking crises.

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Chapter 1

Money markets and borrower transparency: Evidence from the Dodd-Frank Act stress testing policy

1.1 Introduction

In this paper, I attempt to identify effects of increased public information disclosure on lending outcomes in the money markets. In response to the 2008 financial crisis, plenty of new regulation aimed at increasing transparency in the financial system has been introduced. Regulators promoting an increase in information disclosure argued that more information available allows investors to timely detect excessive risk-taking or bad investment decisions, thus serving as a disciplining device to disclosing financial institutions (Freixas and Laux [2011]). In this paper, I empirically study whether public information disclosures in the form of banking stress test results alleviate information asymmetry between money market funds (MMF) as lenders and banks as borrowers in the money markets.

I use the introduction of Dodd-Frank Act Stress Testing (DFAST) policy and its mandatory disclosure of the stress test results as a shock to information available on the disclosing banks. The scope and the staggered implementation of the DFAST rule introduced heterogeneity between tested and non-tested banks in the amount of public information available. Using micro data on MMF portfolio holdings combined with the fund fixed effects to control for the unobserved heterogeneity, I employ difference-in-differences specifications to compare changes in fund lending to tested and non-tested banks after DFAST was introduced. Tested banks are the banks subject to DFAST policy with at least one disclosure of stress test results within the scope of my sample, also referred to as the transparent banks. The non-tested banks are the banks not subject to the DFAST policy, also referred to as the non-transparent banks.

My main finding is that funds increase their lending to transparent relative to non-transparent banks, after DFAST results have been disclosed. In addition, during the period of disclosure anticipation, funds decrease the average maturity of the loans granted to the tested banks that are about to be disclosed. After information is disclosed, the maturity of lending reverts and funds increase the average maturity of the loans granted to transparent banks compared to the non-transparent.

Next, I exploit the role of lending relationships in alleviating asymmetric information to provide evidence that the DFAST disclosures reduce asymmetric information between funds and disclosing banks. I rely on the assumption that the strength of a lending relationship is correlated with the amount of private information the lender has on the borrower. Lenders with more private information should be less affected by the public disclosures. My results indicate that a bank's borrowing increases significantly more from weak compared to strong relationship funds after the disclosure of DFAST results. This is consistent with a public disclosure mitigating information asymmetries between the less informed MMF and disclosing banks.

My results show that the different changes in lending between weak and strong relationship funds already arise during the period of disclosure anticipation. By exploiting information content disclosed in the subsequent stress test results, I show that the difference in funds' lending during the anticipation period is due to strong relationship funds decreasing their lending to banks with below median stress test results. This may suggest that funds with more private information reduce their lending in anticipation of other lenders' reactions once negative information becomes public.

The DFAST rule, introduced in October 2012 by the Federal Reserve Board (Fed), imposed mandatory annual supervisory stress testing and result disclosures for bank holding companies greater than $50 billion in total consolidated assets and for the nonbank financial companies designated for supervision by the Financial Stability Oversight Council (FSOC) (Federal Reserve [2012b]). Mandatory disclosures were supposed to inform investors on banks' capital adequacy and their ability to uninteruptedly function as financial intermediaries in case of severe economic downturns. This required having enough capital and liqudity to fulfill liabilities to its creditors and counter-parties even under very negative macroeconomic conditions. Using DFAST as a shock to information available on borrowers allows overcoming the endogeneity inherent in information disclosures. For example, it is possible that bad quality borrowers are more willing to disclose information in order to gain access to markets, which otherwise would not be granted. Alternatively, bad quality borrowers may be more reluctant to disclose in order to hide their true type and avoid being cut off from the market. Using the mandatory rule imposed by the Fed as a source of heterogeneity in available information on banks subject and exempt from the rule allows addressing these issues.

I begin by investigating changes in fund lending to transparent and non-transparent banks after DFAST disclosures were introduced. If the increased availability of public information affects money market lending outcomes, there should be differential changes in fund lending between disclosing and non-disclosing banks after DFAST disclosure. In order to capture this, I employ the difference-in-differences identification strategy to estimate the differential in the changes of fund lending to transparent and non-transparent banks. Micro data on money market fund portfolio holdings from October 2011 to March 2015, equivalent to lender-borrower loan level data allows me to trace the lending of a given fund to a particular bank in each month. A 'loan' is comprised of all unsecured type of money market securities issued by the bank and held by the fund in a given month. I focus on the unsecured lending because it is more sensitive to the borrowers' creditworthiness affected byh the information available on the borrowers. In contrast, loans collateralized by Treasuries or similar securities are less likely to be affected by the actual borrowers' creditworthiness and related information disclosures. Loan level data allows me to control for unobserved fund level heterogeneity by using fund fixed effects, and thus account for any changes in lending driven by the unobserved liquidity shocks affecting MMF.

When implementing the difference-in-differences I exploit the scope of the DFAST rule which encompassed only the U.S.-domiciled banks while not covering the foreign banks. This allows me to define the treated group of banks, i.e. transparent banks, as banks subject to the DFAST rule with at least one disclosure of stress test results after the introduction of the rule. The control group. i.e. non-transparent banks, , is represented by the large foreign banks actively borrowing in the money markets and not covered by the DFAST rule. At the same time, large foreign banks are comparable to the largest U.S. banks subject to DFAST in terms of the size of their money market debt and scope of money market securities' issuance.

My findings reveal that an average fund increases its dollar lending to transparent relative to non-transparent banks by 15.3% more after information disclosures. A similar result obtains when fund lending is expressed in terms of fund portfolio exposure to a particular bank. Funds on average increase their portfolio exposure to transparent banks by 19.4 basis points more after DFAST results have been disclosed.

In order to address the concern that the effect might be driven by some unobserved heterogeneity between U.S.-domiciled and foreign banks I exploit the staggered implementation of the DFAST rule to narrow down the treated and control group to only DFAST covered banks. In October 2012, when the

DFAST rule was revealed, a subset of rule-covered banks was granted an exemption from participating in the first DFAST cycle (March 2013). This was justified by more time required to develop systems and procedures for conducting stress tests for banks which previously never participated in regulatory exercises of that scope (Federal Reserve [2012b]).[1] Here I define the treated banks as the ones included in the first cycle of DFAST dislcosures, while control group banks are the initially exempt banks. During the period between the first and second round of DFAST, the exempt banks remain non-transparent while the first-round included banks just had their first disclosure. When comparing differences in the fund lending to two bank groups, the results show that funds increase their lending more to banks which have just become transparent, compared to the still non-disclosed banks. There is no significant difference in fund lending after all DFAST-subject banks have become transparent i.e. after the second round of disclosures.

Next, I show that funds decrease the average maturity of the loan at which they lend to tested banks prior to the actual results disclosure. This can be consistent with lenders adjusting their lending in anticipation of some negative information to be disclosed. After the DFAST dislcosure, the average maturity of the fund loan to transparent banks increases compared to the non-transparent banks. Increase in fund lending and average maturity of loans to transparent banks after disclosure is consistent with predictions of models on lending under asymmetric information. Information sharing reduces adverse selection and moral hazard problems, thus leading to more lending (Stiglitz and Weiss [1981], Akerlof [1970], Myers and Majluf [1984])). Also, lenders with more information on borrowers benefit less from an early liquidation option, thus, an increase in the loan maturity is also in line with an increase in available information on the disclosing banks (Berglöf and von Thadden [1994]).

To provide more evidence that public disclosures affect lending in the money markets by mitigating asymmetric information, I distinguish between funds with different sensitivity to disclosure based on the amount of private information funds have on the banks prior to the disclosures. Funds with more private information are expected to be less sensitive to public disclosures. Less informed funds benefit more from the disclosures as they allow them to learn more about the banks to which they are lending, thus reducing asymmetric information problems. Based on the relationship lending literature I define funds with more private information as funds with stronger lending relationships with the borrowers.

Predominantly, lending relationships have been studied in the context of traditional banking (Diamond [1984], Ramakrishnan and Thakor [1984], Sharpe [1990], Hertzberg et al. [2011], Rajan [1992] and Boot [2000]). Proximity between the lender and borrower, as well as repeated interactions between

[1] The banks exempt from the first round of DFAST were banks which were previously not part of the Supervisory Capital Assessment Programme (SCAP), a one-off stress testing exercise undertaken in 2009, in the midst of the financial crisis. At the time, only banks with the total consolidated assets greater than $100 billion were included in the regulatory exercise. Although the exempt banks were still, on average, smaller than the banks immediately included in DFAST, the bank assets in both groups did fluctuate over the years alleviating the differences in the asset size between the groups.

the two, facilitate the lender's monitoring and screening of the borrower. This allows the lender to gain an informational advantage over other potential lenders that previously have not lent to the same borrower.

Although money markets should be less subject to asymmetric information problems given that the majority of borrowers are large and well-established institutions, studies have shown that lending relationships play an important role in these markets as well (Chernenko and Sunderam [2014]).[2] Similar to Bharath et al. [2007] and Cocco et al. [2009] I define the strength of a lending relationship using the average size of the loan prior to introduction of DFAST, measured by the percentage of fund portfolio allocation to the bank. For each fund-bank pair, the lending relationship is classified as strong if the fund has an above-median portfolio exposure to the bank during the pre-DFAST period. A below-median portfolio exposure is classified as a weak lending relationship. For the same borrower strong-relationship fund has informational advanatage over the weak-relationship fund.

Exploiting the heterogeneity in lending relationships to examine the effect of new public disclosures relies on two assumptions. First, the relationship strength is correlated with the amount of private information the lender has on the bank prior to disclosures. Second, the private information gathered through the relationship is correlated with the information disclosed in the stress test results. If this is the case, public disclosures are less informative for the strong compared to weak relationship lenders. Consequently, their lending to the same bank should be less affected by a disclosure.

First, by running separate regressions for funds' weak and strong relationships, I show that among weak relationships, funds on average increase their loans by 32% more to transparent relative to non-transparent banks after DFAST disclosure. This difference in the change in lending to transparent and non-transparent banks is insignificant for strong lending relationships. Second, in order to directly test for differential in the changes between the strong and weak relationship funds' lending, I employ a difference-in-differences specification with the bank fixed effects. Similar to Khwaja and Mian [2008] and Schnabl [2012], borrower fixed effects allow to compare changes in the same disclosing bank's borrowing from the funds with weak and strong lending relationships. This controls for any unobserved bank level heterogeneity, including changes in bank demand for the money market funding. My results indicate that, on average, banks' borrowing from weak relationship funds increases significantly more after stress test disclosures, compared to borrowing from strong relationship lenders.

In order to address the possibility that weak relationship funds expand their lending across all borrowers, irrespective of the transparency, I use a triple-difference specification to compare whether weak

[2] Brauning and Fecht [2016], Cocco et al. [2009] focus on interbank markets to show that bankruptcy of one important relationship lender may pose a therat for the stabiluty of the system . Also, lending relationships proved important in Repo markets (Copeland et al. [2014], Anderson and Kandrac [2016]) More recently, Chernenko and Sunderam [2014] show that relationships matter for money market fund lending decisions when funds are subject to negative liquidity shocks (investor outflows).

increase their lending more than strong to transparent relative to non-transparent banks. This allows me to control for other contemporaneous shocks affecting MMF lending differently for weak and strong lending relationships across all borrowers. The results indicate that after DFAST results have been disclosed weak relationship funds increase their lending to transparent by 24.3% more than to non-transparent banks, compared to the same change for the strong relationship funds.

Focusing on the transparent banks, my results show that lending of the weak compared to strong relationship funds already increases in the period before the DFAST results are disclosed. The magnitude of the effect is lower compared to the period after information disclosure. It is plausible that the announcement of a future disclosure itself represents a piece of information for the less informed funds, conveying some positive signal on the banks included in the disclosure. For example, stress testing may imply that the banks will be supervised more closely by the regulator. Funds with more private information should be less sensitive to the disclosure announcement. However, it is also possible that the anticipation of disclosure induces heterogeneous reaction of informed lenders across banks of different quality. For example, if an informed lender expects negative information on a bank to become public, the lender could reduce its exposure beforehand.

To investigate this further, I focus on the differences in lending between strong and weak relationship funds conditional on the bank quality disclosed in stress tests. If strong relationship lenders have more information prior to disclosure, they may reduce lending to bad banks more during the anticipation period to avoid being exposed to negative market reactions once the information becomes public. In these specifications, a bank is classified as bad if it has a below-median result in its DFAST disclosure. This captures the banks' relative quality with respect to its disclosing peers.

My findings show that during the anticipation period, strong relationship funds reduce lending to bad banks by 23% more than weak relationship funds. There is no difference in fund lending to good banks during the anticipation period. This is consistent with informed lenders being more sensitive to public disclosure of negative information on the borrowers, in line with the existing evidence on lenders' coordination incentives (Hertzberg et al. [2011]). After disclosure, weak relationship funds increase their loans by 35% more to banks disclosed as good, while there is no significant difference in lending to bad banks. This is consistent with uninformed funds adjusting their lending to good banks in response to the information disclosed in DFAST. Regarding the banks disclosed as bad, it is plausible that after information is public, the risk-return tradeoff is such that everyone is equally willing or reluctant to lend to these borrowers.

The evidence supports the hypothesis that public information disclosure reduces asymmetric information, in particular among the fund-bank pairs with previously weak lending relationships. Disclosures allow banks to expand their borrowing from funds with which they previously had weak lending relationships. However, the effect is heterogeneous across banks conditional on their quality revealed in stress test results. For good banks, increased disclosure makes lending relationships less relevant for borrowing in money markets, while for the bad bank increased public disclosure prompts their strong relationship lenders to reduce lending to these banks in anticipation of the negative market reactions.

This paper is one of the few attempts to empirically investigate the effect of increased borrower information disclosure on lending in the money markets.[3] Perignon et al. [2017] analyze the role of asymmetric information in the allocation of wholesale funding in European certificates of deposit market. In order to inform the existing debate on whether more disclosure on issuer quality is beneficial, or whether money market participants benefit more from opacity (see Dang et al. [2015] and Holmstrom [2015]), more empirical insight on the topic is needed. My paper shows that increase in information disclosure alleviates the constraints on lending in the money markets for the banks disclosed as good. Also, it shows that the changes in lending induced by disclosures are in line with the disciplining role of disclosures on the institutions borrowing in the money markets. In the broader context this paper empirically evaluates predictions of theories on lending under asymmetric information. Theories predict that lenders increase their lending more to borrowers with lower information asymmetry to reduce exposure to adverse selection or moral hazard problems (see Akerlof [1970], Stiglitz and Weiss [1981], Myers and Majluf [1984] Rajan [1992]).

Using the introduction of mandatory DFAST disclosures as the informational shock that increased availability of information on certain borrowers, this paper represents an empirical evaluation of the Dodd-Frank Act Stress Testing policy with the focus on the effects in the money markets. An extensive theoretical literature discusses plausible consequences of DFAST based on different theory models of asymmetric information (see Goldstein and Sapra [2013], Leitner [2014])Landier and Thesmar [2011]).

Papers that focus on the positive role of bank information disclosure use theoretical models to study the optimal level of bank disclosure with the emphasis on thir role in reducing risks of bank runs during crises (see Goldstein and Leitner [2016], Bouvard et al. [2015],Leitner [2005]). The strand of literature studying negative consequences of bank information disclosures discusses negative effects on bank managers' behaviour Gigler et al. [2014] as well as willingness of market participants to privately collect the information, which could impair the ability of the regulator to learn from the market (see Bond et al. [2012] and Prescott [2008]).

Empirical attempts to quantify the effects of stress test disclosures are mostly focused on capturing

[3] Papers by Kacperczyk and Schnabl [2013], McCabe [2010], Schmidt et al. [2014], Strahan and Tanyeri [2015] exploit crises episodes to investigate fund decisions to cut lending to borrowers when subject to negative liquidity shock in the form of investor outflows. Chernenko and Sunderam [2014] focus on the role of lending relationships between MMF and borrowers in mitigating the effects of negative liquidity shocks on borrowers in the money markets.

whether markets learned any new information from these disclosures. They use event study methodology to measure stock price, or credit spread market reactions to the information disclosure event (see Neretina et al. [2015], Peristiani et al. [2010], Flannery et al. [2015] for reactions to different DFAST rounds of disclosures and Petrella and Resti [2013] for ECB stress testing undertaken in 2011). In this paper, using micro data, I am able to quantify the changes in the money market fund lending to DFAST-affected banks and to analyze whether and in what way banks' ability to borrow through money markets changes once DFAST has been introduced.

The rest of the paper is organized as follows: section 2 describes the institutional setting and the empirical strategy. Section 3 discusses data and provides the summary statistics. Section 4 presents the empirical results and section 5 concludes.

1.2 Institutional environment and empirical strategy

In this paper, I exploit the introduction of Dodd-Frank Act Stress Testing (DFAST) policy and rule on mandatory results disclosures as an informational shock to lending outcomes in the money markets. The DFAST policy is part of the broader Dodd-Frank legislation introduced in July 2010 as a regulatory response to the 2008 financial crisis. The stated aim of Dodd-Frank is to promote financial stability by improving accountability and transparency in the financial system.

The final rule on the DFAST policy was revealed in October 2012. At the time, the rule prescribed mandatory annual supervisory stress testing and disclosure of results for bank holding companies (BHC) with total consolidated assets greater than $50 billion and nonbank financial companies designated for the Fed's supervision by the Financial Stability Oversight Council.[4] The introduced rule applies only to U.S.-domiciled bank holding companies, while foreign banking organizations are not subject to it. Stress testing was designed as a forward looking quantitative exercise aimed at measuring whether a bank has sufficient capital to support its operations and continue functioning as an intermediary with respect to its creditors and counter-parties under adverse economic conditions. Disclosures contained individual bank detailed information on the resilience of their capital position, risk characteristics and sensitivity of their business acitivities to periods of stress[5].

[4]Asset size was to be calculated as the average of a company's total consolidated assets over previous four calendar quarters. Bank holding company was considered to qualify for the year t's stress testing cycle, if no later than June of the $t-1$ year, it meets the consolidated assets size requirement (Federal Reserve [2012a]).

[5]In parallel with finalising the rule on stress testing, Fed has developed a framework for the forward-looking capital planning in the form of Comprehensive Capital Analysis and Review (CCAR). CCAR represents a complementary exercise to DFAST with the same group of banks targeted, as well as the same timeline as DFAST in terms of results disclosure. The key difference between the two exercises is in the assumption on banks' capital actions. DFAST uses a standardized set of capital action assumptions homogeneous across all participating banks and with no significant changes in banks' forecasted capital actions. In contrast, CCAR uses each bank's planned capital actions to asses whether the bank would be capable of meeting supervisory expectations for minimum capital ratios in economic downturns, for the

One of the empirical challenges when studying the effects of information disclosure and availability of public information on lending outcomes is endogeneity of disclosure. If the decision to disclose information is made by the borrower, it is plausible that depending on the quality and the need for funding, the borrowers may differ in their willing to disclose. For example, borrowers with the greater need for funding or larger difficulty in raising funds would be more willing to disclose information in order to convince investors to lend them the money. However, the opposite is also possible. The lower quality borrowers could be more reluctant to disclose information, as this aggravates their ability to raise funds. Thus, in order to attribute changes in lending to differential transparency across borrowers, an increase in information disclosure would have to be independent from the borrower's decision to disclose. In that respect, introduction of the DFAST policy and mandatory stress test results disclosures resulted in regulator-imposed increase in available public information on certain banks. In addition, regulator-imposed disclosures are argued to be taken as a more credible source of information relative to banks' voluntary disclosures of the similar kind (Goldstein and Sapra [2013]).

Prior to Dodd-Frank, any systematic disclosure of bank-specific information of such scope and content as DFAST was almost non-existent. However, during the financial crisis, a supervisory exercise in the form of the one-off stress test, Supervisory Capital Assesment Program (SCAP), was implemented and bank-specific results disclosed in May 2009. This was an ad hoc exercise with the main goal to reduce the investor panic, and enable proper market functioning by restoring confidence in the banking system. Banks chosen to participate in SCAP had total consolidated assets of 100 billion dollars or above at the time of the exercise.

In October 2012, when the DFAST rule was published, it was revealed that institutions which qualify by the rule, but have not previously participated in the similar regulatory exercises will be granted an exemption from the first round of DFAST. This was justified by the time required to develop systems and procedures to be able to conduct the stress tests and collect information required for the tests (Federal Reserve [2012a]*)*. Therefore, the banks granted an exemption from the first round of DFAST had smaller asset size than $100 billion during the 2009 exercise, but did meet the $50 billion asset size cutoff of the DFAST rule in 2012. Although, on average, the exempt banks are smaller in their asset size relative to their non-exempt peers, banks' balance sheet sizes have evolved since 2009, consequently making the size split from 2009 less relevant. The staggered implementation of the DFAST rule implied that in 2013 the stress testing and the bank-specific result disclosure will include only 18 banks[6] that

particular proposed capital distributions. The focus of this exercise is evaluation of banks' capital planning processes and proposed capital distributions in the context of adverse stress scenarios. See Schuermann [2013] and Hirtle and Lehnert [2014] for more details on stress testing frameworks.

[6]The 18 BHCs that participated in the 2013 Dodd-Frank Act stress test are Ally Financial Inc;American Express Company; Bank fo America Corporation; The Bank of New York Mellon Corporation; BB&T Corporation; Capital One Financial Corporation; Citigroup Inc; Fifth Third Bancorp; The Goldman Sachs Group Inc; JPMorgan Chase & Co; KeyCorp; Morgan Stanley; The PNC Financial Services Group Inc; Regions Financial Corporation; State Street

were previously part of the SCAP regulatory exercises, while the other 12[7] which qualify by the rule were to have their first stress testing and disclosure in March 2014, as part of the DFAST 2014.

1.2.1 Empirical strategy

In order to identify the effects of increased information disclosure in the form of stress testing results on lending outcomes in the money markets, I compare differences in lending to tested (i.e. transparent) and non-tested (i.e. non-transparent) banks before and after DFAST disclosure.

Transparent banks are banks subject to the DFAST policy with at least one stress test result disclosed within the span of the sample and after DFAST was introduced (October 2012 - March 2015). Thus, the transparent group comprises of 30 banks included in stress testing procedure in two waves. The first round of DFAST comprised of 18 banks which has their first DFAST disclosure in March 2013. The remaining 12 banks were granted an exemption from the first round of disclosure, although in October 2012 it was already known that their asset size otherwise qualifies them. These banks had their first stress test results disclosed in March 2014.

Non-transparent banks represent the control group and are defined on the subset of banks borrowing in the money markets and not subject to DFAST policy. Banks in the control group are predominantly large foreign banks not covered by DFAST policy. There were no public information disclosures during the DFAST cycle on these banks[8]At the same time, foreign banks are very important borrowers in the U.S. money markets which represent their main source of short term dollar funding. Thus, they are comparable to the largest US banks subject to DFAST in size of their money market debt and scope of money market securities' issuance.

In addition, staggered implementation of mandatory DFAST disclosures allows me to also define treated and control bank groups while restricting observations only to DFAST covered banks. Between the first and the second round of DFAST disclosure, from March 2013 to March 2014, banks subject to DFAST can be classified in two different transparency groups. During this period, banks included in the first round of DFAST were already transparent, thus representing the treated group. The control group is comprised of banks that were only to become transparent after March 2014. This narrow definition of the treated and control groups using only DFAST covered banks allows controlling for potential differences between US-domiciled and foreign banks. For example, foreign banks may have different

Corporation; SunTrust Banks Inc; U.S. Bancorp and Wells Fargo & Company.

[7]The 12 BHCs that participated in the 2014 Dodd-Frank Act stress test, but were exempt from 2013 DFAST are BBVA Compass Bancshares Inc; BMO Financial Corp; Comerica Incorporated; Discover Financial Services; HSBC North America Holdings Inc; Huntington Bancshares Inc; M&T Bank Corporation; Northern Trust Corp.; RBS Citizen Financial Group Inc; Santander Holdings USA, Inc; UnionBanCal Corp and Zions Bancorp.

[8]Although some of these banks may have been subject to similar types of regulation implemented by the European Central Bank for example (ECB stress testing), first relevant disclosures occured only in October 2014 which does not coincide with the timing of DFAST disclosures.

ability to find substitute for money market dollar funding, which may differently affect borrowing patterns of these banks.

In an attempt to capture the effect of increased information availability on some borrowers, I exploit fund-bank level data and employ a difference-in differences identification strategy to capture differential changes in fund lending to transparent and non-transparent banks after DFAST disclosure. This specification assumes that the evolution of non-transparent banks' borrowing represents a reasonable counterfactual for money market borrowing of the transparent banks. Namely, had there not been mandatory disclosures under the DFAST policy for transparent banks, their money market borrowing would evolve in the same way as the borrowing of the non-transparent banks. Figure 1.1 shows the average MMF lending to transparent and non-transparent banks over the event time, which is centered around each banks' first DFAST disclosure (event time=0). Prior disclosure, the average fund loans to transparent and non-transparent banks evolve in parallel, while there is an increase in the average loan to transparent banks after the disclosure.

In order to estimate the changes in lending between transparent and non-transparent banks, using broader or narrower definition of treated and control groups, I employ a difference-in-differences specification given in (1.1):

$$\begin{aligned} loan_{f,b,t} &= Transparent_b + \beta_{Interim} \times Interim_{b,t} \times Transparent_b + \\ &+\beta_{Post} \times Post_{b,t} \times Transparent_b + u_{f,b,t} \\ u_{f,b,t} &= \phi_f + \tau_t + X_{f,t} + \varepsilon_{f,b,t} \end{aligned} \tag{1.1}$$

Dependent variable is (log) dollar loan of fund f to bank b in a given month. $Transparent$ is an indicator variable equal to 1 for the banks in the DFAST tested bank group. $Interim$ is a time dummy equal to 1 during the period between the introduction of the DFAST rule and the bank's actual first stress test results' disclosure (anticipation period). $Post$ is a time dummy equal to 1 after disclosure has happened and information on the bank is public. Specification also includes fund-specific controls $X_{f,t}$ (asset size and maturity of portfolio). Fund fixed effects, ϕ_f, address the time-invariant heterogeneity across funds and time fixed effects τ_t control for the aggregate shocks affecting money market lending.

Second, I attempt to provide evidence that changes in MMF lending are due to information disclosure alleviating informational asymmetries between MMF and banks as borrowers. In order to do so, I assume that lending relationships, in the absence of public information disclosures, serve as a mechanism mitigating information asymmetry. The underlying assumption is that a strong lending relationship allows the lender to gather more information on the borrower and thus makes him more willing to lend relative to the lender with no previous lending relationship. Thus, strength of a lending relationship is reciprocal to the degree of information asymmetry which exists between that lender fund and bank as borrower.

I use a difference-in-differences specification to compare the differences in the changes of the same bank's borrowing from weak and strong relationship lenders. Specifications at the fund-bank loan level with bank fixed effects control for bank level heterogeneity, including changes in demand for money market funding, which affect lending across all relationships in the same way (similar to Khwaja and Mian [2008] and Schnabl [2012]). The underlying assumption is that a strong relationship fund's lending decision is less affected by the public information disclosure, given these funds are already better informed. The larger the information asymmetry, the stronger the effect of information disclosure on lending decisions of that lender.

I define strength of lending relationships using lending patterns prior to introduction of the DFAST policy, during October 2011- October 2012 period. Measures used follow Bharath et al. [2007] and Cocco et al. [2009] and define stregth of lending relationship using the amount of lending fund allocates to the borrower. Also, this is consistent with the predictions of the standard portfolio theory postulating that investors with more precise information on a particular investment/issuer (loan/borrower) allocate a larger fraction of their portfolio to that investment.

In the context of money market funds, strength of lending relationship is classified using two measures based on the average fund's portfolio exposure to a particular bank during pre-DFAST period. First, fund-bank lending relationship is strong if a fund's portfolio exposure to the bank is above median exposure the fund allocated to any single bank during the pre-DFAST period (fund-based measure). The second measure classifies the relationship as strong if the fund's portfolio exposure is above the median exposure that any fund lending to that bank allocated during the pre-DFAST period (bank-based measure).

Figure 1.2 shows how the evolution of the average loan (scaled by fund size) by the strong and weak relationship funds to transparent banks over the event time defined with respect to banks' first disclosure of DFAST results. Parallel trend prior to DFAST disclosure supports the assumption that lending of strong relationship funds represents a good counterfactual for the weak relationship funds' lending, had there not been any public information disclosures on the borrowing banks.

1.3 Data and summary statistics

I construct a novel dataset of the US prime money market fund portfolio holdings. Starting from November 2010, Securities and Exchange Commision (SEC) has imposed mandatory filing of detailed information on the fund and securities held in its portfolio for all money market funds. Funds are required to submit the N-MFP form within 5 business days after the end of the month, while the forms become publicly available only 60 days later. My dataset is constructed using individual money market fund filings of the N-MFP form from October 2011 until March 2015. The N-MFP form contains detailed information on the fund including asset size, age, yield, portfolio maturity and the like. Portfolio holdings information includes information on the security type, name of the issuer and security, different security and issuer identifiers (CUISP, CIK), maturity at issuance, dollar amount of the security held by the fund and percent of fund net assets invested in the particular security.

In order to capture lending to borrowers affected by the mandatory DFAST disclosures, I focus on the portfolio holdings of prime money market funds which are funds allowed to invest in non-government securities. The analysis is restricted to 164 funds existing throughout the entire span of the sample period (October 2011-March 2015).[9] On the borrower's side, my sample encompasses large U.S. bank holding companies subject to DFAST regulation as well as large non-U.S. banks not covered by the DFAST regulation.

To arrive at the fund-bank level dataset, I use security identifiers submitted in the N-MFP form to match each security to the issuer at the highest level of aggregation. Each security issuer is matched with their parent bank holding company. The matching algorithm combines information on securities' CUSIP with the CUSIP database, also Moody's Investor Service information on ABCP vehicles and their sponsors, SEC's list of all CIKs matched with entity names, as well as the organizational hierarchy of bank holding companies provided by Federal Financial Insitutions Examinations Council - National Information Center (FFIEC) for matching the bank subsidiary level issues to the holding company. For example, in case of JP Morgan Chase & Co, all securities issued by JP Morgan bank and JP Morgan securities, or Jupiter securitization (ABCP conduit sponsored by JP Morgan) will be ultimately matched to JP Morgan bank holding company.

When studying changes in the money market lending outcomes, the subject of my analysis is predominantly the fund-bank loan. 'Loan' is defined as the total fund holdings of unsecured money market securities issued by a particular bank and held by the fund in a given month. Unsecured securities represent more infomration sensitive type of money market securities as they are either enitrely non-

[9]This ensures that none of the results are driven by funds entering or exiting the sample. However, all the results remain robust to including all filing funds in the analysis.

collateralized or do not use Treasuries or Government Agency debt as collateral. Therefore, this type of unsecured lending should be more sensitive to issuer's perceived creditworthiness. Thus, loans studied comprise of certificates of deposits, commercial paper, floating rate notes, other repo (repurchase agreements collateralized by non-Treasury and non-Government Agency type of securities) and the like.[10]

Table 1.1 reports fund summary statistics calculated using observations on 164 prime money market funds at the fund-month level. Table 1.1 shows that there is a significant variation across funds in their asset size, with the mean asset size being $8,400 million, while the median size is only $1,490 million. However, funds are quite similar along other characteristics including their portfolio maturity, age and portfolio yield. Portfolio maturity and fund age as well as fund yield are based on the total fund portfolio holdings, while bank portfolio maturity represents the weighted average maturity of the loans granted to banks in the sample. Unsecured fund lending to banks in the treated and control group, on average amounts to 25% of total fund assets. Table 1.1 shows that within the matched sample a fraction of unsecured lending to treated banks represents on average 45% of the total unsecured lending, with little variation across funds.

Table 1.2 reports bank summary statistics separately for banks subject to mandatory stress test disclosures (transparent), and for banks not subject to DFAST (non-transparent). Statistics are calculated using bank-month level observations over the entire sample period (October 2011-March 2015). Transparent and non-transparent banks differ in the size of the average total money market debt. The total debt of transparent banks averages at 10.4 billion with the median being only 1.46 billion. This implies a significant dispersion in the size of total money market debt among the treated banks. On the other hand, this is not the case with non-transparent banks which have an average total debt at $26.7 billion (median $26.8bn).

Relative importance of the unsecured debt for both bank groups is similar, averaging at 82% of total money market debt per bank for transparent banks, while being slightly lower at 72% for the non-transparent. Since unsecured debt is more information-sensitive, this implies that information asymmetries between fund lenders and banks may be equally important for both bank groups.

Maturity of bank's money market borrowing is calculated using only unsecured debt. Table 1.2 underlines that transparent banks on average borrow at longer maturities from money market funds, relative to the non-transparent. Weighted average maturity of banks' unsecured debt has a mean of 68 days for transparent, while only 33 days for the non-transpatenr banks. Average number of lenders per bank is higher for the non-transparent banks in line with the overall larger amount of debt these banks

[10]It may be argued that the riskiness of other repo securities is affected by both issuer's creditworhtiness and the quality of the collateral. My results remain robust to excluding other repo from the analyses.

raise from the money markets. A fraction of strong lending relationships is balanced across both bank groups, with the mean being at 33% for DFAST-tested banks, while 36% for the banks not subject to DFAST.

Tables 1.3 and 1.4 show summary statistics on the fund-bank loans. The unit of observation is at the fund-bank-month level and the statistics are presented separately for the period before and after introduction of the DFAST policy. The pre-DFAST period spans from October 2011 to October 2012, while the post-DFAST period, from October 2012 to March 2015. During the post-DFAST period, transparent banks have at least one DFAST disclosure with the first round of disclosures in March 2013 and the second round in March 2014.

Table 1.3 compares characteristics of loans to transparent and non-transparent banks before and after mandatory stress test disclosures were introduced. The average fund loan to transparent and non-transparent banks as well as fund portfolio exposure is similar across both bank groups, with dollar loans being slightly higher for the non-transparent banks. The average loan maturity is higher for the transparent banks with the mean at 47 days during the pre-DFAST and increasing even further after stress test disclosures were introduced. For the transparent banks, both the mean and dispersion of the size of dollar loans increase after DFAST is introduced. This is consistent with more information on borrowers allowing lenders to adjust their lending accordingly, conditioning on transparent banks' disclosed quality. One can think that prior to information disclosure, lenders assume some average bank quality when granting loans. However, after stress test results on banks are disclosed, it is plausible to condition lending decisions on the bank's quality disclosed in the stress test. This may generate greater variability in the size of the loan among transparent banks. On the other hand, there is no similar increase in dispersion of the loan size among the non-transparent banks, consistent with no information shock affecting them.

Furthermore, the average fraction of the new loans granted by the fund within the bank group is 50% among the loans to transparent banks, and 20% among loans to non-transparent ones after DFAST was introduced. This is in line with disclosures alleviating information asymmetry between funds and transparent banks. With more public information available on the borrower, lenders are more willing to start lending to the new borrowers.

In the second part of the analysis I explore changes in transparent bank's borrowing from funds with strong and weak lending relationships. Table 1.4 presents summary statistics on fund-bank loans between strong and weak lending relationships, before and after DFAST was introduced. Loans are restricted to transparent banks. By construction, weak relationship loans are significantly lower compared to strong relationships loans during pre-DFAST period. However, after disclosures happen, weak relationship loans increase from an average 90 to 158 million dollars after DFAST was introduced. Similarly, funds' portfolio exposures increase for weak lending relationship funds after DFAST was introduced, while no comparable increase exists within strong relationship lenders.[11] Persistence of a lending relationship is defined as a percentage of dates during each sub-period (pre and post-DFAST) when fund lends to a bank. Among weak relationships, there is an increase in lending persistence after DFAST was introduced.

1.4 Empirical results

1.4.1 Effect of information disclosure on MMF lending to transparent vs. non-transparent banks

In order to investigate whether public information disclosure affects MMF lending, I begin by documenting heterogeneity in fund lending to transparent and non-transparent banks after stress test results of DFAST tested banks have been disclosed. Using the loan level data, I employ difference-in-differences specification with fund fixed effects given in (1.2) to compare the changes in fund lending to transparent and non-transparent banks. Dependent variable is fund-bank loan defined as fund f's holdings of uncollateralized securities issued by bank b expressed either using log of dollar amount invested in securities or as a percentage of fund's net assets (portfolio exposure).

$$\begin{aligned} loan_{f,b,t} &= Transparent_b + \beta_{Interim} \times Interim_{b,t} \times Transparent_b + \\ &\quad + \beta_{Post} \times Post_{b,t} \times Transparent_b + u_{f,b,t} \\ u_{f,b,t} &= \phi_f + \tau_t + X_{f,t} + \varepsilon_{f,b,t} \end{aligned} \tag{1.2}$$

Variable $Interim$ is a dummy equal to 1 for the period of disclosure anticipation for a given bank. During this period, funds know that the tested bank's information is to be disclosed at a given point in the future. Variable $Post$ is a dummy variable equal to 1 after disclosure happens and information on the bank is public. $Transparent$ is an indicator variable representing the group of banks subject to mandatory disclosures under DFAST. The specification also includes fund fixed effects ϕ_f which control for the unobserved, time-invariant heterogeneity across funds, and time fixed effects τ_t which capture

[11]MMF regulation, under Rule 2a-7 of the Investment Company Act of 1940, prescribes that money market funds must not hold more than 5% of their assets in any unsecured instrument by a single issuer with the highest rating and not more than 1% of their assets in any instrument of a single issuer with the second-highest rating. However, both loans within both types of lending relationships when expressed as a percentage of fund net assets are quite below diversification imposed portfolio limits.

the time-varying aggregate shocks that homogenously affect lending in the money markets across all the funds. Standard errors are clustered at the fund level. Coefficients of interest are $\beta_{Interim}$ and β_{Post} which estimate the differential in the changes of fund lending to transparent relative to non-transparent banks during anticipation of disclosure period and after disclosure happens for transparent banks.

Table 1.5 shows that an average fund increases its loan to transparent relative to non-transparent banks by 15.3% more after the DFAST disclosure happens for the transparent banks. Similarly, if loans are expressed as fund portfolio exposure to a particular borrower, funds, on average, increase their portfolio exposure to transparent banks by 19.4 basis points more, after the disclosure. It follows that public information disclosure affects fund lending and prompts funds to increase their loans and portfolio exposure more to disclosing banks after they become transparent.

In addition, Table 1.5 shows that during the interim period, on average, fund's portfolio exposure to a bank from the tested group decreases relative to the non-tested group. The effect is negative, although not significant, when loans are measured in dollars. The interim period captures the fund behaviour during anticipation of future information disclosure for transparent to-be banks. It is plausible that funds abstain from lending while waiting for the information asymmetry to be resolved by public information disclosure.

Documented lending patterns are consistent with lenders being more willing to lend to transparent borrowers with more information available on them after the disclosures. To an extent to which more public information available on the borrower can be associated with a lower degree of information asymmetry, identified fund lending patterns are consistent with hypothesis that public information disclosure alleviates information asymmetry between lenders and borrowers in the money markets.

Next, I show that these result also hold when observations are restricted only to the banks subject to DFAST. Using staggered implementation of mandatory DFAST disclosures, I am able to distinguish between the treated and control groups while focusing only on the banks subject to the DFAST policy (all U.S.-domiciled). In this specification the subset of banks included in the first round of DFAST disclosure represents the treated group. Banks exempt from the first round of DFAST but known to be included in disclosures from the second round represent the control group. Variables T_1, T_2 and T_3 are dummy variables capturing different time periods over the calendar time after DFAST rule was introduced. Variable T_1 is equal to 1 for time periods from October 2012 to February 2013, encompassing the anticipation period for the DFAST banks included in the first round of disclosures. Variable T_2 is a dummy equal to 1 between the first two rounds of DFAST, spanning from March 2013 to February 2014. During this period DFAST subject banks have different realized levels of transparency, measured by the stress test results disclosure. Finally, variable T_3 is equal to 1 after

March 2014 spanning the period after the second round of DFAST disclosure when all DFAST banks have become transparent.

Similar to previous results, Table 1.6 shows that funds on average increase their lending to banks included in the 1st round DFAST disclosure by 12.1% more when loans are measured in dollar terms, and by 20.5 basis points more in terms of portfolio exposure, after their DFAST results are disclosed in March 2013, while exempt banks remain non-transparent. After March 2014, when all DFAST banks had their stress test results disclosed at least once, there is no significant difference in fund lending between the two bank groups. It is worth acknowledging that the result on the increased lending to banks disclosed in the first round of DFAST may as well be attributed to a decline in lending to exempt banks prior their disclosure. Still, the captured dynamics corresponds to the identified differences in fund lending between transparent and non-transparent banks in Table 1.5. This mitigates concerns that the unobserved differences between DFAST covered (transparent) and foreign banks (non-transparent) may be driving the results on fund increased lending to transparent banks after information disclosure.

Next, I analyze the changes in the average loan maturity between the loans granted to transparent and non-transparent banks after DFAST disclosure has been introduced. As before, the transparent banks are defined as all DFAST covered banks, while the non-transparent banks are foreign banks not covered byh the DFAST rule. Using the same difference-in-differences specification given in (1.2), I focus on the weighted average maturity of a fund-bank loan as a dependent variable. Coefficients $\beta_{Interim}$ and β_{Post} now capture differences in the changes of the average loan maturity granted by the fund to transparent relative to non-transparent banks, during anticipation and after DFAST disclosure.

Table 1.7 shows that during anticipation of the disclosure, DD estimate $\beta_{Interim}$ is significant and negative. An average fund decreases the maturity of loans granted to transparent compared to non-transparent banks by 4.6 days more during the anticipation period. This result may indicate that lenders have incentives to coordinate due to the announced public disclosure (for example see Morris and Shin [2004], Goldstein and Pauzner [2005] for theory, and Hertzberg et al. [2011] for empirical evidence on lender coordination motives). Lenders may choose to abstain from lending before the information becomes public, in order to avoid holding securities of the issuer once the negative information on the issuer is publicly disclosed.

The results show that an average fund increases loan maturity to transparent banks by 3.23 days more than to the non-transparent banks, after public disclosure takes place. Longer term lending is consistent with the lower level of information asymmetry between lenders and borrowers. From the lender's perspective, the value of the early liquidation option is lower when more information is available on the borrowers (see Berglöf and von Thadden [1994], Hart and Moore [1994], Bolton and

Scharfstein [1996]).

Presented results on the increased fund lending and loan maturities to transparent banks are consistent with a decline in information asymmetries between fund lenders and banks included in the stress testing. However, observed loans represent equilibrium lending outcomes. Thus, it is plausible that a change in lending outcomes comes from transparent banks increasing their overall demand for MMF borrowing after disclosure. This would also result in a greater increase in fund holdings of transparent banks' debt. In order to further investigate if public disclosures mitigate information asymmetries, I exploit the heterogeneity in lenders' sensitivity to disclosure based on differences in the amount of private information they may have on the banks before any disclosures happening.

If public information in the form of DFAST results disclosure indeed alleviates informational asymmetries between MMF and banks in the money markets, this effect should be stronger for funds with less private information on the borrowers. Consequently, funds with less private information are expected to increase their lending to transparent banks more, after public information disclosure. For these funds the public disclosure reduces the level of information asymmetry with respect to borrowers the most.

Drawing on the relationship lending literature I use the strength of lending relationships to distinguish between lenders with different amount of private information on borrowers prior DFAST disclosure. Theories on relationship lending postulate that the stronger lending relationship allows the lender to gather more private information on the borrower, thus reducing the problems of asymmetric information (Berger and Udell [1995], Rajan [1992], Petersen and Rajan [1994], Boot [2000]).

Similar to Bharath et al. [2007] and Cocco et al. [2009], I define measures of lending relationship strength using quantity of fund lending to a particular bank prior to introduction of the DFAST policy. The strength of lending relationship per fund-bank pair is defined using the average fraction of fund's portfolio invested in bank's securities during the pre-DFAST period. A fund-bank relationship is classified as strong if fund-portfolio exposure to a bank is above the median fund portfolio exposure to any bank fund lends to prior to DFAST is introduced (fund-based measure). The second measure classifies a fund-bank relationship as strong if the fund-bank portfolio exposure is above bank's median loan granted by any fund lending to the bank prior to the introduction of the DFAST (bank-based measure).

Assuming that a stronger lending relationship implies that the fund has more private information on the bank, I expect to find that the public information disclosure has a stronger impact on lending outcomes of the weak relationship fund-bank pairs. As a first indication of heterogeneity induced by DFAST disclosure on different lending relationships, I estimate specification in (1.2) separately for strong and weak fund-bank relationships. Table 1.8 shows that among weak relationships, on average, a fund increases lending to transparent relative to non-transparent banks by 32.2% more, after disclosure of stress test results. On the other hand, there is no significant difference in the changes of fund lending to transparent relative to non-transparent banks after DFAST disclosure among the strong lending relationships. Since the strength of the relationship is assumed to be reciprocal to the information asymmetry between the lender and the borrower, a larger increase in lending for weak relationships is consistent with the public information disclosure being more impactful when previous information asymmetry is higher.

DD estimate capturing the differential in the changes in lending during the anticipation period points to another difference between the strong and weak lending relationships. Table 1.8 shows that within strong lending relationships, on average, a fund decreases lending to treated relative to control group banks by 12.1% (7% using the bank-based strength measure) during the anticipation period, prior to public information disclosure. This may be consistent with informed lenders adapting their lending decisions prior to the information becoming public. Informed lenders may prefer to abstain from lending to borrowers on which disclosed information may result in the negative reaction and withdrawal of funding by other lenders, thus aggravating borrower's ability to repay its outstanding loans. Next, I investigate in greater detail heterogeneity between funds with different private information on borrowers and how stress test result disclosures differently affect their lending decisions.

1.4.2 Public information disclosure and lending relationships in the money markets

Here, I directly test whether public information disclosure differently affects lending decisions of funds with more and less private information on borrowers. Using difference-in-differences specification given in (1.3), I compare differences in the changes of the same bank's borrowing from the funds with weak compared to strong lending relationships. Exploiting the granular loan level data combined with the borrower fixed effects (similar to Khwaja and Mian [2008] and Schnabl [2012]) allows to control for the bank level heterogeneity or changes in bank demand for money market debt that equally affect the funds. Thus, DD estimate of differential changes in lending between weak and strong relationship funds captures the effect of increase in available information on lending decisions of the uninformed relative to informed lenders.

$$\begin{aligned} loan_{f,b,t} &= \beta_{Interim} \times Interim_{b,t} \times Weak_{f,b} + \beta_{Post} \times Post_{b,t} \times Weak_{f,b} + u_{f,b,t} \\ u_{f,b,t} &= \alpha_b \times \tau_t + \alpha_b \times Weak_{f,b} + X_{f,t} + \varepsilon_{f,b,t} \end{aligned} \quad (1.3)$$

Dependent variable is (log) dollar loan of a fund f to bank b in a given month t. In this specification observations are restricted only to Transparent banks, capturing changes in fund lending during anticipation and post-disclosure periods relative to before DFAST was introduced. Treatment variable is defined at the fund-bank relationship level, using lending pattern from before the introduction of DFAST to distinguish between strong and weak lending relationships with the weak lending relationships being the treated ones. Variables $Interim$ and $Post$ are time dummy variables defined as before, capturing the anticipation and the post-disclosure period for each bank.

Specification includes the interaction of bank and type of relationship fixed effects, which account for within bank differences in lending levels across funds with strong and weak lending relationships (and consequently different amount of private information on the bank). Second, it contains the interaction of bank and time fixed effects capturing the aggregate shocks differentially affecting bank's borrowing over time. Finally, some specifications also include the interaction of fund and time fixed effects which capture aggregate shocks differentially affecting fund lending over time.

Coefficients of interest are $\beta_{Interim}$and β_{Post} which represent DD estimates of differential change in bank's borrowings from weak compared to strong relationship funds during the anticipation period ($Interim$), and after public information disclosure happened ($Post$), relative to the period before DFAST was introduced. Thus, differential changes in lending estimate the effect of the announcement and the actual stress testing disclosure on funds, depending on the strength of their lending relationship with the banks. Table 1.9 shows that bank's borrowing from the weak relationship funds increases by 51.1% more (or by 42.3% more if using the bank-based relationship strength measure) compared to strong relationship funds, after the disclosure of stress test results.

In order to control for possibility that weak relationship funds increase their lending across all banks, irrespective of transparency, I employ triple-difference specification to estimate if the increase in lending by the weak compared to the strong relationship funds is more pronounced among the transparent relative to the non-transparent banks, after DFAST disclosure. This allows me to control for other contemporaneous shocks differently affecting MMF lending across weak and strong lending relationships. The results in Table 1.10 indicate that after DFAST disclosure weak relationship funds increase their lending to transparent banks by 24.3% more than to non-transparent banks, compared to the same change for the strong relationship funds.

Focusing on transparent banks' borrowing from lenders of different relationship strength, Table 1.9 shows that banks' increased borrowing from weak relationship lenders is positive and significant already during the disclosure anticipation period, as captured by the DD coefficient $\beta_{Interim}$. Although the magnitude of the coefficient is much lower, it follows that even during anticipation of the future information disclosure, weak relationship funds increase their lending by 14% (or 9.8% using bank-based relationship strength measure) more than strong funds, when lending to the same bank.

It is plausible that being included in disclosures represents a positive signal on banks' quality to less informed lenders. For example, stress testing may imply that banks will be supervised more closely by the regulator. Thus, the announcement of the future disclosure may prompt less informed lenders to increase lending during *Interim* period, while lenders with more private information are less sensitive to this announcement. Such reaction of the less informed lenders would yield homogeneous differences in lending between weak and strong relationship funds across all banks to be included in the disclosure.

However, the anticipation of disclosure may induce a heterogeneous reaction of informed lenders across banks of different quality. If strong relationship funds have more information on the banks prior to public disclosure, during the anticipation period they may choose to reduce their exposure to banks on which negative information is to be disclosed in DFAST. This may be a result of coordination incentives prompting informed lenders to change their lending prior to the information becoming public.[12] Previous findings, in Table 1.8 indicate that strong relationship funds actually decrease lending to transparent relative to non-transparent banks during the anticipation of disclosure period. In order to explore this possibility, and provide additional evidence on whether strong relationship funds have more private information on banks prior to disclosure, I analyze differences in fund lending conditional on banks' quality disclosed in the stress tests.

1.4.3 Changes in banks' money market borrowing, conditional on the quality disclosed in the stress tests

In order to expect any heterogeneity in fund lending to banks of different quality, prior to information on quality being disclosed, I rely on two assumptions. First, as in the previous analysis, the strength of the lending relationship is correlated with the amount of private information lender gathers about the borrower. Second, I assume that the private information gathered through a lending relationship is correlated with information disclosed in public disclosure of stress test results.

[12] This can be further supported by fund exposure to so-called headline risk, risk that their investors could withdraw their money from the MMF mentioned in the headlines as funding (being exposed) to a bank disclosed in the stress testing as a bad or an undercapitalized one.

Thus, in order to investigate whether privately informed lenders change their lending to good and bad banks before information on the bank quality becomes public, I define bank quality based on the information disclosed in the stress test. A bank is classified as 'bad' if it had a below-median result in its first stress test result disclosure.[13] Also, this allows me to claim that funds' decision to change lending is driven by the actual information content to be disclosed and the plausible effect that the dislcosure of that information will induce on other lenders in the money markets.

I use the specification in (1.4) to test whether, during the anticipation period, strong relationship funds differently change their lending to good and bad banks compared to the weak relationship funds. In particular, I am interested in tracing whether the differential changes in tested banks' borrowing from different lenders during the anticipation are driven by the strong relationship funds' decrease in lending to bad banks. Uninformed lenders are not expected to discriminate between banks before information on quality is disclosed.[14]

$$\begin{aligned} loan_{f,b,t} &= \beta_{Interim} \times Interim_{b,t} \times Strong_{f,b} + \beta_{Interim} \times Interim_{b,t} \times Strong_{f,b} + \\ &\quad + \beta_{Interim\theta} \times Interim_{b,t} \times Strong_{f,b} \times \theta_b + \beta_{Post\theta} \times Post_{b,t} \times Strong_{f,b} \times \theta_b + u_{f,b,t} \\ u_{f,b,t} &= \phi_f \times \tau_t + \alpha_b \times \tau_t + \theta_b \times Strong_{f,b} + X_{f,t} + \varepsilon_{f,b,t} \end{aligned} \tag{1.4}$$

Dependent variable is (log) dollar loan of fund f to bank b while the right hand side variables include the interactions of the bank and time fixed effects, $\alpha_b \times \tau_t$, as well as fund and time fixed effects, $\phi_f \times \tau_t$. These capture the time-varying shocks affecting each bank's borrowing, and each fund's lending patterns over time. Variable θ_b represents the bank's quality, and is equal to 1 for banks with below-median result in their first stress test result disclosure, i.e. the bad banks. Else, it is equal to 0 for banks with above-median stress test results i.e. good banks. The specification includes the interaction of the bank quality type and relationship fixed effects which account for within bank type (good vs bad) differences in borrowing levels across funds with strong and weak lending relationships. Coefficients of interest are DDD estimates $\beta_{Interim\theta}$ and $\beta_{Post\theta}$ which represent the differential in the changes of bad banks' relative to good banks' average borrowing from strong relative to weak relationship funds, during the anticipation period of the future public disclosure ($Interim$), and after public information disclosure happened ($Post$).

Table 1.11 shows that prior to the disclosure of stress test results, the average bad bank's borrowing

[13] Result used to specify the bank quality is based on the minimum stress tested capital ratio (Tier 1 capital)).

[14] In these specifications I restrict observations to capture only the effect of the first stress test disclosure across all banks (bank quality based on its first stress test results dislcosure), in order not to confound changes in lending induced by disclosure content of the second round of results. In my study, after the first disclosure took place the banks are considered transparent.

from its strong relationship lenders decreases by 22.9% (by 38% if relationship strength is measured using the bank-based measure) more than borrowing from weak relationship lenders. On the other hand, the coefficient capturing the difference in good bank's borrowing from strong compared to weak relationship lenders during the anticipation period, is negative yet not significant when using fund-based strength measure, but positive and significant for the bank-based strength measure. This implies that, if anything, strong relationship funds increase lending to the good banks more relative to the weak relationship funds. Also, strong relationship funds decrease their lending to bad banks before the stress test results are disclosed.

Once the information on bank quality is disclosed, an average good bank's borrowing from its strong relationship lenders decreases by 35% relative to borrowing from the former weak relationship lenders. This implies that weak relationship funds increase their lending significantly more to banks disclosed as good once the stress test results become public. Lending to banks disclosed as bad does not significantly differ between strong and weak relationship lenders. It is plausible that after information on bank quality is disclosed, the risk-return trade-off for bad banks makes all lenders either equally willing or equally reluctant to lend to these banks.

Presented evidence is consistent with the hypothesis that public information disclosure reduces information asymmetry between lenders and borrowers, particularly among fund-bank pairs with previously weak lending relationships. Disclosures allow banks to expand their borrowing from funds with which they previously had weak lending relationships. However, the effect is heterogeneous across banks conditional on the information revealed in the stress test results.

1.5 Discussion

Presented evidence is consistent with the hypothesis that public information disclosures reduce information asymmetry between lenders and borrowers, particularly among fund-bank pairs with previously weak lending relationships. Disclosures allow banks to expand their uncollateralized borrowing from funds with which they previously had weak lending relationships. To further support this hypothesis I investigate differential in secured fund lending to the same bank conditional on the strength of the lending relationship . Due to the existence of collateral, this type of lending should be less affected by the lender-borrower information asymmetry. Therefore, there should be no significant increase in weak relative to strong relationship fund collateralized lending to stress-tested banks after the disclosure of stress test results.

Using the same relationship strength classification previously defined, I analyze whether weak relative to strong relationship funds change their collateralized lending to DFAST banks differently after introduction of DFAST. Collateralized lending is comprised of Government Agency and Treasury collateralized repo securities.

Table 1.12 shows that after DFAST disclosure the same bank's collateralized borrowing from its weak relationship funds decreases, on average, by 54.3% more relative to borrowing from its strong relationship funds. At the same time weak relationship funds increase their uncollateralized lending to transparent banks more, as previously shown. This is consistent with lenders being more willing to substitute the former collateralized lending with uncollateralized loans after more information about the borrowers has been disclosed. Uncollateralized lending bears more risk, but also comes at a higher yield. More public information disclosed on banks and inherent supervision of DFAST banks by the regulator may prompt funds to lend more to these banks through unsecured loans as this would allow them to earn higher yield, while the probability of a sudden negative shock or news dislcosed on these borrowers is lower, given the higher amount of already disclosed public information.

Evidence presented is consistent with the asymmetric information story and increased public disclosures alleviating information asymmetry between less informed lenders and disclosing banks. However, this interpretation relies on the assumption that any changes in bank demand, if any, equally affect all lenders irrespective of the lending relationship strength. If this is not the case, documented lending patterns could be subject to alternative interpretation.

For example, it is plausible that measures used to classify lending relationships into strong and weak are correlated with some other constraints determining fund lending. Strength of lending relationships is defined using fund portfolio exposure to each particular borrower. This classification of lending relationships could be correlated with risk management limits funds set for exposures to individual borrowers. Money market fund portfolio limits are regulated under Rule 2A-7 of the 1940 Invetsment Company Act such that funds must limit their exposure to no more than 5% of fund assets invested in uncollateralized securities of any single issuer. In the sample, funds' average portoflio exposures are at 2.3%. Although funds could expand their lending without the portfolio limit constraint binding, they could also have their own internal risk management contraints set at different optimal levels.

Finding that weak relationship funds expand their lending to transparent banks more than strong relationship funds is consistent with strong relationship funds already having saturated lending positions with respect to these banks. Therefore, strong relationship funds are not able to expand their lending more without breaching their internal portfolio limits. In that case, presented results can be interpreted as evidence for the importance of risk management in the money market fund industry and how existing fund exposures may determine lenders that are more able to absorb increased debt issuance by certain borrowers.

1.6 Conclusion

In this paper, I document the effects of increased public information disclosure on lending outcomes in the money markets. Introduction of Dodd-Frank Act Stress Testing policy and mandatory stress test results disclosure is used as a shock to availability of public information on banks. In order to capture the effect of increased public information I analyze differential changes in money market fund lending between transparent (stress tested) and non-transparent (non-tested) banks using micro data on money market fund portfolio holdings. My results indicate that funds increase their lending to transparent relative to non-transparent banks, after DFAST results are disclosed. These results are consistent with more available information reducing problems of adverse selection or moral hazard between the lender and the disclosing borrowers.

In order to further investigate whether stress testing disclosures reduce information asymmetries between lenders and disclosing banks in the money markets, I use the strength of lending relationships to distinguish between funds with different sensitivity to disclosures. Namely, I rely on the assumption that the strength of lending relationship is correlated with the amount of private information lender gathers on the borrower. Lenders with more private information should be less affected by public information disclosures. My results indicate that bank's borrowing increases significantly more from weak compared to strong relationship funds after DFAST results disclosure. This is consistent with public disclosure mitigating information asymmetries between less informed MMF and disclosing banks.

In addition, my results indicate that differential changes in lending between informed and uninformed funds exist during the period of disclosure anticipation. By exploiting the informational content of the disclosed stress test results, I show that the strong relationship funds decrease their lending to banks wth below-median stress test results more during the disclosure anticipation period. This is consistent with privately informed lenders adjusting their lending beforehand in anticipation of negative information disclosure. During the same period, there is no significant difference in strong relative to weak relationship funds' lending to banks with above-median stress test results.

Regulators in favour of greater transparency and information disclosure in the financial system argue that an increase in available information serves as a disciplining device for disclosure-making financial institutions. My results show that stress test result disclosures did affect lending outcomes in the money markets. Disclosures allow banks to expand their borrowing from previously weak lending relationship funds. However, the effect is heterogeneous across banks conditional on their quality revealed in the stress test results. Banks disclosed as good are able to increase their money market borrowing, while the banks disclosed as bad may suffer from a decline in their borrowing after the introduction of disclosures. Identified lending patterns are consistent with previously less informed lenders learning from the public information dislcosures.

1.7 Tables and figures

Figure 1.1: Transparent vs. non-transparent banks: (ln) dollar loan

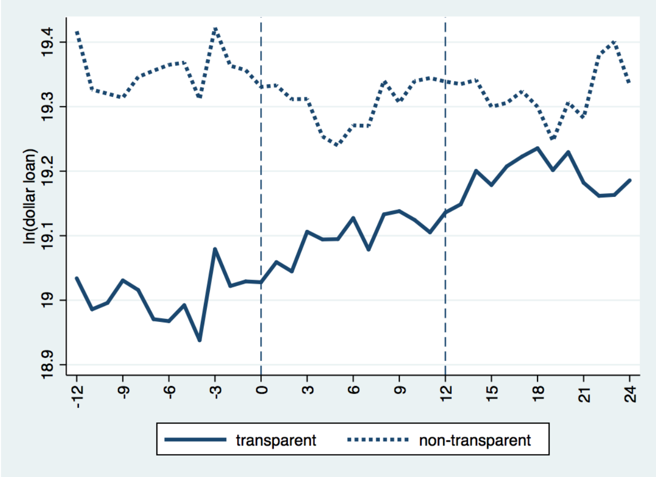

Figure 1.2: Transparent banks: strong vs. weak lending relationship (fund portfolio exposure)

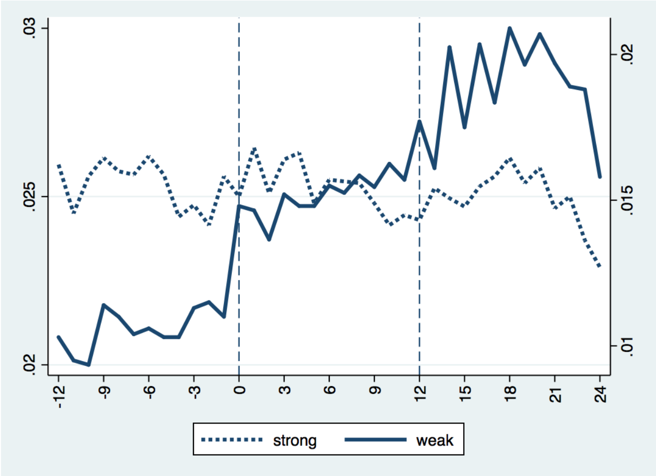

Table 1.1: Summary statistics: Funds

The table reports summary statistics on 164 prime money market funds over the sample period from October 2011 to March 2015. Portfolio maturity and fund age are based on the total fund portfolio holdings, while bank portfolio maturity is the weighted average maturity of the fund exposure to all banks in the sample. Fund yield is the yield on the total portfolio, as reported by the funds in their N-MFP forms. Unsecured lending to transparent banks represents the fraction of the fund's total sample lending invested in transparent banks' uncollateralized securities.

			Percentile		
	Mean	SD	p25	p50	p75
Total Net Assets (millions)	8,790	17,900	432	1,470	10,200
Portfolio maturity (days)	42	11	35	44	51
Fund age (days)	67	24	49	67	86
Fund yield (bps)	21	7	16	20	25
Bank Portfolio maturity	40	20	28	39	50
Unsecured lending to Transparent (%)	0.45	0.19	0.33	0.44	0.55

Table 1.2: Summary statistics: Transparent and non-transparent banks

This table reports summary statistics for transparent, i.e. DFAST covered banks and non-transparent, i.e. foreign banks not subject to DFAST. The unit of observation is at the bank-month level. Bank's unsecured debt is defined as the sum of all uncollateralized money market securities issued by the bank and held by prime money market funds in a given month. *% Strong relationships* represents a percentage of strong relationship lenders in the total number of funds lending to the bank in a given month.

			Percentile		
	Mean	SD	25	50	75
Transparent					
Debt outstanding (millions)	10,400	15,100	23.5	1,460	18,000
Unsecured debt (millions)	7,810	12,800	21,9	558	11,500
Unsecured debt (%)	0.82	0.29	0.78	0.99	1
Maturity (days)	68	84	11	38	77
Number of lenders	29	37	2	9	46
% Strong relationships	0.33	0.28	0	0.33	0.54
Non-transparent					
Debt outstanding (millions)	26,700	19,300	6,370	26,800	43,800
Unsecured debt (millions)	21,200	17,400	2,910	18,400	37,700
Unsecured debt (%)	0.72	0.24	0.55	0.78	0.93
Maturity (days)	33	18	19	34	45
Number of lenders	64	39	25	65	98
% Strong relationships	0.36	0.25	0.14	0.39	0.58

Table 1.3: Summary statistics: Loans to transparent and non-transparent banks

This table reports summary statistics for the fund-bank loans. It compares loans to transparent and non-transparent banks, before and after DFAST introduction. A fund-bank loan is defined as the fund's dollar holdings of all unsecured money market securities issued by a particular bank, while portfolio exposure represents the loan expressed as a percentage of the fund's net assets in a given month. *New loans granted* represents the fraction of the total loans granted by the fund, during the Post-DFAST period, to transparent or non-transparent issuers without any prior lending relationship with the fund in the pre-DFAST period.

			Percentile					Percentile		
	Mean	SD	25	50	75	Mean	SD	25	50	75
	Transparent banks									
	Pre-DFAST					Post-DFAST				
Fund-bank loan (millions)	202	472	10	44.3	182	218	507	10	37	191
Portfolio exposure (%)	2.24	1.90	0.8	1.8	3.3	2.25	1.71	0.93	1.93	3.17
Loan maturity (days)	47	62	9	26	59	52	55	16	37	70
New loans granted						0.52	0.36	0.50	0.50	0.60
	Non-transparent banks									
	Pre-DFAST					Post-DFAST				
Fund-bank loan (millions)	261	560	14.8	51	260	254	547	12.3	49	238
Portfolio exposure (%)	2.57	1.61	1.25	2.34	3.8	2.48	1.62	1.19	2.25	3.51
Loan maturity (days)	34	36	7	25	48	39	36	10	31	59
New loans granted						0.23	0.20	0.10	0.23	0.33

Table 1.4: Summary statistics: Loans conditional on the relationship strength

This table reports summary statistics for the fund-bank loans, conditional on the fund-bank lending relationship strength. Statistics are reported separately for strong and weak lending relationships, during pre-DFAST (October 2011- September 2012) and post-DFAST periods (October 2012- March 2015). A loan is defined as the fund dollar holdings of all securities issued by a particular bank, while portfolio exposure is the loan expressed as a percentage of the fund's net assets in a given month. *Lending relationship persistence* is defined as a frequency of fund lending to the bank, expressed as a percentage of time periods during which the fund lends to a bank.

			Percentile					Percentile		
	Mean	SD	25	50	75	Mean	SD	25	50	75
	Strong relationships (fund based)									
	Pre-DFAST					Post-DFAST				
Fund-bank loan (millions)	291	596	19	72	306	300	638	14.3	52	294
Portfolio exposure (%)	3.05	2.01	1.64	2.62	4.09	2.74	1.87	1.4	2.37	3.73
Lending relationship persistence (%)	0.73	0.31	0.45	0.82	1	0.75	0.31	0.55	0.93	1
	Weak relationships (fund based)									
	Pre-DFAST					Post-DFAST				
Fund-bank loan (millions)	90.10	189	5	22	92	158	370	7.7	29	150
Portfolio exposure (%)	1.26	1.18	0.38	0.86	1.72	1.72	1.38	0.64	1.37	2.53
Lending relationship persistence (%)	0.51	0.31	0.27	0.45	0.82	0.56	0.32	0.31	0.55	0.90

Table 1.5: Lending to transparent vs. non-transparent banks

The dependent variable in columns 1-2 is the (log) of fund-bank dollar loan, while in columns 3-4 the dependent variable is the loan expressed as a percentage of the fund's net assets (portfolio exposure). Variable *Interim* is a time dummy equal to 1 during the period of disclosure anticipation, while *Post* is equal to 1 during the post-disclosure period. *Transparent* is an indicator variable for the banks subject to DFAST disclosures. *Fsize* is defined as the (ln) of fund net assets and *Fage* is the weighted average maturity of the fund portfolio. Specifications include fund and time fixed effects and errors clustered at the fund level.

Dependent variable:	*ln(Fund-bank dollar loan)*		*Fund-bank portfolio exposure*	
	(1)	(2)	(3)	(4)
Transparent	-0.300	-0.289***	-0.00341**	-0.00340***
	(0.281)	(0.0624)	(0.00135)	(0.00127)
Interim x Transparent	-0.0143	-0.0282	-0.00152***	-0.00149***
	(0.0519)	(0.0339)	(0.000559)	(0.000560)
Post x Transparent	0.166**	0.153***	0.00192***	0.00194***
	(0.0644)	(0.0380)	(0.000674)	(0.000684)
Fsize		0.935***		-0.00133***
		(0.0188)		(0.000381)
Fage		0.002		0.0001
		(0.0011)		(0.0001)
Fund FE	yes	yes	yes	yes
Time FE	yes	yes	yes	yes
N	64736	64736	64736	64736
adj. R^2	0.556	0.814	0.141	0.148

Standard errors in parentheses: clustered at the fund level
* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Table 1.6: Lending within transparent banks: exploiting the staggered rule implementation

In columns 1-2 the dependent variable is the (log) of fund-bank dollar loan, while in columns 3-4 the dependent variable is fund-bank portfolio exposure. Variable *Transparent First* is an indicator equal to 1 for the banks included in the first round of DFAST representing the treated group in these specifications. The control group are the banks exempt from the first round of disclosures but covered by the DFAST rule. Here, *T1* is a time dummy equal to 1 during the months from October 2012 to February 2013, which is the anticipation period for the treated banks. *T2* is equal to 1 for the time periods between the first two rounds of DFAST, from March 2013 to February 2014. *T3* is equal to 1 from March 2014 onwards, spanning the period after the second round of disclosures when all DFAST banks are transparent.*Fsize* s defined as the (ln) of fund net assets, while *Fage* is the weighted average maturity of the fund portfolio. Specifications include fund and time fixed effects and errors clustered at the fund level.

Dependent variable:	*ln(Fund-bank dollar loan)*		*Fund-bank portfolio exposure*	
	(1)	(2)	(3)	(4)
Transparent First	0.0759	0.0657	0.00264***	0.00267***
	(0.0541)	(0.0536)	(0.000894)	(0.000893)
T1 x Transparent First	-0.0107	0.000739	0.00110	0.00107
	(0.0472)	(0.0464)	(0.000784)	(0.000786)
T2 x Transparent First	0.100*	0.121**	0.00212**	0.00205**
	(0.0544)	(0.0529)	(0.000880)	(0.000887)
T3 x Transparent First	0.0124	0.0216	-0.000129	-0.000177
	(0.0590)	(0.0571)	(0.000909)	(0.000910)
Fsize		0.858***		-0.00201**
		(0.0523)		(0.000909)
Fage		0.00295**		0.0000422**
		(0.00130)		(0.0000200)
Fund FE	yes	yes	yes	yes
Time FE	yes	yes	yes	yes
N	30056	30056	30056	30056
adj. R^2	0.772	0.785	0.200	0.201

Standard errors in parentheses:clustered at fund level

* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Table 1.7: Loan maturity: Transparent vs. non-transparent banks

The dependent variable is the weighted average maturity of the fund-bank loan.Variable *Interim* is a time dummy equal to 1 during the period of disclosure anticipation, while *Post* is equal to 1 during the post-disclosure period.*Transparent* is an indicator variable for the banks subject to DFAST disclosures, representing the treated group, while the control group comprises of foreign banks not covered by the DFAST rule. Variable *ln(loan)* is the (ln) of fund-bank dollar loan. *Fsize* is defined as the (ln) of fund net assets and the, while *Fage* is the weighted average maturity of the fund portfolio. Specifications include fund and time fixed effects and errors clustered at the fund level.

	Dependent variable: *Loan maturity*		
	(1)	(2)	(3)
Transparent	14.65***	14.69***	12.80***
	(3.066)	(3.004)	(2.754)
Interim x Transparent	-4.445**	-4.405***	-4.589***
	(1.633)	(1.634)	(1.605)
Post x Transparent	2.219	2.235	3.237*
	(1.817)	(1.796)	(1.717)
Fsize		-1.443	4.667***
		(1.181)	(1.422)
Fage		0.0442	0.0541
		(0.0598)	(0.0564)
ln(loan)			-6.532***
			(1.262)
Fund FE	yes	yes	yes
Time FE	yes	yes	yes
N	64736	64736	64736
adj. R^2	0.114	0.115	0.130

Standard errors in parentheses: clustered at the fund level
* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Table 1.8: Lending to transparent vs. non-ransparent banks conditional on the lending relationship

Dependent variable is the (ln) of fund-bank dollar loan and specifications are run separately for the funds' strong and weak lending relationships. The fund-based measure classifies the lending relationship as strong if the fund-bank portfolio exposure is above the median value for the fund. The bank-based measure classifies the lending relationship as strong if the portfolio exposure if above the median value for the bank. Variable *Interim* is a time dummy equal to 1 during the period of disclosure anticipation, while *Post* is equal to 1 during the post-disclosure period. *Transparent* is an indicator variable for the banks subject to DFAST disclosures. *Fsize* is defined as the (ln) of fund net assets and the, while *Fage* is the weighted average maturity of the fund portfolio. Specifications include fund and time fixed effects and errors clustered at the fund level.

Dependent variable: *ln(Fund-bank dollar loan)*				
	Strong relationships		Weak relationships	
	fund-based	bank-based	fund-based	bank-based
	(1)	(2)	(3)	(4)
Transparent	-0.189***	-0.214***	-0.488***	-0.377***
	(0.0598)	(0.0501)	(0.0883)	(0.0687)
Interim x Transparent	-0.121***	-0.0691*	0.0682	0.0600
	(0.0417)	(0.0392)	(0.0543)	(0.0538)
Post x Transparent	0.0457	0.0565	0.322***	0.250***
	(0.0499)	(0.0485)	(0.0591)	(0.0465)
Fsize	0.972***	0.975***	0.883***	0.967***
	(0.0181)	(0.0173)	(0.0257)	(0.0182)
Fage	0.000460	-0.00126	0.00203	0.00420***
	(0.00124)	(0.00113)	(0.00143)	(0.00107)
Fund FE	yes	yes	yes	yes
Time FE	yes	yes	yes	yes
N	30897	27296	26278	29878
adj. R^2	0.874	0.861	0.821	0.832

Standard errors in parentheses: clustered at the fund level
* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Table 1.9: Lending to transparent banks: Weak vs. strong lending relationship

Dependent variable is the (ln) of fund-bank dollar loan. Regressions are restricted to banks subject to DFAST and compare the same bank's borrowing from its weak and strong relationship funds before and after DFAST disclosure. *Weak* is an indicator variable equal to 1 for the fund-bank lending relationship classified as weak using any of the two measures both defined using the pre-DFAST period.The fund-based measure classifies the relationship as weak if the fund-bank portfolio exposure is below the median value for the fund. The bank-based measure classifies the lending relationship as weak if the portfolio exposure is below the median value for the bank. Variable *Interim* is a time dummy equal to 1 during the period of disclosure anticipation, while *Post* is equal to 1 during the post-disclosure period.*Fsize* is defined as the (ln) of fund net assets and the, while *Fage* is the weighted average maturity of the fund portfolio. Specifications include different fixed effects and errors are clustered at the fund level.

	Dependent variable: *ln(Fund-bank dollar loan)*					
	fund-based			bank-based		
	(1)	(2)	(3)	(4)	(5)	(6)
Weak	-0.770***			-1.040***		
	(0.042)			(0.035)		
Interim x Weak	0.204***	0.166***	0.140***	0.249***	0.169***	0.0981**
	(0.055)	(0.055)	(0.052)	(0.045)	(0.045)	(0.044)
Post x Weak	0.457***	0.438***	0.511***	0.505***	0.491***	0.423***
	(0.072)	(0.063)	(0.062)	(0.057)	(0.056)	(0.056)
Fsize	0.923***	0.925***		0.959***	0.960***	
	(0.012)	(0.012)		(0.008)	(0.008)	
Fage	-0.0007	-0.0007		0.0003	0.0003	
	(0.0011)	(0.0011)		(0.0008)	(0.0008)	
Bank x Time FE	yes	yes	yes	yes	yes	yes
Bank x Weak FE	no	yes	yes	no	yes	yes
Fund x Time FE	no	no	yes	no	no	yes
N	26246	26246	25636	26246	26246	25636
adj. R^2	0.834	0.837	0.853	0.854	0.857	0.858

Standard errors in parentheses: clustered at the fund level
* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Table 1.10: Transparent and non-transparent banks: Weak vs. strong relationship lending to the same bank

Dependent variable is the (ln) of fund-bank dollar loan. Triple-difference specification is used to estimate differential in the changes of weak compared to strong relationship lending to transparent relative to non-transparent banks, before and after DFAST disclosure. *Weak* is an indicator variable equal to 1 for the fund-bank lending relationship classified as below-median pre-DFAST portfolio exposure. The median value corresponds to the fund or to the bank, depending on the measure used. *Transparent* is an indicator variable for the banks subject to DFAST disclosures. Variable *Interim* is a time dummy equal to 1 during the period of disclosure anticipation, while *Post* is equal to 1 during the post-disclosure period.*Fsize* is defined as the (ln) of fund net assets and the, while *Fage* is the weighted average maturity of the fund portfolio. Specifications include different fixed effects and errors are clustered at the fund level.

	Dependent variable: *ln(Fund-bank dollar loan)*			
	fund-based		bank-based	
	(1)	(2)	(3)	(4)
Interim xTransparent x Weak	0.0618	0.0541	-0.00232	-0.0125
	(0.0605)	(0.0671)	(0.0625)	(0.0600)
postw3f	0.243***	0.229***	0.139**	0.112*
	(0.0689)	(0.0850)	(0.0614)	(0.0627)
Fsize	0.932***	0.935***	0.970***	0.974***
	(0.0171)	(0.0169)	(0.0119)	(0.0118)
Fage	0.000160	0.000158	0.00105	0.00106
	(0.00168)	(0.00167)	(0.00118)	(0.00118)
Fund x Time FE	yes	yes	yes	yes
Transparent x Weak FE	yes	yes	yes	yes
Weak x Time FE	yes	yes	yes	yes
Transparent x Time FE	yes	no	yes	no
Bank FE	yes	no	yes	no
Bank x Time FE	no	yes	no	yes
N	56926	56894	56926	56894
adj. R^2	0.857	0.866	0.867	0.875

Standard errors in parentheses:clustered at the fund level
* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Table 1.11: Lending to good and bad banks conditional on lending relationships

Dependent variable is the (ln) of fund-bank dollar loan. Regressions are restricted to banks subject to DFAST and compare if strong compared to weak relationship funds differently change their lending to good and bad banks that are to become transparent. Coefficients on the interaction with the *Interim* captures differential changes in lending during the period of disclosure anticipation, while the coefficients on the interaction with the *Post* capure differential lending during the post-disclosure period. *Strong* is an indicator variable equal to 1 for the fund-bank lending relationship classified as above-median portfolio exposure where the median value corresponds to the fund or the bank, depending on the measure used. Relationship strength measure is defined using portfolio exposures from the pre-DFAST period.*Fsize* is defined as the (ln) of fund net assets and the, while *Fage* is the weighted average maturity of the fund portfolio. Specifications include different fixed effects and errors are clustered at the fund level.

Dependent variable: *ln(Fund-bank dollar loan)*				
	fund-based		bank-based	
	(1)	(2)	(3)	(4)
Interim x Strong	-0.00108	-0.00644	0.134*	0.137*
	(0.0852)	(0.0885)	(0.0751)	(0.0728)
Post x Strong	-0.234*	-0.353**	-0.337***	-0.357**
	(0.139)	(0.152)	(0.0990)	(0.108)
Interim x Strong x Bad	-0.265***	-0.229**	-0.435***	-0.380***
	(0.0976)	(0.105)	(0.0866)	(0.0951)
Post x Strong x Bad	-0.142	-0.0252	-0.0386	0.0996
	(0.140)	(0.153)	(0.103)	(0.144)
Fsize	0.968***		0.974***	
	(0.0475)		(0.0430)	
Fage	0.00247**		0.00245**	
	(0.00104)		(0.000974)	
Fund FE	yes	no	yes	no
Fund x Time FE	no	yes	no	yes
Strong x Bad FE	yes	yes	yes	yes
Bank x Time FE	yes	yes	yes	yes
N	21375	20300	21375	20300
adj. R^2	0.866	0.854	0.873	0.861

Standard errors in parentheses
* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Table 1.12: Collateralized lending to transparent banks: strong vs. weak lending relationships

Dependent variable is the (ln) of fund-bank dollar secured loan comprising of Government Agency and Treasury collateralised repo securities. Regressions are restricted to banks subject to DFAST and compare the same bank's borrowing from its weak and strong relationship funds before and after DFAST disclosure. *Weak* is an indicator variable equal to 1 for the fund-bank lending relationship classified as weak using any of the two measures both defined using the pre-DFAST period.The fund-based measure classifies the relationship as weak if the fund-bank portfolio exposure is below the median value for the fund. The bank-based measure classifies the lending relationship as weak if the portfolio exposure is below the median value for the bank. Variable *Interim* is a time dummy equal to 1 during the period of disclosure anticipation, while *Post* is equal to 1 during the post-disclosure period.*Fsize* is defined as the (ln) of fund net assets and the, while *Fage* is the weighted average maturity of the fund portfolio. Specifications include different fixed effects and errors are clustered at the fund level.

	Dependent variable: *ln(Fund-bank dollar loan)*					
	fund-based			bank-based		
	(1)	(2)	(3)	(4)	(5)	(6)
Weak	0.0756			-0.174		
	(0.197)			(0.187)		
Interim x Weak	-0.183	-0.133	-0.290	-0.0703	-0.0397	0.0872
	(0.173)	(0.150)	(0.237)	(0.156)	(0.127)	(0.294)
Post x Weak	-0.602***	-0.418**	-0.543**	-0.466**	-0.307*	-0.378
	(0.208)	(0.196)	(0.263)	(0.191)	(0.178)	(0.281)
Fsize	0.723***	0.721***		0.734***	0.737***	
	(0.0432)	(0.0405)		(0.0445)	(0.0394)	
Fage	-0.0104**	-0.0114***		-0.00931**	-0.00780*	
	(0.00411)	(0.00383)		(0.00424)	(0.00352)	
Bank x Time FE	yes	yes	yes	yes	yes	yes
Bank x Weak FE	no	yes	yes	no	yes	yes
Fund x Time FE	no	no	yes	no	no	yes
N	3786	3786	1940	3786	3786	1945
adj. R^2	0.584	0.607	0.709	0.589	0.619	0.693

Standard errors in parentheses: clustered at the fund level
* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Chapter 2

Where did the money go? Evidence from money market funds on the portfolio balance channel of Quantitative Easing

2.1 Introduction

What are the effects of Quantitative Easing (QE) on lending in the money markets? Quantitative Easing is an unconventional monetary policy which involves large scale asset purchases by the central bank with the aim to improve liquidity, affect interest rates and provide support to the overall economy. Quantitative Easing used the Federal Reserve's balance sheet as a tool aimed at achieving price stability, supporting economic growth and contributing to the decline of unemployment (Bernanke [2012]). The Federal Reserve Board posited the portfolio balance channel as the main transmission mechanism through which QE is to affect the economy. This mechanism assumes that due to a decline in QE targeted asset's availability and imperfect substitutability of assets, investors will substitute towards other asset classes and this will affect prices and yields of the broader spectrum of assets in the markets.[1]

This paper explores the changes in money market fund (MMF) lending decisions to identify the portfolio

[1]Based on the ideas of a number of well-known monetary economists, including Brunner and Meltzer [1972]Tobin [1969]Friedman and Schwartz [1982]Brunner and Meltzer [1972].

balance channel as a transmission mechanism of QE. In order to do so, it exploits the third wave of QE (QE3) implemented from October 2012 to October 2014 which involved Fed's extensive purchases of Agency Mortgage Backed Securities (Agency MBS). In the money markets, Agency MBS serve as a collateral for Agency repurchase agreement securities (Agency repo), widely held by MMF as part of their collateralized lending. Banks act as borrowers from the money markets using repo loans to fund Agency MBS held on their balance sheets. The Fed's extensive purchases of Agency MBS resulted in a decline of available collateral and consequently decline in Agency repo securities outstanding in the money markets. In the analysis to follow, I explore in detail the response of MMF prompted by these changes. One possibility is that MMF investors withdraw their funds from the money markets in the absence of collateralized securities to invest in. This would result in a decline of MMF assets size and cash available for investment. Alternatively, if there are no outflows from the money markets, funds may subsitute former repo loan investments by other asset classes within money markets, which would allow me to identify the substitution prompted by the portfolio balance channel within the money markets.

My main findings are that QE3 purchases of Agency MBS formerly used as collateral, do not result in investor outflows from the money markets, in spite of a declining availability of collateralized assets funds can invest in. Instead, I show that funds with above median exposure to QE3 increase their uncollateralized lending once QE3 is introduced. This suggests that QE3 freed up liquidity in the money market funds to be invested in other, uncollateralized securities. This is consistent with predictions of the portfolio balance channel being a transmission mechanism of the policy. However, the increase in funds' available liquidity does not evenly spread over all money market borrowers, but remains concentrated within former repo issuing banks. This implies that the effects of QE3 are heterogeneous, and highly depend on the previous distribution of the targeted asset.

First, I show that the introduction of QE3 and extensive purchases of Agency MBS coincide with the changes in the aggregate portfolio composition of prime money market funds. Between the period prior to QE3 (pre-QE3 period) and period when QE3 was introduced (post-QE3 period) the aggregate fund holdings of Agency repo securities decline from 11% to 7%. This is consistent with QE3 purchases targeting Agency MBS which banks previously funded through repo loans in the money markets, as previously shown by Elamin and Bednar [2014].

Exploring different plausible responses of MMF and their investors to the reduction in availability of Agency repo securities, I show that there has been no decrease in the size of money market assets overall. This implies that money market funds did not suffer from investor outflows due to decreased availability of collateralized securities. In fact, I show that on aggregate, QE3 resulted in the substitution of collateralized for uncollateralized debt in money market fund holdings. It follows that QE3 purchases of Agency MBS, formerly used as collateral in repo loans, freed up fund liquidity for investment in other securities. This is consistent with the proposed portfolio balance channel as a transmission mechanism of the QE policy.

However changes in the aggregate money market fund holdings may be affected by other contemporaneous aggregate shocks or simply driven by the changes in borrowers' demand for money market funding. Thus, I turn to a more granular analysis to identify the portfolio balance channel induced by QE3. At a macro level the challenge is, usually, to find an adequate control group unaffected by the macro effects of QE. Having micro data on security level MMF holdings allows to distinguish between funds differentially affected by QE3 by exploiting heterogeneity in fund holdings of QE3 affected securities (Government Agency repo). Cross-sectional variation in fund exposure to QE3 enables me to classify funds into a treated and control group. Thus, I employ a difference-in-differences identification strategy to isolate the effect of the QE3 induced portfolio balance channel on fund lending decisions. Additionally, fund-borrower loan level data allows me to control for the unobserved heterogeneity at the borrower level by employing borrower fixed effects.

I capture the intensity of fund's exposure to QE3 using the fund's average fraction of total assets invested in Government Agency repo securities before the introduction of QE3. The intensity of QE3 exposure varies significantly across funds, ranging from 0 to 77.7%, with the median exposure being 7.5%. A fund is classified as a high QE3 exposure fund (treated group) if it has above-median average portfolio holdings of Agency repo securities in the pre-QE3 period. Else, it is classified as a low QE3 exposure fund (control group).[2]

First, I show that funds with higher exposure to QE3 increase other lending by 6.05% more relative to lower QE3 exposure funds. This is consistent with QE3 purchases of MBS generating excess available liquidity for investment in other securities for funds with high pre-QE3 portfolio holdings of Agency repo. Other lending is defined as uncollateralized lending, excluding any Treasuries and Agency debt or any other government sponsored securities.

Next, I turn to granular fund-borrower loan level analysis to explore how increase in other lending is distributed across differrent borrowers. One possibility is that high exposure funds homogeneously increase other lending across all borrowers. However, it is plausible that the portfolio balance channel generates heterogeneous effects across borrowerrs. Similar to Khwaja and Mian [2008] and Schnabl [2012], I use the loan level data to estimate a difference-in-differences specification with borrower fixed

[2]My results are robust to using the actual percentage exposure as a continuous treatment variable as well as to using specifications that define treated and control group using the top and bottom quartile of the exposure distribution.

effects. A loan is defined as all other securities[3] issued by one borrower and held by the fund in its portfolio at a given date. Thus, in order to identify the effect of QE3 on fund lending I explore heterogeneity in fund exposure to QE3 to capture a differential between high and low QE3 exposure funds' lending to the same borrower.

When comparing fund lending across all borrowers, the coefficient on the differences in lending between high and low exposure funds to an average borrower is positive, yet not significant. However, when the set of issuers is restricted to banks, in particular former repo issuing banks, I find that the high QE3 funds increase their lending by 8.9% more than low QE3 exposure funds while lending to the same repo bank. This difference cannot be attributed to unobservable borrower characteristics, including changes in demand, since these equally affect all MMF. The results imply that the QE3 induced increase in other lending of high exposure funds, remains concentrated among former repo borrowers. Thus, the increase in available fund liquidity for other investments gets heterogeneously transmitted across issuers, with the former repo issuing banks absorbing most of it.

Funds' concentrated increase in uncollateralized lending to banks may be consistent with search for yield behaviour. In the low interest rate environment generated by QE3, funds find higher yield instruments attractive as they allow them to deliver higher returns to their investors and thus attract more investor flows (see Kacperczyk and Schnabl [2013] for evidence on fund yield chasing behaviour and Di Maggio and Kacperczyk [2017] for evidence on MMF behaviour in the low interest rate environment). At the same time, higher yield always comes at a higher risk. Therefore, uncollateralized lending to banks is consistent with for the same yield banks being considered safer relative to other issuers of uncollateralized securities, due to implicit support provided by the regulator.

For the banks previusly using repo loans to fund Agency MBS securities, selling MBS in exchange for liquid reserves with the Fed eliminated their repo positions and implied that they no longer need to raise funding for these securities. All else equal, this would have reduced the banks' overall money market borrowing. However, if these borrowers target particular levels of short-term leverage (Adrian and Shin [2010]), repaying repo loans may prompt their increased issuance of other types of money market securities, in order to keep the overall level of borrowing unchanged. Thus, lending which remains concentrated among former repo banks is consistent with banks' maintaining stable levels of short term borrowing from the money markets.

In order to test the hypothesis that banks subject to a larger decrease in the overall money market borrowing due to QE3 are more able or willing to absorb excess fund liquidity, I distinguish within repo banks based on the intensity of the QE3 induced shock to banks' overall level of money market debt. I

[3]Other securities comprise of all uncollateralized securities excluding Treasuries and Agency debt or any other government sponsored securities.

measure the intensity of the QE3 shock using the bank's average pre-QE3 fraction of MMF borrowing issued in Agency repo securities. Heterogeneity in repo issuing banks' QE3 exposure is significant. It ranges from only 0.4% up to 85.4% of total money market debt being issued in Agency repo, with the median being 19.6%. High QE3 exposure banks, also referred to as high repo borrowers, are defined as banks with the above-median fraction of debt issued in Agency repo securities prior to QE3. If banks target a certain level of short term debt, higher QE3 exposure implies that a bank will be more inclined to increase other borrowing, since a larger fraction of its money market debt is eliminated by its sales of MBS through QE3.

The results show that within repo issuing banks, high QE3 exposure banks increase total other borrowing by 22.2% more relative to low QE3 exposure repo banks. It follows that, after selling MBS to the Fed, banks increase their unsecured money market borrowing. This increases the liquidity of their balance sheets and may contribute to an expansion of their lending and further transmission of QE3 to the real economy (see Darmouni and Rodnyansky [2017] for evidence on the QE liquidity channel). Differences in total other borrowing of repo issuing banks of different QE3 exposures imply that these banks borrow in line with maintaining stable money market leverage. Alternative explanation is that these differences can be attributed to the heterogeneity of lenders from which different banks borrow, in particular high repo banks being more exposed to funds with a greater increase in available liquidity.

In order to understand the heterogeneity in lending stemming from the QE3 induced portfolio balance channel, I further explore what determines lending decisions at the fund level among funds with freed up liquidity to distribute. Restricting the analysis to high QE3 exposure funds, I investigate whether, at the fund level, lending to different repo banks is determined by banks' ability to absorb more money market funding. In order to control for fund heterogeneity, I use difference-in-differences with fund fixed effect specification to capture differential lending of the same fund between high and low QE3 exposed banks. Results imply that there is no significant difference in fund lending between repo banks of different QE3 exposure intensity. The borrower's ability to absorb liquidity does not seem to be the key determinant of lending decision at the fund level.

Second, as QE3 prompted funds to substitute their former collateralized for uncollateralized portfolio holdings, I explore whether the lack of collateral, and thus, increase in the riskiness associated with the new loans affects fund lending decisions. In particular, greater holdings of uncollateralized loans may have increased the emphasis funds put on portfolio diversification. This would prompt funds to limit their portfolio exposure to each borrower more than when lending through collateralized loans. In addition, money market fund regulation prescribes strict portfolio limits on funds' unsecured exposures to individual issuers. Thus, diversification motives combined with the existing portfolio exposure to unsecured debt issuers may play an important role in determining the distribution of the excess supply of funds across borrowers.

In order to analyze the importance of diversification motives for high QE3 exposure fund lending decisions within repo banks, I define two measures of the fund-borrower unsecured lending relationship diversification relying on the lending patterns during pre-QE3 period. A relationship is considered less diversified (more saturated) if the fund already holds large fraction of its portfolio in other securities issued by that particular borrower. If portfolio diversification motives are important, the fund increases other lending more to issuers with which it has a more diversified (non-saturated) lending relationship.

The first measure classifies a lending relationship as non-saturated if the fund's average pre-QE3 Agency repo lending to the issuer is larger than its non-repo lending to the same issuer. This measure includes only relatonships with positive average total lending during pre-QE3 period. The second measure uses the fund's pre-QE3 non-repo loans to classify a lending relationship as non-saturated if the fund's non-repo exposure to the borrower is below the fund's median non-repo exposure across all borrowers.[4]Relative to the first measure, the second measure includes the relationships in which the fund never lent to the borrower before the QE3 period.

Focusing on lending decisions of funds to repo issuers, high QE3 exposure funds, on average, increase other lending by 21.8% more to issuers with non-saturated unsecured lending relationships. The effect is even stronger when lending to new borrowers is included in non-saturated relationships. In that case, funds increase other lending by 43.7% more to issuers with non-saturated unsecured lending relationships. The larger magnitude of the lending increase when using the second measure implies that QE3 prompted funds to start lending to new borrowers through uncollateralized loans.[5]

These results suggest that less saturated borrowing relationships can absorb more of the available liquidity. The importance of diversification motives gave certain borrowers within repo banks an advantage in raising money market funding, after they sold their MBS to the Fed. In particular, being a former repo issuer with little or none non-repo borrowing from funds with increased available liquidity to QE3 purchases would allow for the largest expansion in unsecured money market borrowing.

This paper sheds light on the role of private investors in the transmission of QE3 effects, as they previously provided funding to banks for the QE3 targeted asset, Agency MBS. Without money market funds substituting former collateralized lending for the unsecured lending, QE3 would prompt banks to repay their repo loans without gaining much liquidity. Thus, it is the interaction of the

[4]Here, median is defined conditional on the group of borrowers, in particular, within repo issuing banks.

[5]This result complements previous studies on the effects of negative liquidity shocks on the money market fund lending. Chernenko and Sunderam [2014] show that when facing investor outflows, funds cut lending to the borrowers with weak lending relationships first. However, the implications of weak lending relationships may overturn in the presence of positive liquidity shocks, in particular when portfolio diversification limits become binding.

QE3 and the money markets that allowed banks to both sell their Agency MBS to the Fed and still raise more short term funding and plausibly expand their lending activity. My results show that QE3 yielded heterogeneous effects across money market borrowers, depending on their exposure to QE3, as captured by the fraction of total money market borrowing in the form of Agency repo securities.

The rest of the paper is organized as follows: Section 2 discusses the relevant literature. Section 3 outlines the institutional setting of quantitative easing and money markets. Section 4 gives an overview of the data and the empirical strategy, as well as summary statistics. Section 5 presents the results, and Section 6 concludes.

2.2 Literature review

My paper contributes to the literature on the impact of unconventional monetary policy, in particular literature on the transmission mechanisms of large scale asset purchases programmes.Within this literature a substantial number of papers focus on the macroeconomic consequences of quantitative easing by capturing the changes in the bond prices and interest rates induced by QE (see Gagnon et al. [2010], Krishnamurthy and Vissing-Jorgensen [2011], Krishnamurthy et al. [2013], Wright [2012], D Amico and King [2013] for evidence on the effects of Fed's QE programme;Joyce et al. [2011] and Breedon et al. [2012] for evidence on the effects of the Bank of England's large scale asset purchases). These papers consistently find that QE purchases of targeted longer-term securities coincide with the reduction of interest rates and relevant credit spreads.

The portfolio balance channel, proposed as the most prominent mechanism of QE, relies on economic theories and ideas presented in Tobin [1965, 1969], Friedman and Schwartz [1982], Modigliani and Sutch [1966] Brunner and Meltzer [1972]. The channel relies on the imperfect substitutability of assets in investors' portfolios (introduced by Vayanos and Vila [2009]), to generate increase in prices and decline in yields over a broader set of assets, as investors sell the QE targeted asset to the Fed and susbtitute towards other asset classes. Bernanke and Reinhart [2004] and Bernanke et al. [2004] provide a discussion and evaluation of the channel in the context of Fed's large-scale asset purchases. The literature aiming to identify the portfolio balance channel of QE mostly focuses on capturing a decrease in yields or credit spreads of the targeted asset and plausible substitute assets during different waves of Fed's QE (see Krishnamurthy et al. [2013], Gilchrist and Zakrajšek [2013] Stroebel and Taylor [2012])

Chodorow-Reich [2014] investigates the effects of QE on different classes of financial institutions focusing on the value of their assets and tendency to reach for yield in the low interest rates environment.

Carpenter et al. [2015] provide macro level evidence on different investors participating in large-scale asset purchases to show that investors on aggregate subtitute towards riskier asset classes during QE purchases of longer-term Treasuries. Thornton [2012] provides evidence on the limitations of the portfolio balance channel and shows that the interest rate changes induced by QE seem to be overestimated once the trend in interest rates is accounted for.

Studies taking a more micro approach to identify the effects of quantitative easing policy focus on the effect of QE on bank lending behaviour. Darmouni and Rodnyansky [2017] find that the effects of QE highly depend on the asset targeted in the Fed's purchasing program and are largely heterogeneous across banks. They argue that the increased liquidity of the balance sheet, stemming from banks replacing less liquid MBS for the liquid reserves with the Fed, prompts more bank lending.[6] Kandrac and Schlusche [2017] provide more evidence in support of this liquidity channel prompting the increase in bank lending. Chakraborty et al. [2016] identify the negative spillover effects of large-scale MBS purchases by showing that QE incentivized banks to increase origination of the mortgage loans, while reducing the amount of commercial and other loans. Acharya et al. [2017] study the effect of ECB's large scale asset purchases on bank lending.

In relation to this literature, my paper sheds light on the QE induced changes on the money market funds' investment decisions and the liability side of banks' balance sheet. Since banks extensively used Agency MBS as collateral to borrow in the money markets, selling this collateral to the Fed could have affected their ability or willingness to borrow. For QE to increase the liquidity of a bank's balance sheet, and consequently, affect its lending, it matters whether money market lenders are willing to substitute their former repo lending with uncollateralized loans.

More broadly, this paper contributes to the literature on the effects of unconventional monetary policy on the private transactions in financial markets. For example, Di Maggio and Kacperczyk [2017] study the effects of zero interest rate policy on the industrial organization of the money market fund industry and behaviour of money market investors. Kandrac [2014] and Anderson and Kandrac [2016] attempt to capture potential crowding out effects for private transactions induced by the Fed's purchases by measuring the changes in volume and number of private transactions and other market liqudity measures, once large scale purchases are introduced.

[6] Having said that, Darmouni and Rodnyansky [2017] find no effects on bank lending during QE2. They argue that this is consistent with QE2 purchases targeting only Treasuries, while banks overall hold fewer Treasuries on their balance sheets. On the other hand, they find that QE1 and QE3 which targeted MBS, induced positive effects on bank lending, as banks sold their MBS held on the balance sheet in replacement for the liquid reserves which allowed for the expansion of lending.

2.3 Institutional setting

2.3.1 Quantitative Easing

During 2008, the Federal Reserve (Fed) reduced its federal funds rate target to nearly zero in its efforts to tackle the consequences of the financial crisis. The aim was to support economic recovery by providing stimulus to household and business spending. Soon after the federal funds rate hit the zero lower bound, the Fed additionally engaged in other, more unconventional types of monetary policy in order to further support the improvement of the economic and financial market conditions. The unconventional policies involved large-scale asset purchases (LSAP), also known as quantitative easing (QE).

During the period from 2008 until 2014, the Fed has conducted several waves of large scale asset purchases. LSAP encompassed purchases of the longer-term securities issued by the U.S. government and securities issued or guaranteed by government-sponsored agencies such as Fannie Mae or Freddie Mac, including Agency debt and Mortgage Backes Securities (MBS). Securities were purchased in the private market through a competitive process.

The Fed argued that quantitative easing would affect financial markets and provide stimulus for the economic recovery through several channels. The mechanism strongly advocated by B.Bernanke, the Fed Chairman at the time, was the portfolio balance channel. This mechanism relied on the assumption that different classes of financial assets are not perfect substitutes in investors' portfolios. Imperfect substitutability implies that changing the supplies of certain assets available to private investors as a first-order effect may change the prices and yields of these assets. Second, as investors reshuffle the composition of their portfolio and invest in other assets, prices and yields of the broader set of assets can be affected.[7]

The first series of large-scale asset purchases was initiated in November 2008 (Quantitative Easing 1 (QE1)) when the Federal Open Market Committee (FOMC) announced a programme to purchase up to $500 billion of agency MBS and $100 billion of agency debt. During 2009 this programme expanded by increasing the Fed commitment to $1.25 trillion of agency MBS. The purchases were completed in March 2010. The main goal of QE1 was to resuscitate the mortgage markets by providing liquidity and boosting prices of MBS.

In November 2010, although market liquidity normalized, the FOMC launched the second round of large-scale asset purchases, known as QE2, which lasted until June 2011. This wave targeted solely

[7] The imperfect substitutability assumption may hold due to certain regulatory restrictions, high transaction or information costs or particular risk characteristics costly to hedge for some investors.

the long-term Treasuries. It encompassed a $600 billion programme allocated purchases and $178 billion as reinvestment of the principal payments from the Fed's agency debt and MBS holdings. Even when QE2 ended the reinvestment of the agency debt and MBS holdings payments continued, but throughout 2011 was directed into agency MBS. At the time, these reinvestment purchases were the only source of Fed's demand for MBS.

In September 2012, the FOMC announced the third round of Quantitative Easing (QE3) after establishing that economic recovery is still very slow while unemployment high. The novelty about QE3 was that it was posited as an open-ended programme with the purchases to continue until economic outlook improves and unemployment decreases. The initial size of purchases was set to be $40 billion per month targeting solely the agency MBS, and in December 2012, £45 billion in long-term Treasuries were added to the monthly purchase programme. The third wave of quantitative easing formally ended on October, 29, 2014.

2.3.2 MMF regulation

Money market funds (MMF) represent financial intermediaries which invest in low-risk and liquid securities issued by banks and corporations with short-term borrowing needs. Money market funds,with an aggregate volume of $1.8 trillion, are the most important lenders in the wholesale short term debt markets, and the most important source of dollar funding for large international banks and corporations.

In the United States, MMF are regulated by Rule 2a-7 of the Investment Company Act of 1940. By the Rule, funds are prohibited from purchasing long-term assets such as mortgage-backed securities, corporate bonds or equity and can only invest in short-term, highly rated securities.The type of instruments MMF invest in spans from commercial paper, certificates of deposit, and repurchase agreements to Treasury and Agency debt. In March 2010 after the unraveling of the financial crisis, certain amendments to the 2a-7 Rule have been introduced with the goal of limiting risks and reducing the fragility of money market funds. New rules have introduced stricter requirements on portfolio holdings disclosure and tighter restrictions on particular portfolio exposure to second tier securities.

Regarding fund portfolio diversification, the rule specifies that money market funds must limit their exposure to first tier securities issued by any single issuer to no more than 5% of fund assets. This restriction does not hold for government securities and securities subject to a guarantee issued by a non-controlled person. Portfolio exposure to any single issuer's securities of the second tier must not exceed 1% of fund assets.

In my analysis, I focus on the effects of QE3 on the lending outcomes in the money markets. In other words, I analyze how purchases of Agency MBS and Treasuries during QE3 affected portfolio composition of the money market funds. Although MMF are allowed to invest in the Treasuries, they face a constraint on the maximum remaining maturity of the security held in their portfolio not exceeding 397 days.[8] Treasuries purchased through the QE3 spanned maturities from 4 to 30 years, with the estimated average duration of the bonds purchased being around 9 years, as stated in FOMC statement from December 2012. Thus, QE3 purchases of Treasuries have not directly affected MMF porfolio holdings. At the same time, Treasuries used as collateral were not affected by QE3 purchases, also shown in steady and QE3 unaffected MMF holdings of Treasury repo securities (see Figure 2.4).

Similarly, the MMF are not allowed to directly invest in the MBS securities. However, there is evidence that QE3 purchases of MBS have significantly changed the composition of collateral in the repo markets (Elamin and Bednar [2014]) by reducing the availability of Agency securities used as collateral (also see Figure 2.2). MMF extensively invested in repo securities collateralized by Agency MBS. The removal of the safe collateral from the markets may have lead to significant changes in investor behaviour and fund's portfolio decisions.

2.4 Data and Empirical strategy

2.4.1 Data

In March 2010, one of the amendments introduced to the rule regulating money market fund industry was the increased requirement for transparency and more frequent public disclosure. Starting in November 2010, MMF are required to disclose detailed security level information on their portfolio holdings. The information is filed to EDGAR through the N-MFP form each month. Funds are required to submit the form within 5 business days after the end of the month, while the forms become publicly available only 60 days later.

The N-MFP form contains information on fund characteristics and details on securities held in the portfolio in that particular month. Fund information includes total asset and net asset value, fund age, yield, maturity of its portfolio and the like. With regards to the portfolio holdings, the form contains information on the type of security, name of the issuer,CUISP identifier, CIK (Central Index Key - EDGAR identifier) of the issuer, maturity at issuance, dollar amount of the security held by the fund and percent of fund net assets invested in the particular security.

[8] In order to limit the interest rate and credit spread risk, the remaining maturity of securities in the fund's portfolio should not exceed 397 days, while the dollar-weighted average maturity of the securities owned by the fund may not exceed 60 days.

My analysis is focused on the lending decisions of prime money market funds, since prime MMF are allowed to invest in both government and non-government securities. In order to capture the portfolio balance channel induced by QE3, it is valuable to analyze the broader set of asset classes towards which funds can substitute, once QE3 purchases reduce availability of collateralized securities.

Using monthly filings of the N-MFP form, I construct a novel dataset of the U.S. prime money market fund portfolio holdings at the fund-security-issuer level. The dataset spans a period from September 2011 until October 2014.

In order to analyze the effects of QE3 on fund lending decisions with respect to different issuers, I exploit the granularity of fund-security level information to construct fund-issuer loan at each time period, as the total dollar amount lent by the fund to an issuer through investment in that issuers' money market securities.

Using security identifiers submitted in the N-MFP form, I match each security to the issuer at the highest level of aggregation. For example, in the case of banks, all securities issued by different bank subsidiaries or ABCP vehicles sponsored by the bank are matched to the bank holding company. The matching algorithm combines information on securities' CUSIP with the CUSIP database, also Moody's Investor Service information on ABCP vehicles and their sponsors, SEC's list of all CIKs matched with entity names, as well as the organizational hierarchy of bank holding companies provided in the FFIEC for matching the bank subsidiary level issues to the holding company.

In total, the matched sample comrpises of 195 issuers in the money market fund portfolio holdings. There are 123 non-financial and 72 financial issuers (banks), out of which 28 banks have issued Agency repo securities prior QE3, and thus are classified as repo issuers. Other issuers, in total 167, including banks which did not use Agency repo to raise funding and the non-financial issuers represent the non-repo issuers. Matched sample of fund-issuer level holdings represents my fund-issuer loan level dataset. The loan is defined as the total amount of securities held by the fund and issued by the same issuer, expressed in dollars or as a percentage of fund's net assets. Most of the analysis focuses on the fund portfolio holdings of the matched subset of issuers. In the analysis I distinguish between repo and other loans. Repo loans stand exclusively for Government Agency collateralized repurchase securities, while other loans comprise of mostly uncollateralized securities, excluding any Treasuries, Agency debt or other government-sponsored securities. In the analysis, other lending also includes the so-called other repo securities which are repo loans collateralized by the nongovernment securities. The results are robust to excluding other repo securities from other lending.

2.4.2 Empirical strategy

First, I show that QE3 purchases of Agency MBS coincide with a decline in money market fund portfolio holdings of Agency repo securities. Figure 2.1 shows that both dollar amount, as well as the overall percentage of total money market assets invested in Agency repo decreases during the period of QE purchases of Agency MBS securities, implemented from October 2012 onwards.

This is consistent with the existing evidence that a significant decline in the Agency collateral in the repo market happened in a lockstep with the Fed expanding its balance sheet through QE purchases of Agency securities. Elamin and Bednar [2014] argue that over the course of QE3, the Fed increased its market share of Agency MBS securities by 10 percent of the total market, while MBS used as collateral in the triparty repo transactions constituted only about 12 percent of the Agency MBS market at the time. This suggests that the Fed's purchases targeted exactly MBS used as a collateral in repo transactions. Figure 2.2 shows a negative correlation between the Fed's holdings of Agency MBS and availability of Agency MBS collateral in the repo markets.

In order to claim that QE3 purchases resulted in freed up liqudity to be invested in other securities, I first show that the prime money market funds industry did not experience any outflows due to a decline of collateralized securities for investment. Figure 2.3 shows that total asset size of MMF industry, if anything, has only increased during QE3 period. This implies that fund investors did not withdraw in the absence of Agency collateralized loans to invest in. Thus, QE3 has generated liquidity available for investment across other asset classes within money markets. This as a positive liquidity shock for investments in other securities, affecting funds which were highly invested in Agency collateralized repo securities.

The goal of this exercise is to identify the portfolio balance channel of the QE policy by attributing changes in the MMF lending decisions to QE3 induced changes in available securities. One of the empirical challenges is to disentangle the effect of QE from other possible contemporaneous shocks affecting MMF lending decisions. Capturing the QE induced changes in fund lending solely in a time series could confound the effects of the protfolio balance channel with other contemporaneous shocks also affecting the money market fund lending. Thus, being able to distinguish between the treated and control group funds in the context of QE3 allows controlling for macroeconomic shocks that coincide with QE3 and equally affect all the funds.

When using macro data, the challenge is to determine a control group unaffected by the policy. For example, all MMF were affected by the overall decrease in interest rates during QE3 period. Therefore, the advantage of having granular data on fund portfolio holdings allows to define QE3 exposure at the fund level. Then, using the cross-sectional variation in fund exposure to QE3 I am able to employ a difference-in-differences specification to estimate the effect of QE3 induced portfolio balance channel.

I construct the measure of fund QE3 exposure using the average fund holdings of Government Agency repo securities before QE3 was implemented, from September 2011 - September 2012. Fund QE3 exposure is defined as the average fraction of fund portfolio invested in Government Agency repo (across all issuers) during the pre-QE3 period (specified in (2.1)).

$$fexpQE3_f = \frac{1}{T}\sum_t \frac{\sum_i fgar_{i,t}}{fnet\_assets_t} \tag{2.1}$$

Variable $fgar_{i,t}$ represents the dollar amount invested in the Government Agency repo securities issued by the issuer i at time t, while $fnet\_assets_t$ are fund assets measuring the total size of fund portfolio at the time t. Basically, for each month in the pre-QE3 period, I construct the measure of fund portfolio exposure to Government Agency repo (GAR) securities, and then average this across the entire pre-QE3 period in order to obtain the measure of a fund's exposure to QE3.

A fund is classified as treated if it has above median portfolio exposure to Agency repo during the pre-QE3 period. Control group funds have below median portfolio holdings of Agency repo. While for the high exposure funds QE3 significantly affected the composition of the portfolio by reducing the availability of Agency repo securities, for the low-exposure funds it induced low or no shock. This allows me to implement a difference-in-differences identification strategy to estimate the differential changes in other lending between high and low QE3 exposure funds.

An implicit assumption behind this empirical approach is that lending of low QE3 exposure funds' represents a good counterfactual for the high QE3 exposure fund lending. In other words, changes in other lending of high and low QE3 exposure funds would have evolved in a similar fashion had there not been any QE3 purchases of Agency MBS securities, and the consequent positive liquidity shock on high QE3 exposure funds. Figure 2.5 supports this assumption by showing the evolution of the average total other lending by high and low exposure funds before and after QE3 was introduced. Consistent with the identification assumption it shows that other lending of high and low QE3 funds follows a parallel trend before the introduction of QE3. During QE3, both groups increase their total other lending with the increase for high QE3 funds being somewhat larger. Focusing on the evolution of the average other loan issued to repo banks, figure 2.6 shows that loans by high and low QE3 exposure funds follow the parallel trend prior introduction of QE3 with high QE3 funds substantially increasing their lending to repo banks once QE3 was introduced.

In an attempt to identify the portfolio balance channel by estimating differential changes in MMF lending, I use the following difference-in-differences specification:

$$y_{f,i,t} = \alpha_i + \tau_t + \beta_1 \times QE3_t + \beta_2 \times HighF_f + \beta_3 \times QE3_t \times HighF_f + X_{f,t} + \varepsilon_{f,i,t} \quad (2.2)$$

The dependent variable is the (log) loan of fund f to borrower i in a month t. This specification exploits the granularity of the fund-issuer loan level dataset to compare the changes in lending between high and low QE3 exposure funds to the same borrower, before and after QE3 was introduced. This allows to control for any borrower specific unobserved heterogeneity, including changes in demand for money market funding which equally affect all MMF. The coefficient of interest is β_3, coefficient on the interaction term between time dummy variable $QE3$ and the fund treatment indicator $HighF$. The $QE3$ is an indicator variable equal to one during the treatment period of QE3 implementation (October 2012-October 2014), while $HighF$ is a fund indicator variable equal to 1 for any fund that belongs to the high QE3 exposure group. DD estimate β_3 captures the effect of QE3 on fund lending decisions.

In the analysis, I also explore the QE3 exposure heterogeneity within former repo issuing banks. Namely, since repo banks used Agency repo securities to raise funding in the money markets, it is reasonable to expect that QE3 may affect their ability or willingness to borrow from the MMF. In particular, a reduction in availability of Agency repo can be attributed to banks selling Agency MBS to the Fed during QE3. Therefore, banks have to repay their former Agency repo loans, which, all else being equal, decreases their total level of money market debt. In order to investigate differences in banks' response to QE3, I distinguish between banks using the intensity of their exposure to QE3. Banks' QE3 exposure is defined as the average fraction of its total money market debt issued in the form of Agency repo securities during the pre-QE3 period:

$$issuerexpQE3_i = \frac{1}{T} \sum_t \frac{Igar_t}{Idebt_t}$$

$Igar_t$ represents the total dollar Agency repo issuance of a particular bank at time t, and $Idebt_t$ is the total money market debt of the bank at time t. High QE3 exposure banks (i.e. high repo intensity banks) are the ones with the above median fraction of the total money market debt issued in Agency repo securities. For the higher fraction of debt issued in Agency repo securities, QE3 prompts a larger decrease in the overall money market leverage, thus increasing the bank's capacity for issuance of other securities. In this context, a bank's QE3 exposure captures the positive shock to its ability to absorb more money market funding.

I exploit the variation in borrowers' exposure to QE3 within repo banks, to analyze whether this affects fund lending decisions, once the fund has available liquidity to lend. Using granularity of the fund-issuer loan level dataset, combined with the fund fixed effects DD specification in (2.3) captures the effect of QE3 by estimating differences in lending of the same fund between high and low QE3 exposure repo banks.

$$y_{f,i,t} = \alpha_f + \tau_t + \beta_1 \times QE3_t + \beta_2 \times HighRepoB_i + \beta_3 \times QE3_t \times HighRepoB_i + \varepsilon_{f,i,t} \tag{2.3}$$

The underlying assumption of this within fund difference-in-differences specification is that high intensity repo banks would not have changed their other money market borrowing differently from the low intensity repo banks, had QE3 purchases of Agency collateral not prompted the repayment of former Agency repo loans. Figure 2.9, supports the assumption on total other borrowing between high and low repo banks following a parallel trend prior introduction of QE3 in October 2012. It also shows that after QE3 was introduced, high repo banks significantly expand their other borrowing, consistent with the predictions of QE3 generating a positive shock to their ability to absorb money market funding.

2.4.3 Summary statistics

The analysis is restricted to 159 prime funds which exist and report their monthly portfolio holdings throughout the entire sample (September 2011 - October 2014). Table 2.1 presents first evidence in support of the portfolio balance channel being the transmission mechanism of QE3 in the money markets. It provides detailed breakdown of aggregate money market fund portfolio composition by asset class, before and after introduction of QE3. Also, it shows that, on aggregate, there has been no fund outflows from prime money market industry, captured by the increase in average size of total money market assets during QE3 (from 1.28 trillion to 1.38 trillion dollars).

Consistent with the QE3 purchases of Agency MBS, there is a decline in aggregate holdings of Agency repo securities, from 11% to 7% once QE3 was introduced. The most pronounced change in the holdings of other securities is the increase in aggregate holdings of certificates of deposits from 27% to 33% of total money market portfolio during QE3 period. Certificates of deposits are longer-term, uncollateralized money market securities issued by the banks. Given Agency repo are also issued exclusively by banks, this suggests that QE3 resulted in funds substituting collateralized for uncollateralized lending within the same group of borrowers. On the borrowers' side, this allowed banks to expand their unsecured borrowing from the money markets.

Using heterogeneity in fund exposure to QE3 to identify the effects of portfolio balance channel induced by QE3, I first show that there is a sufficient cross-sectional variation in QE3 exposure among the funds. Figure 2.7 shows a histogram for the distribution of Agency repo holdings across funds, before the introduction of QE3 (September 2011- September 2012). Fund QE3 exposure ranges from a minimum exposure being 0 to a maximum 78%, with a mean 11% (median 7.5%) and standard deviation of 12%. High QE3 exposure funds are defined as funds with the above median holdings of Agency repo prior to QE3.

Table 2.2 reports summary statistics at the fund level, before and after QE3 was introduced (September 2011-September 2012 and October 2012-October 2014), separately for high and low QE3 exposure funds. Consistent with fund sorting in two groups, the difference in QE3 exposure between high and low exposure funds is significant, with the average QE3 exposure being 20% for the high, and only 2% for the low exposure group. The average size of total fund assets does not vary much between the groups, yet dispersion in the asset size is much larger among low QE3 exposure funds. Also, there is almost no change in fund asset size following the introduction of QE3, corroborating previous observation that there were no outflows from the money market industry due to decline in availability of collateralized securities.

Changes in the portfolio exposure to Agency repo and other securities are consistent with QE3 reducing availabilty of Agency repo, while funds respond by increasing their investment in other uncollateralized securities. Focusing on lending within the matched sample, the average fraction of Agency repo loans in high QE3 funds' total lending is 33% before the introduction of QE3, and declines to 24% after QE3 is introduced. The fraction of other securities in high QE3 funds' lending increases from 57% to 68%.

Table 2.2 also shows that QE3 period coincides with the changes in fund portfolio characteristics beyond asset composition. In particular, portfolio maturity of high exposure funds increases from 36.44 to 40.62 days. Since the average in-sample maturity of Agency repo loans is 7 days, while the average maturity of other securities is 49 days[9], the increase in portfolio maturity is consistent with the high QE3 exposure funds susbtituting former Agency repo holdings for the holdings of other, uncollateralized securities. Increase in portfolio maturity is more modest among low QE3 exposure funds, given their maturity was already higher prior QE3, consistent with larger portfolio holdings of other securities. Also, the average fund yield decreased across both high and low exposure funds during the QE3 period, consistent with the predictions on the macroeconomic effects of quantitative easing on the interest rates.

Table 2.3 reports summary statistics on issuers, using their Government Agency repo issuance to distinguish between the issuer groups with different exposure to QE3. Histogram in Figure 2.8 shows a significant cross-sectional variation in the intensity of QE3 exposure across repo issuers ranging from 0.5% to 85% of the total money market debt, with mean being 26% (median 19%) and standard

[9] Asset class with the largest increase in portfolio holdings, Certificate of Deposits, has an average maturity of 72 days in the sample.

deviation 25%. Non-repo issuers, by definition, have zero exposure to QE3.

Table 2.3 shows that the average repo issuer has $25.4 billion total debt outstanding held by the prime money market funds. Non-repo issuers are much smaller in terms of their total debt outstanding in the prime money markets, borrowing on average only $1.53 billion. Within repo banks, high and low QE3 exposure issuers do not significantly differ in the size of their total borrowing from the money market funds. On average, repo borrowers issued 24% of their money market debt in the form of Agency repo securities, while 69% in other securities. Non-repo issuers predominantly use other securities to raise money market funding, with other debt comprising on average 96% of the total debt outstanding.

Table 2.4 shows summary statistics at the fund-issuer loan level, separately for high and low QE3 exposure funds, during the pre-QE3 (Sepmteber 2011-September 2012) and QE3 period (October 2012 - October 2014). The table shows that the size of the average dollar loan does not differ much across high and low exposure funds, both before and during QE3. With the introduction of QE3, the average other loan of high exposure funds increases from $160 to $174 million, while average outstanding Agency repo loan decreases from $79 to $49.7 million. Interestingly, when the loan is expressed as a percentage of fund's total assets i.e. portfolio exposure, a portfolio exposure to an average issuer's other securities does not change with the introduction of QE3. High exposure funds on average increase other portfolio exposure from 1.7% to 1.8% once QE3 is introduced. Lack of significant increase in fund-issuer portfolio exposure combined with the overall increase in fund holdings of other securities, indicates that fund lending remains quite diversified across issuers. As shown in Table 2.2, high exposure funds increase their other lending substantially. At the same time, the modest change in the fund-issuer loan size suggests that funds start lending to new borrowers once QE3 is introduced.

2.5 Empirical results

2.5.1 QE3 Portfolio balance channel: changes in MMF lending

QE3 purchases of Agency MBS have reduced the availability of Agency collateralized repo loans, by reducing the availability of the required collateral. This change did not induce investor withdrawals from the money market industry. Thus, depending on their previous exposure to MBS collateralized investments, funds were left with available excess liquidity to reinvest in other money market securities.

First, I show that QE3 purchases of MBS coincide with the increase in fund lending through other securities. This is consistent with funds having ample liquidity to invest in other securities after Agency repos are no longer available in the market. This effect should be stronger for the funds with high pre-QE3 portfolio holdings of Agency repo securities, i.e. high QE3 exposure funds.

Table 2.5 shows that, on aggregate, high QE3 exposure funds increase their total other lending by 20.9% more relative to the low exposure funds. The dependent variable in these specifications is (log) total other lending of the fund. Specification includes fund fixed effects to control for any time-invariant unobserved fund heterogeneity and time fixed effects to control for the aggregate shocks which equally affect lending across funds. Standard errors are clustered at the fund level.

Although consistent with QE3 prompting the substitution between former repo loans and other loans, a differential increase in total other lending captured between high and low exposure funds may easily be attributed to differences between borrowers to which these two groups of funds lend. Namely, these borrowers may have very diffrent demand for money market funding, or their demand for funding may differentially change once QE3 is introduced.

Thus, I explore the granularity of my dataset to run loan level specifications with issuer fixed effects to control for differences in borrower characteristics or changes in demand for money market funding. Including the issuer fixed effects in the specifications where dependent variable is the fund-issuer loan, allows comparing the changes in lending between high and low QE3 exposure funds to the same issuer. This ensures that any issuer level unobserved heterogeneity equally affecting lenders is differenced out. In the loan level specification, capturing the effects of the increase in available liquidity will be contingent on the way funds decide to distribute this liqudity over different borrowers. It is plausible that the high QE3 funds favour certain borrowers when distributing this liqudity. This would result in heterogeneous effects of QE3 across borrowers.

Table 2.6 presents the results on the issuer fixed effect specifications (as defined in (2.2)), which compare differences in lending to the same issuer by high and low QE3 exposure funds. Column (1) of the table shows that DD estimate of the QE3 effect on issuer's borrowing is positive, yet not significant when the effect is measured across all borrowers. However, when the set of borrowers is restricted to banks, high exposure funds increase their loans by 8.4% more relative to low exposure funds when lending to the same bank. When the set of financial borrowers is narrowed down to the former Agency repo issuing banks, the magnitude of the coefficient increases to 8.9%. At the same time, there is no significant effect of the QE3 induced available liqudity shock on the fund lending to non-financial borrowers.

Specifications estimated in Table 2.7 use funds' actual holdings of Agency repo securities to distinguish between different intensities of QE3 induced liquidity shock. Similar to the previous DD regressions, they compare changes in the loans to the same borrower by funds with different intensity of QE3 exposure. In this case, for every 10% higher exposure to QE3, issuer's borrowing increases by 4.6% more relative to the fund with lower QE3 exposure. The magnitude of the effect increases once the set of borrowers is narrowed to financial borrowers, and in particular former repo issuing banks.

Results in Tables 2.6 and 2.7 document heterogeneity in the transmission of QE3 effects across different groups of borrowers in the money markets. This may indicate that the changes in available liquidity across different MMF are not the only determinant of lending outcomes during QE3. For example, funds particular preference towards financial issuers could be consistent with the search for yield incentives which often arise in the low interest rate environment generated by QE3 (see Di Maggio and Kacperczyk [2017]). Uncollateralized instruments are riskier, but offer higher yield for bearing this additional risk relative to the collateralized securities. Allocating most of the freed up liquidity to banks could be due to banks offering higher yield securities while posing the lowest risk for a given yield due to implicit support provided by the regulator (Acharya et al. [2016]). Documented heterogeneity in lending is also consistent with issuers having different ability to absorb the excess supply of funds. Next, I discuss plausible effects of QE3 on different borrowers' ability to absorb the money market funding.

2.5.2 Heterogeneous effects across borrowers

During QE3, the Fed's purchases of Agency MBS allowed the owners of these securities to exchange them for the reserves with the Fed. For Agency repo borrowers, selling MBS to the Fed would eliminate their repo borrowing positions, thus reducing their total borrowing from the money markets. If repo banks simply used the money markets to obtain funding for Agency MBS held on the balance sheet, selling MBS during QE3 purchases would imply that these banks no longer have to raise the short term funding from the MMF.

However, if these banks target certain level of short term borrowing, repaying repo loans may prompt an increase in the issuance of other money market securities. In order to maintain the overall level of money market debt unchanged, repo banks can increase their borrowing from MMF through other securities. Therefore, banks subject to the larger QE3 induced decrease in the overall money market borrowing may be more able or willing to absorb the fund excess liquidity to keep their borrowing levels unchanged. Repo bank's exposure to QE3 is defined using its pre-QE3 fraction of total borrowing issued in Agency repo securities. This corresponds to the intensity of QE3 induced shock to the bank's overall level of money market debt.

Table 2.8 shows that, on aggregate, high exposure repo banks increase other borrowing by 22.2% more relative to the low QE3 exposure repo banks. The effect is significant and of the similar magnitude when comparing the high repo banks to all other borrowers. These findings are consistent with the high QE3 exposure repo banks being more able to absorb the money market funding once they repay their former repo loans. If repo banks aim to maintain the stable level of their money market debt, high QE3 exposure banks should increase other borrowing more, since the larger fraction of their money market debt is affected by the sales of MBS to the Fed. Figure 2.9 supports this by showing the evolution of other money market debt for high and low QE3 exposure repo banks. Total other borrowing increases significantly for the high exposure banks while total money market borrowing of low repo banks remains almost unchanged during QE3. The results imply that the ample liquidity of high QE3 exposure funds, generated by QE3, remains concentrated among the former repo issuing banks. In order to better understand the heterogeneous effects of the QE3 induced portfolio balance channel in the money markets, I analyze determinants of the fund lending decision within repo borrowers while focusing on the high QE3 funds, funds with ample liquidity made available by QE3 purchases.

2.5.3 Fund lending within repo banks

First, I analyze whether, at the fund level, lending between repo banks is determined by the bank's ability to absorb more money market funding. In order to control for fund heterogeneity, I use the fund fixed effect specification to capture the differential changes in lending of the same fund between high and low QE3 exposed banks. If distribution of the available liquidity is determined by the borrowers' ability to absorb money market debt, the same fund, on average, increases lending more to the high QE3 exposure banks.

Second, QE3 coincides with the funds substituting the former collateralized for the uncollateralized portfolio holdings. All else being equal, lending through uncollateralized loans is riskier, and thus, may incentivize funds to put more emphasis on diversification considerations when making lending decisions. Diversification implies spreading the loans over more issuers to ensure smaller unsecured exposure to each individual issuer. In addition, money market funds face strict regulatory requirements on their portfolio limits on the fund unsecured exposures to the individual issuer. As prescribed by Rule 2a-7 , MMF are not allowed to have a higher than 5% portfolio exposure to a single issuer through securities other than Treasuries or Agency debt, as well as repo securities collateralized with the former two. Thus, reducing the availability of the loans not subject to diversification requirement (Agency collateralized repos) puts substantial pressure on the funds to rebalance their portfolios in accordance with diversification requirements. Thus, I explore whether diversification motives combined with the existing portfolio composition of unsecured debt issuers affects fund lending decisions within repo banks.

In the analysis, a lending relationship is considered diversified (i.e. non-saturated) if the fund does not hold a large fraction of its portfolio in other securities issued by that particular borrower. I construct two measures characterizing the degree of unsecured lending relationship diversification for each fund-borrower pair. First measure is based on the fund-issuer lending relationships which exist prior introduction of the QE3 (through either secured or unsecured lending). It includes only lending relationships which existed prior QE3 introduction. Fund-issuer relationship is classified as diversified (non-saturated) if the percentage of the average pre-QE3 total lending issued in Agency repo is larger than the percentage of lending in non-repo securities, for that fund-issuer pair.

Second measure classifies the lending relationship as the non-saturated if the fund's portfolio non-repo loans exposure to that issuer is below the fund's median (non-repo) exposure. This includes the relationships in which funds never lent to the borrower before the QE3 period. All measures are constructed per fund-issuer pairs using lending exposures during the pre-QE3 period (September 2011-September 2012). If the distribution of excess liquidity is determined by diversification motives, the fund would increase lending more to issuers with more diversified (non-saturated) lending relationship.

The specifications given in Table 2.9 explore how high QE3 exposure fund, on average, changes its lending to different subsets of former repo banks. In order to control for the fund heterogeneity these regressions include fund fixed effects, while the dependent variable is at the fund-borrower level. Results in Column (1) of the Table indicate that there is no significant difference in lending to high and low QE3 exposure repo banks, at the fund level. This indicates that at the fund level, the borrowers' ability to absorb money market funding does not seem to determine fund lending within repo borrowers.

Columns (2) and (3) show differences in fund lending to borrowers with the non-saturated relative to saturated lending relationships, using two measures previously defined. These specifications include issuer-time fixed effects, in order to control for any issuer specific changes in demand. On average, a fund increases other lending by 21.8% more to issuers with non-saturated unsecured lending relationship. The effect is even stronger when the second measure which includes lending to new borrowers is used. In that case, a fund, on average, increases other lending by 43.7% more to issuers with non-saturated relationship. Larger magnitude of the effect indicates that substitution to uncollateralized loans prompted funds to start lending to new borrowers. These results are consistent with diversification motives being an important determinant of the fund lending decisions within former repo borrowers.

In order to analyze how diversification motives interact with the borrower's ability to absorb additional money market funding, I compare how the fund-issuer lending relationship characteristics matter for borrowers with different exposure to QE3. Using DDD specification I test whether bank's ability to abosrb additional money market funding matters in determining fund lending decisions, after controlling for the degree of lending relationship diversification. The results in Columns (3) and (6) of Table 2.10 show that even after controlling for different intensity of issuers' QE3 exposure, the effect of non-saturated fund-issuer relationship remains positive and significant. When restricting the observed relationships to the ones existing pre-QE3, on average, the fund increases its other lending to high QE3 exposure bank by 30.3% more than to low QE3 exposure borrower with non-saturated lending relationship. Lending to low QE3 exposure borrowers with non-saturated lending relationships does not change significantly.When including the new lending relationships created after QE3 was introduced in the regression, the fund, on average, increases its other lending to non-saturated low QE3 banks by 38.6%, while to the non-saturated high QE3 exposure banks by additional 14.8% more relative to the low QE3 banks.

The difference in DDD coefficient magnitudes between the two measures of relationship saturation comes from the fact that the second measure also captures the fund's decision to initiate new lending relationships once it increases lending through the uncollateralized loans. The results imply that the fund initiates new lending relationships across both high and low QE3 exposure banks. In addition, positive and significant DDD coefficient captures that the lending increase is larger to banks with the greater ability to absorb more money market funding. Within the old lending relationships, once the relationship saturation is controlled for, the bank's ability to absorb additional funding determines the fund lending.

My findings underline the importance of the fund diversification motives once the availability of secured loans declines in the money market. Presented evidence implies that less saturated unsecured borrowing relationships can absorb more of the available liquidity for investment in unsecured loans. Diversification incentives together with existing portfolio composition of unsecured debt issuers determine the distribution of excess funds across borrowers. In particular, being a repo issuing bank with little or no non-repo borrowing from high QE3 exposed fund, would have allowed for the largest expansion in money market borrowing and overall increase in liqudity for the bank.

2.6 Conclusion

This paper uses granular data on money market fund portfolio holdings to identify the portfolio balance channel as a transmission mechanism of QE policy. It focuses on the effects of the third wave of QE implemented by the Fed, from October 2012 until October 2014 which involved extensive purchases of Agency MBS, formerly used as collateral in money markets. First, it shows that QE3 purchases coincide with a declline in the money market fund holdings of the collateralized debt. Second, it shows that this decline in availability of collateralized securities did not induce investor outflows and decrease in the asset size of the money market industry. Thus, QE purchases freed up fund liquidity previously invested in Agency repo securities.

The paper exploits heterogeneity in the intensity of the fund's QE3 exposure using fund pre-QE3 holdings of Agency repo loans to distinguish between treated and control funds. The cross-sectional variation in the fund QE3 exposure together with the fund-borrower loan level data allows to implement a difference-in-differences identification strategy to capture differential changes in fund lending between high and low exposure funds, that can be contributed to the effects of QE3. My results show that the high QE3 exposure funds increase their uncollateralized lending more once QE3 is introduced. This is consistent with the predictions of the portfolio balance channel suggesting that investors substitute towards other asset classes as QE purchases reduce the availability of the targeted asset in the markets.

Next, I show that that the QE3 induced portfolio balance channel has heterogeneous effects across different market participants. Namely, results imply that the increase in funds' available liquidity does not get evenly distributed across borrowers, but remains concentrated within the former repo issuing banks. This is consistent with the repo issuers having greater ability to absorb additional fund liquidity after sales of Agency MBS to the Fed through the QE3 purchases allowed them to eliminate their former repo loans. Further, the paper explores potential channels determining fund lending within former repo issuing banks. It provides evidence consistent with diversification motives strongly determining fund uncollateralized lending. On average, funds increase uncollateralized lending more to issuers with less saturated or no previous unsecured lending relationships.

The paper presents evidence on the role of private investors in the transmission of QE3 effects, as they previously provided funding for the QE3 targeted asset (Agency MBS) held by banks. Without money market funds substituting the former collateralized lending by the unsecured lending, the banks would only repay their repo loans without gaining much liquidity, irrespective of the QE3. Thus, the interaction of QE3 and the money markets allowed the banks to both sell their Agency MBS to the Fed and still raise more short term funding from the money markets.

2.7 Tables and figures

Figure 2.1: Total holdings of Government Agency repo: Dollar amount (USD million) and % of total fund assets

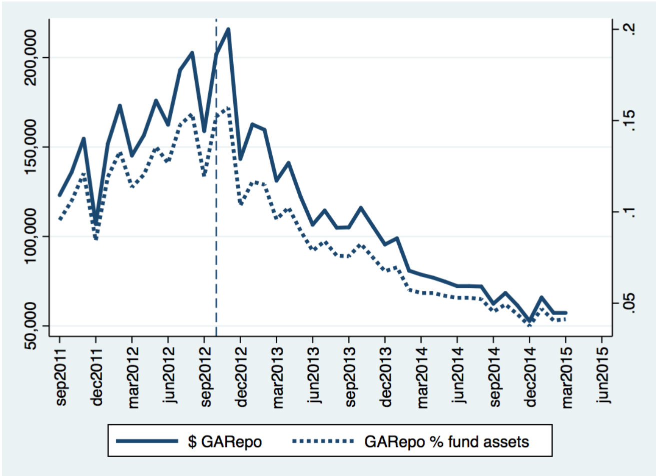

Figure 2.2: Fed holdings of Agency MBS vs. collateral value of Agency securities

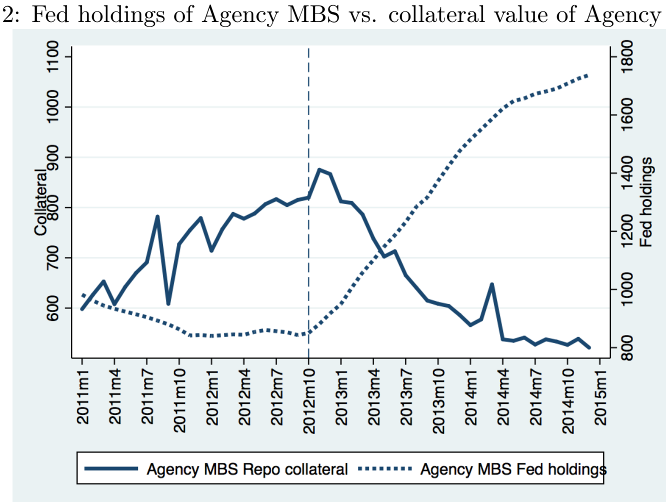

Figure 2.3: Total MMF assets (USD billion)

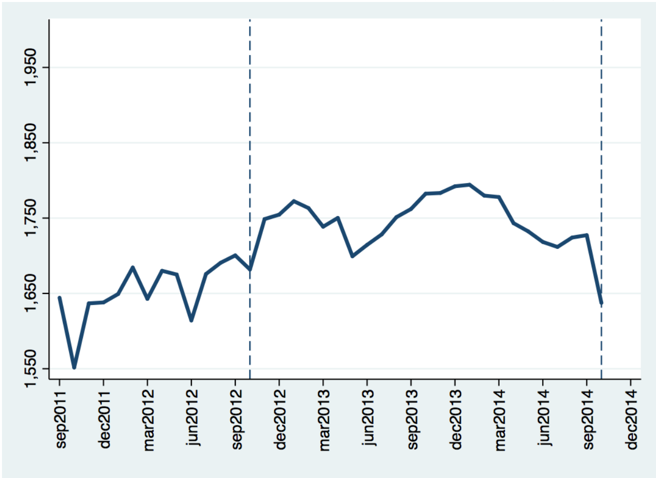

Figure 2.4: Fund holdings of Treasury repo securities: Dollar amount (USD milion) and % of total MMF assets

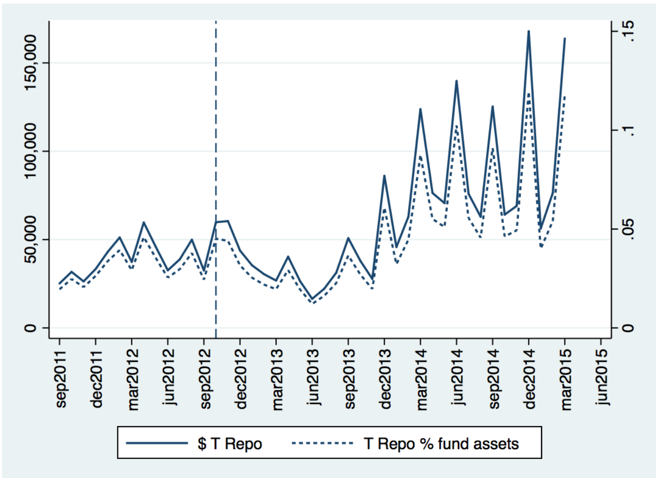

Figure 2.5: High vs. low QE3 funds: Total other lending

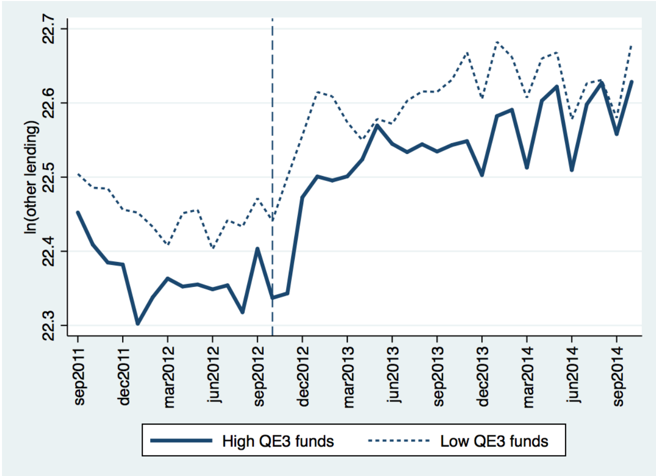

Figure 2.6: Average other loan to repo banks: ln(dollar loan)

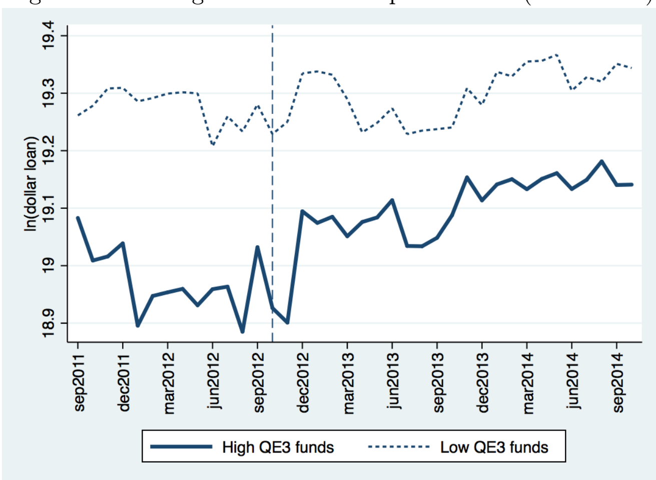

Table 2.1: Portfolio holdings by asset class

This table reports summary statistics for the aggregate MMF portfolio composition by asset class, before and after the introduction of QE3. Portfolio holdings are defined as total dollar holdings of the particular asset class scaled by the size of the aggregate money market fund portfolio. MMF total assets represent the size of the aggregate money market fund portfolio.

	Pre-QE3			QE3		
	Mean	SD	p50	Mean	SD	p50
GovAgency Repo	0.108	0.015	0.108	0.071	0.028	0.067
Agency debt	0.109	0.009	0.111	0.088	0.012	0.091
Treasury Repo	0.030	0.007	0.029	0.042	0.023	0.037
Treasury debt	0.093	0.012	0.098	0.072	0.012	0.077
Certificate of Deposits	0.267	0.014	0.261	0.325	0.032	0.321
Financial CP	0.128	0.006	0.127	0.145	0.009	0.148
ABCP	0.067	0.003	0.067	0.052	0.005	0.050
Other CP	0.037	0.004	0.037	0.046	0.006	0.044
Other Note	0.051	0.004	0.052	0.053	0.005	0.054
Other Repo	0.043	0.003	0.043	0.044	0.004	0.044
All other sec	0.073	0.010	0.071	0.067	0.013	0.065
MMF total assets (billions)	1,290	17.8	1,290	1,380	21.6	1,380

Table 2.2: Fund characteristics

This table reports summary statistics for 159 prime money market funds in my sample. Statistics are reported separately for high and low QE3 exposure funds, prior to the introduction of QE3 (september 2011- October 2012) and during QE3 (October 2013 - October 2014). Funds are classified as high QE3 exposure if they have the above-median portfolio holdings of Agency repo securities during the pre-QE3 period. Total secured loans comprise of Treasuries and Agency securities as well as repo loans collateralised with these securities. Total GAR loans represent fund total holdings of government Agency collateralised repo securities. Total other loans comprise of uncollateralised lending and repo loans collateralised by non-Treasuries and non-Agency debt.

			Percentile					Percentile		
	Mean	SD	25	50	75	Mean	SD	25	50	75
	High QE3 exposure funds									
	Pre-QE3					QE3				
Total Net Assets (millions)	8,230	11,900	904	2,210	11,700	8,820	13,000	811	2,090	12,400
Portfolio maturity (days)	36.44	12.43	28	38	46	40.62	12.16	33	44	50
Fund age	56.43	23.83	41	53	75	66.92	23.60	51	70	85
Fund yield (bps)	24.09	8.01	18	24	30	18.75	6.22	15	19	23
Total loans (millions)	4,680	7,010	469	1,210	6,590	4,710	7,190	435	1,120	6,470
Total GAR loans	0.33	0.17	0.21	0.30	0.41	0.24	0.19	0.08	0.21	0.34
Total secured loans	0.43	0.22	0.28	0.38	0.55	0.32	0.24	0.15	0.27	0.43
Total Other loans	0.57	0.22	0.45	0.62	0.72	0.68	0.24	0.57	0.73	0.84
QE3 exposure (Supply shock)	0.20	0.12	0.12	0.18	0.24					
	Low QE3 exposure funds									
	Pre-QE3					QE3				
Total Net Assets (millions)	8,030	19,900	332	1,010	4,520	8,590	21,900	300	861	3,530
Portfolio maturity (days)	42.13	11.22	34	43	52	44.83	9.77	39	47	52
Fund age	65.42	25.77	43	63	88.50	68.34	24.29	49	69	87
Fund yield (bps)	25.27	9.08	19	26	31	18.97	6.23	15	18	23
Total loans (millions)	3,810	9,510	117	369	2,190	4,070	10,400	124	403	1,670
Total GAR loans	0.05	0.08	0	0	0.07	0.06	0.12	0	0	0.08
Total secured loans	0.21	0.21	0.05	0.17	0.32	0.17	0.20	0.02	0.12	0.25
Total Other loans	0.79	0.21	0.68	0.82	0.95	0.83	0.20	0.75	0.88	0.98
QE3 exposure (Supply shock)	0.02	0.03	0	0.01	0.04					

Figure 2.7: Cross sectional variation in funds' QE3 exposure

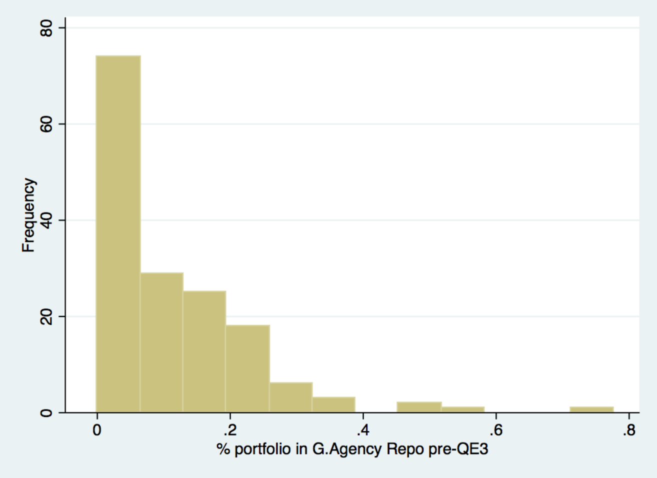

Figure 2.8: Cross-sectional variation in repo issuing banks' QE3 exposure

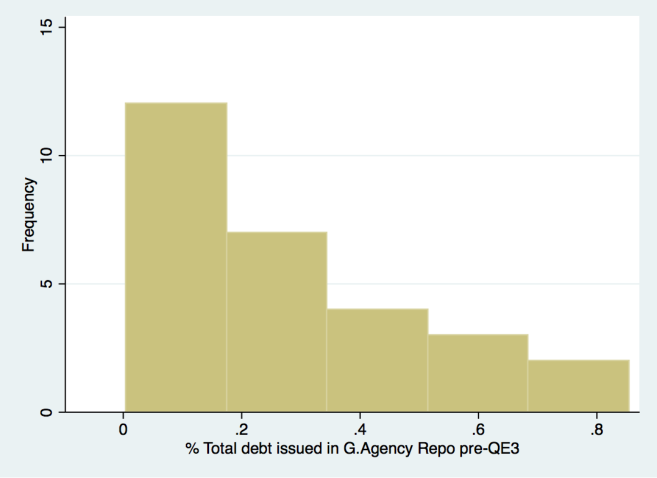

Table 2.3: Issuer characteristics

This table reports summary statistics for the issuers in the sample, separately for repo (in total 28) and non-repo issuers (in total 167). Within repo issuers, high and low intensity issuers are distinguished using the above/below median exposure to QE3, as captured by the average pre-QE3 fraction of total debt issued in Agency repo securities.The table reports statistics on the fraction of Agency repo loans and other loans in the issuers' total borrowing from the money market, where other loans are defined as uncollateralized securities.

			Percentile		
	Mean	SD	25	50	75
	High Repo				
Total debt (millions)	21,600	16,800	6,440	18,900	34,600
Total Agency Repo debt (millions)	6,830	6,300	2,080	4,800	9,480
Total Other debt (millions)	13,000	11,800	1,180	11,400	22,400
Agency Repo % debt	0.43	0.30	0.18	0.34	0.71
Other % debt	0.51	0.30	0.22	0.58	0.75
QE3 Exposure	0.49	0.20	0.33	0.44	0.61
	Low Repo				
Total debt (millions)	28,500	17,900	9,510	31,900	43,100
Total Agency Repo debt (millions)	2,470	2,810	305	1,590	3,700
Total Other debt (millions)	24,900	16,700	5,850	27,900	38,600
Agency Repo % debt	0.09	0.10	0.02	0.06	0.12
Other % debt	0.85	0.18	0.80	0.92	0.97
QE3 Exposure	0.09	0.07	0.02	0.07	0.16
	All Repo				
Total debt (millions)	25,400	17,700	7,430	26,100	39,800
Total Agency Repo debt (millions)	4,460	5,200	800	2,800	6,010
Total Other debt (millions)	19,500	15,800	3,750	18,000	32,900
Agency Repo % debt	0.24	0.27	0.04	0.13	0.34
Other % debt	0.69	0.29	0.53	0.79	0.93
QE3 Exposure	0.27	0.25	0.06	0.19	0.42
	Non-Repo				
Total debt (millions)	1,530	3,640	28	173	1,130
Total Agency Repo debt (millions)	0	0	0	0	0
Total Other debt (millions)	1,390	3,410	20	149	1,010
Agency Repo % debt	0	0	0	0	0
Other % debt	0.96	0.19	1	1	1
QE3 Exposure	0	0	0	0	0

Table 2.4: Fund-issuer loan level characteristics

This table reports summary statistics for the fund-issuer loans, separately for high and low QE3 exposure funds prior to QE3 and during QE3. Loans are expressed in millions of dollars, while portfolio exposure represents the loan as the fraction of the fund's net assets. Loans and portfolio exposures per fund-issuer are presented separately for different types of securities included in the definition of the loan: across all types of securities (total loan), uncollateralized securities (other loan) and Government Agency repo securities (Agency repo loan).

			Percentile					Percentile		
	Mean	SD	25th	50th	75th	Mean	SD	25th	50th	75th
	High QE3 exposure funds									
	Pre-QE3					QE3				
Total loan (millions)	255	463	18	75	290	233	430	15	63.7	250
Other loan (millions)	160	325	3	30	175	174	349	5	35	188
Agency Repo loan (millions)	79	265	0	0	2.65	47.9	187	0	0	0
Total Fund Portfolio exposure	0.031	0.033	0.010	0.022	0.041	0.027	0.028	0.010	0.020	0.035
Other Fund Portfolio exposure	0.017	0.017	0.003	0.012	0.027	0.018	0.016	0.005	0.014	0.027
Repo Fund Portfolio exposure	0.010	0.027	0	0	0.002	0.007	0.022	0	0	0
	Low QE3 exposure funds									
	Pre-QE3					QE3				
Total loan (millions)	251	687	9.78	35	180	238	645	8.94	30	146
Other loan (millions)	201	539	5.40	25	140	214	575	6	24.70	124
Agency Repo loan (millions)	17.50	140	0	0	0	11.90	130	0	0	0
Total Fund Portfolio exposure	0.028	0.026	0.011	0.022	0.038	0.025	0.023	0.01	0.021	0.035
Other Fund Portfolio exposure	0.022	0.017	0.007	0.019	0.033	0.021	0.016	0.008	0.019	0.031
Repo Fund Portfolio exposure	0.001	0.009	0	0	0	0.002	0.013	0	0	0

Table 2.5: Total other lending of high vs. low QE3 exposure funds

The dependent variable is (ln) of the fund's total other dollar lending, with other lending comprised of uncollateralized securities. Variable *HighF* is a dummy variable equal to 1 for the high QE3 exposure funds, classified as the funds with above-median pre-QE3 holdings of Agency repo securities. Variable *QE3* is a time dummy equal to 1 during the period of QE3 (October 2012-October 2014). *Fsize* is defined as the (ln) of fund net assets and the, while *Fage* is the weighted average maturity of the fund portfolio. Specification in column 1 includes only time fixed effects, while specification in column 2 includes fund and time fixed effects. Errors are clustered at the fund level in both specifications.

	Dependent variable: *Fund ln(Total Other lending)*	
	(1)	(2)
HighF	-0.281***	
	(0.0680)	
QE3 x HighF	0.209**	0.0605**
	(0.0955)	(0.0300)
Fsize	1.036***	0.936***
	(0.0227)	(0.0283)
Fage	-0.000462	0.00104
	(0.000998)	(0.000610)
const	-1.093**	
	(0.497)	
Time FE	yes	yes
Fund FE	no	yes
N	5921	5921
adj. R^2	0.920	0.994

Standard errors in parentheses: clustered at fund level
* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Table 2.6: Changes in borrowing from high vs. low QE3 exposure funds

The dependent variable is (ln) of the fund-issuer dollar loan, comprised of uncollateralized securities (other securities). Specifications 1-4 estimate differences in the changes of an issuer's borrowing from high compared to low QE3 exposure funds, across different groups of issuers. Column 1 results include all the issuers, while column 2 and 3 estimate the effects for the non-financial and financial issuers. Column 4 results are restricted to only repo issuing banks. Variable *HighF* is a dummy variable equal to 1 for the high QE3 exposure funds, classified as the funds with above-median pre-QE3 holdings of Agency repo securities. Variable *QE3* is a time dummy equal to 1 during the period of QE3 (October 2012-October 2014). *Fsize* is defined as the (ln) of fund net assets and the, while *Fage* is the weighted average maturity of the fund portfolio. Specifications include issuer and time fixed effects and errors are clustered at the fund level.

	Dependent variable: *Fund-issuer ln(Other loan)*			
	All issuers	Non-financial issuers	Financial issuers	Repo issuers
	(1)	(2)	(3)	(4)
HighF	-0.145***	-0.109	-0.156***	-0.147**
	(0.0550)	(0.0768)	(0.0572)	(0.0577)
QE3 x HighF	0.0489	-0.0687	0.0838**	0.0887**
	(0.0298)	(0.0601)	(0.0335)	(0.0353)
Fsize	0.932***	0.897***	0.943***	0.956***
	(0.0121)	(0.0143)	(0.0125)	(0.0121)
Fage	-0.00191*	-0.00447***	-0.00133	-0.000319
	(0.00112)	(0.00151)	(0.00112)	(0.00112)
Time FE	yes	yes	yes	yes
Issuer FE	yes	yes	yes	yes
N	96066	23542	72524	63995
adj. R^2	0.818	0.803	0.823	0.831

Standard errors in parentheses: clustered at the fund level

* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Table 2.7: Changes in borrowing from funds with different QE3 exposure intensity

The dependent variable is (ln) of the fund-issuer dollar loan, comprised of uncollateralized securities (other securities). These specifications use the actual percentage of fund's pre-QE3 holdings of Agency repo loans as the the treatment variable defined by *Fund QE3 exp*. The results estimate differences in the changes of an issuer's borrowing from funds with different intensities of their QE3 exposure. Column 1 results include all the issuers, while column 2 and 3 estimate the effects for the non-financial and financial issuers. Column 4 results are restricted to the repo issuing banks only. Variable *HighF* is a dummy variable equal to 1 for the high QE3 exposure funds, classified as the funds with above-median pre-QE3 holdings of Agency repo securities. Variable *QE3* is a time dummy equal to 1 during the period of QE3 (October 2012-October 2014). *Fsize* is defined as the (ln) of fund net assets and the, while *Fage* is the weighted average maturity of the fund portfolio. Specifications include issuer and time fixed effects and errors are clustered at the fund level.

	Dependent variable: *Fund-issuer ln(Other loan)*			
	All issuers	Non-financial issuers	Financial issuers	Repo issuers
	(1)	(2)	(3)	(4)
Fund QE3 exp	-0.943***	-0.683*	-1.010***	-0.934***
	(0.309)	(0.375)	(0.335)	(0.350)
QE3 x Fund QE3 exp	0.463**	0.0203	0.565***	0.601***
	(0.196)	(0.323)	(0.210)	(0.226)
Fsize	0.931***	0.893***	0.942***	0.955***
	(0.012)	(0.015)	(0.012)	(0.012)
Fage	-0.002*	-0.004***	-0.001	-0.001
	(0.001)	(0.002)	(0.001)	(0.001)
Time FE	yes	yes	yes	yes
Issuer FE	yes	yes	yes	yes
N	96066	23542	72524	63995
adj. R^2	0.819	0.803	0.824	0.831

Standard errors in parentheses: clustered at the fund level
* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Table 2.8: Total other borrowing of repo issuers

The dependent variable is (ln) of an issuer's total dollar borrowing, issued in uncollateralized securities. Variable *RepoB* is a dummy equal to 1 for the repo issuing banks defined as banks borrowing through Agency repo loans prior to QE3. Specification in column 1 estimates differential changes in the borrowing of repo and non-repo issuers. Variable *QE3* is a time dummy equal to 1 during the period of QE3 (October 2012-October 2014). Specifications in columns 2 and 3 define high intensity repo issuers as the treated group, captured by the indicator variable *High RepoB* equal to 1 for repo issuing banks with above median QE3 exposure. Columns 2 and 3 compare differential changes in total borrowing between high repo issuers and all other issuers, and within the repo issuers between high and low repo issuing banks. All specifications include issuer and time fixed effects and robust errors are estimated.

	Dependent variable: ln(Total Other borrowing)		
	All: Repo	All: High Repo	Repo: High Repo
	(1)	(2)	(3)
QE3 x RepoB	0.09		
	(0.0825)		
QE3 x High RepoB		0.21^{*}	0.22^{***}
		(0.11)	(0.08)
Time FE	yes	yes	yes
Issuer FE	yes	yes	yes
N	5138	5138	1034
adj. R^2	0.92	0.92	0.93

Standard errors in parentheses

* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Figure 2.9: Repo issuing banks: total other debt (USD million)

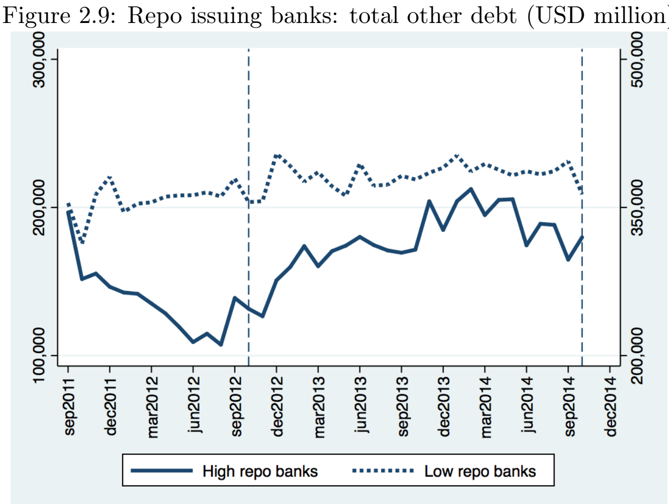

Table 2.9: Borrower's QE3 exposure vs. fund portfolio diversification

Dependent variable is (ln) of the fund-issuer dollar loan, comprised of uncollateralized securities (other securities). Variable *High RepoB* is equal to 1 for the repo issuing banks with above median QE3 exposure. QE3 exposure is defined as the average fraction of total debt issued in Agency repo securities during the pre-QE3 period. Variable *QE3* is a time dummy equal to 1 during the period of QE3 (October 2012-October 2014). Specification in column 1 estimates differential changes in fund lending to high and low QE3 exposure repo banks. Specifications in columns 2 and 3 present the results on differential changes in fund lending to borrowers with different lending relationship saturation. Variable *Non-Sat* captures two different measures of the relationship saturation. The first measure (column 1) classifies the lending relationship as non-saturated if the fund's average pre-QE3 Agency repo lending to the issuer is larger than its non-repo lending. The second measure (column 2) classifies the relationship as non-saturated if the fund's non-repo exposure to that issuer is below the fund's median non-repo exposure across all issuers. The second measure also includes lending relationships which did not exist prior to QE3 period.*Fsize* is defined as the (ln) of fund net assets and the, while *Fage* is the weighted average maturity of the fund portfolio. Specifications include fund and time fixed effects and errors are clustered at the issuer level.

	Dependent variable: *Fund-issuer ln(Other loan)*		
	Demand channel	Diversification channel	
	(1)	(2)	(3)
High RepoB	-0.238		
	(0.140)		
QE3 x High RepoB	0.0168		
	(0.138)		
Non-Sat		-0.323***	-0.826***
		(0.0733)	(0.0600)
QE3 x Non-Sat		0.218**	0.437***
		(0.090)	(0.065)
Fsize	0.886***	0.903***	0.904***
	(0.021)	(0.025)	(0.023)
Fage	0.00217*	0.00313***	0.00279***
	(0.001)	(0.001)	(0.001)
Time FE	yes	no	no
Fund FE	yes	yes	yes
Time x Issuer FE	no	yes	yes
N	33807	31731	33776
adj. R^2	0.820	0.855	0.871

Standard errors in parentheses: clustered at the issuer level
* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Table 2.10: Interaction of diversification motives and intensity of the QE3 shock

Dependent variable is (ln) of the fund-issuer dollar loan, comprised of uncollateralized securities (other securities). Variable *High RepoB* is equal to 1 for the repo issuing banks with above median QE3 exposure. QE3 exposure is defined as the average fraction of total debt issued in Agency repo securities during the pre-QE3 period. Variable *QE3* is a time dummy equal to 1 during the period of QE3 (October 2012-October 2014). Specifications in columns 1-3 use the measure of relationship saturation defined only on the pre-QE3 existing lending relationships. Specifications in columns 3-6 use the measure which also includes the new lending relationships entered into during the QE3 period. Triple-difference specifications are estimated in columns 3 and 6, for different measures of the relationship saturation. The coefficient of interest is the triple interaction term, estimating whether the effect of the non-saturated lending relationship differs for high and low repo intensity borrowers. *Fsize* is defined as the (ln) of fund net assets and the, while *Fage* is the weighted average maturity of the fund portfolio. Specifications include fund and issuer - time fixed effects, while errors are clustered at the fund level.

	Dependent variable: *Fund-issuer ln(Other loan)*					
	Non-saturated: old relationships			Non-saturated: old and new relationships		
	High Repo	Low Repo	DDD	High Repo	Low Repo	DDD
Non-Sat	-0.356***	-0.156*	-0.156*	-0.707***	-0.840***	-0.859***
	(0.0716)	(0.0913)	(0.0882)	(0.0524)	(0.0571)	(0.0574)
QE3 x Non-Sat	0.322***	0.0294	0.0276	0.510***	0.389***	0.386***
	(0.103)	(0.112)	(0.114)	(0.0803)	(0.0481)	(0.0480)
High RepoB x Non-Sat			-0.265**			0.104
			(0.117)			(0.0673)
QE3 x High RepoB x Non-Sat			0.303*			0.148*
			(0.155)			(0.0834)
Fsize	0.846***	0.938***	0.901***	0.859***	0.936***	0.905***
	(0.0730)	(0.0516)	(0.0520)	(0.0621)	(0.0441)	(0.0446)
Fage	0.00319*	0.00304***	0.00318***	0.00234	0.00273***	0.00266***
	(0.00175)	(0.000789)	(0.000940)	(0.00164)	(0.000836)	(0.000967)
Time x Issuer FE	yes	yes	yes	yes	yes	yes
Fund FE	yes	yes	yes	yes	yes	yes
N	10261	21470	31731	11492	22284	33776
adj. R^2	0.840	0.872	0.855	0.846	0.890	0.871

Standard errors in parentheses: clustered at the fund level

* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Chapter 3

If fail, fail less: Banks' decision on systematic vs. idiosyncratic risk

3.1 Introduction

The recent financial crisis revealed an overall increase in correlations in the financial system and the underlying fragility stemming from that. The 2008 banking crisis was a clear example that a large number of banks simultaneously being at the verge of failure represents a serious threat to the stability of the entire financial system. As a result, a systematic response by the regulators was neccessary given the potential negative repercussions arising out of multiple banks failing at the same time. The Federal Reserve Board and U.S. Treasury, as well as ECB responded by putting in place different liquidity provision programmes and troubled asset purchases programmes in order to provide emergency support to banks and mitigate negative spillovers to the rest of the system. This represents just one of the most recent episodes wherein the regulators' behaviour during the banking crises was substantitally impacted by the implicit 'too many to fail' guarantees.

Both anecdotal and empirical evidence suggests that regulatory interventions in the event of bank failures tend to be state contingent. In other words, the regulator's implemented bailout policy differs in the systemic banking crisis when the regulator confronts multiple simultaneous bank failures, as opposed to tackling individual bank failures (Kasa and Spiegel [2008], Santomero and Hoffman [1998] and Hoggarth et al. [2004]). For example, regulatory intervention is more likely to happen when bank failures are attributed to the aggregate conditions, instead of some idiosyncratic reasons. Deterioration in aggregate conditions affects everyone and may trigger simultaneous bank failures, thereby increasing the risks of a systemic banking crisis. Simultaneous multiple bank failures posit constraints on a set of available resolution policies that a regulator can employ for the purpose of resolving multiple bank failures. For example, negative aggregate conditions may imply a lack of liquidity among the surviving banks to acquire the failing ones, a significant decrease in asset prices due to negative market expectations and the like. A confluence of such factors increases the probability of the regulator bailing out the banks to avoid the negative consequences arising from multiple bank failures.

Too many to fail guarantees capture the effect that bailouts are more likely when many banks fail together, i.e. the banking crisis is systemic, while in the case of isolated bank failures, regulators resort to different bank failure resolutions. This feature of the regulator's policy affects the ex ante banks' risk taking incentives. Although saving banks that fail together may be ex post optimal, this generates the ex ante incentives for banks to herd, thus increasing the risk of simultaneous bank failures and the systemic crisis (Acharya and Yorulmazer [2007]).

The literature has discsussed several channels that may alleviate these harmful herding incentives among banks, thus reducing the negative effects of implicit too many to fail bailout guarantees. For instance, if banks increase their value by seizing the market share of their failing competitors, this creates incentives for the bank to survive at a time when other banks fail (Perotti and Suarez [2002]). Also, surviving banks can benefit from purchasing the assets of the failing banks at the fire-sales prices which also reduces the incentives to increase their correlation with other banks, in order to benefit from being 'the-last-bank-standing' when others fail (Acharya and Yorulmazer [2008a]).

In this paper, I argue that a bailout policy contingent on both the aggregate state and bank's individual characteristics relative to its failing peers may reduce the banks' incentives to herd. Basically, if a bank's individual bailout probability no longer depends only on the total number of banks that failed, but also on each bank's individual characteristics, this may break the link between the increase in interbank correlation and bailout probability. In other words, if the probability of the overall bailout intervention still relies on how systemic the banking crisis is, whereas a bank's individual bailout probability also depends on the bank's asset value in failure, this may provide more incentives for the bank to differentiate from its peers. Bailout rules based on the banks' relative performance have already been studied in the literature. Kasa and Spiegel [2008] empirically show that U.S. bank closures are based on bank relative performance and that such closure rules are less costly to taxpayers than the absolute closure rules.

Here, I investigate the effect of different bailout policies on the banks' risk-taking incentives. In particular, I focus on the choice between correlated and uncorrelated risk, also referred to as systematic and idiosycnratic risks. The risk-taking decision is modelled as the bank's choice to invest in the common or bank-specific project.

I show that introducing the regulator who chooses to bail out banks that have failed less relative to peers can mitigate banks' herding incentives. When a bank's value in failure affects its bailout probability, banks may prefer to invest in an idiosyncratic project. In some states, this allows them to have a higher value and consequently, a higher bailout probability, conditional on the bailout intervention happening, as opposed to peers that invested in a common project. In cases when the bank-specific project also happens to be the more efficient one (the higher expected value project), this bailout policy, termed as a "fail less" policy, implements the ex ante optimal investment outcome.

The analysis is undertaken using a two-period model which comprises of n identical risk-neutral banks, each with a continuum of depositors, a regulator and outside investors endowed with liquidity available for purchasing the failing banks' assets, if offered by the regulator. Depositors are assumed to be fully insured, with the regulator covering their promised return r in case of a bank failure.

Each bank can choose between investing in one of the two projects. The common project is accessible to everyone and captures the correlated, systematic risk that a bank may choose to undertake. In addition, each bank is endowed with the bank-specific project, independent across banks and independent from the common project, thus representing the uncorrelated risk bank may choose to undertake. The choice between undertaking idiosyncratic or systematic risk is modelled as the choice between investing in the common or the bank-specific project. Investing in the common project allows achieving the perfect portfolio correlation with the peers, while choosing the bank-specific project, depending on the individual project characteristics, may increase the bank's value in failure. Both projects are two-period projects with the first-period cash flow realization determining whether or not the bank is in default. If the low cash flows realize, regardless of the project choice, the bank does not have enough cash to repay the depositors and is considered to be in default.

The regulator decides on the optimal bank failure resolution policy by maximizing the total output of the banking sector net of any intervention costs related to the optimal policy. The regulator chooses between liquidating the bank by selling its assets to the outside investors or bailing the bank out, thus allowing it to continue operating as a going concern. Selling it to outsiders reduces the cost of deposit insurance incurred by the regulator, but comes at a cost of potential losses in the banking output that are attributed to the outsiders' inefficiency at operating the banking assets.

Two assumptions are central to my results and allow me to endogeneize the regulators preference to bailout better banks. First, I assume that bank's continuation value, in the event of a default, depends on its realized value in failure such that the greater severity of its failure, the lower the bank continuation value. This represents a reduced form of capturing the fact that bank failures are costly and have repercussions on its future value as a going concern. This can be justified by the effect of reputation channel or more stringent constraints imposed by the regulator and the like. Second, I assume that the liquidation of the failed banks through the sales to outside investors has diminishing returns. In other words, the liquidation values that outside investors are able to generate from the purchased banking assets decline in the number of banks that these investors acquire. Therefore, losses arising out of bank liquidations increase in the number of liquidated banks . This can be justified by the limited number of investors able to operate banking assets stemming from the asset-specificity (Williamson [1988], Shleifer and Vishny [1992] and James [1991])

These two features in combination with the regulator who decides on the bank's failure resolution strategy by maximizing the total banking output net of any intervention costs, ensures that the bank's bailout probability depends on the extent of the crisis aa well as the bank's value in failure. In other words, the overall probability of the bailout intervention happening depends on how systemic the banking crisis is (number of banks failing at the same time). However, the bank's bailout probability, conditional on the regulator bailing out any bank, will depend on its value in failure i.e. the project choice the bank makes ex ante. In this model, banks will be trading off the probability that any bailout intervention happens (probability that enough banks fail together) with the probability of actually being among the bailed out banks (bank's bailout probability conditonal on the intervention happening).

I begin by introducing the benchmark model wherein the banks' value in failure is independent from the choice between correlated and uncorrelated risks, since all projects are assumed to have identical cash flows across all state realizations. This captures the effect of the 'too many to fail' feature of the bailout policy on the banks' ex ante choice between systematic and idiosyncratic risk. In this setup, given the fact that all banks are homogeneous in failure, regardless of the project choice, the bailout probability is solely contingent on the aggregate state, which is defined by the total number of failing banks. In order to maximize the expected payoff in the state of default, i.e. maximize the expected value of bailout subsidies received, banks choose to invest in a common project so as to maximize the probability of systemic enough crises occuring, thus, maximizing the probability of a bailout intervention. The bailout policy where the bank's bailout probability is solely dependent on the aggregate number of bank failures is referred to as the 'too-many-to-fail' policy.

Next, I introduce the banks' heterogeneity in failure by allowing common and bank-specific projects to yield different cash flows at a low state. Here, an underlying assumption is that low state cash flow realizations of the bank-specific projects are higher than the common project ones. This implies that in expectation, the bank-specific projects are better than the common project (probability of the low state remains the same across projects). When faced with bank defaults, the regulator is no longer indifferent between banks when deciding on liquidation or bailout, since banks may have different values in failure, thus determining different continuation values. In order to maximize the expected value of the bailed out banks' output in the second period, the regulator prefers to liquidate failed banks with the lowest continuation values first. This minimizes the losses from liquidation, while enabling the regulator to reduce the costs of deposit insurance by capturing the proceeds from the sales to outsiders.

Here, the probability of any bailout intervention still depends on the aggregate state, determined by the total number of failures. However, the bank's bailout probability conditional on the bailout intervention depends on the bank's ex ante investment decision and cash flows that are realized in default. In order to maximize the expected bailout subsidy, the banks trade off the probability of the crisis being systemic enough for the regulator to intervene with the probability of their value in failure being high enough to be bailed out. Thus, for a high enough probability of the low cash flow state realization, banks always prefer to invest in a bank-specific project. A bailout policy where the bank's value in failure affects its bailout probability is referred to as the 'fail less' policy.

Finally, I relax the assumption on the bank-specific project being more efficient one in terms of the expected value, by introducing the ex ante heterogeneity among banks. I distinguish between good and bad banks based on their bank-specific projects being better or worse, relative to the common project in the low cash flow state. Given the 'fail less' bailout policy, it is always optimal for bad banks to choose a common project since it is both efficient and maximizes their bailout probability. The existence of bad banks which produce enough correlated bank failures for the regulator to intervene, makes the good banks less likely to herd and consequently, choose their efficient bank-specific projects more often.

This paper contributes to the literature studying the effects of bailout policy on the banks' risk-taking incentives. Large part of this literature studied different manifestations of the moral hazard problem arising from the regulator's implicit bailout guarantees (see Bagehot [1873], Mailath and Mester [1994], Huang and Goodhart [1999] and Freixas [2000]). These papers focus on analyzing a single bank's risk-taking incentives in the presence of bailout policies. They abstract away from the potential strategic interactions among banks and the implications on the regulator's policy stemming from these interactions.

Papers that introduce the state-contingency in the regulator's bailout policy attempt to capture the feature that bailouts are more frequent when the aggregate state of the economy is bad, and the more bank failures occur simultaneously (see Nagarajan and Sealey [1995], Cordella and Yeyati [2003] for theoretical analysis) Kasa and Spiegel [2008], Brown and Dinc [2011], Santomero and Hoffman [1998] and Hoggarth et al. [2004] provide relevant empirical evidence that bailout interventions are more likely if the crisis is systemic, while bank closures happen more often in the case of isolated bank failures.

Theoretical models which account for the banks' strategic response to the regulator's state-contingent bailout policy and also endogeneize the systemic nature of the crisis arising from the banks' decisions are provided in Acharya and Yorulmazer [2007] and Acharya and Yorulmazer [2008a]. These papers introduce a framework of the 'too-many-to-fail' channel of bank herding incentives. They contribute to a larger strand of literature that explains bank herding incentives using alternative channels (see Penati and Protopapadakis [1988] and Mitchell [1998] for more discussion on the bailout channel; Rajan [1994] for the effect of bank managers' reputational considerations on herding). Since my paper exploits the changes in the regulator's bailout policy which can reduce bank herding incentives, it also contributes to the literature studying the alternative channels which generate a strategic substitutability within the banks' actions (see Perotti and Suarez [2002] and Acharya and Yorulmazer [2008b]).

The remainder of the paper is structured as follows. Section 2 presents the setup of the model. Section 3 analyzes the 'too many to fail' benchmark model, whereas Section 4 introduces heterogeneity in failure and the 'fail less' model. Section 5 discusses welfare implications of the 'fail less' bailout policy when banks are identical during the first period. Section 6 introduces the ex ante heterogeneous banks and discusses their optimal investment strategies under the 'fail less' bailout policy. Finally, Section 7 concludes. The proofs and derivations that are not in the text are given in the Appendix.

3.2 Model setup

Players

In this economy, there are three dates $t = 0, 1, 2$, n risk-neutral banks, and one risk-neutral regulator. Each bank i can borrow from a continuum of depositors of measure 1. At date 0 depositors deposit their one unit of endowment in the bank. Deposits are in the form of a standard debt contract such that depositors are promised to receive return r at date 1. Deposits are assumed to be fully insured. In addition, outside investors are endowed with some liquidity to be spent on purchasing the banking assets, following the offer made by the regulator.

Banks

Each bank has access to the common investment project $\tilde{R}_m$, which I refer to as the market investment project. In addition, each bank is endowed with the bank-specific, investment project $\tilde{R}_I$. Bank-specific nvestment projects' are independent of each other, and independent of the market. Given that all banks can access the market project and achieve a perfect correlation of investment portfolios, market project represents a systematic, correlated risk. Independent bank-specific projects represent the idiosyncratic risk that banks can undertake.

Both market and bank-specific projects are two-period projects. First-period cash flows are high $\overline{R}_{1j}$ with probability α, or low $\underline{R}_{1j}$ with probability $1-\alpha$, where $j = I, m$. If high cash flows are realized, the bank is able to repay r to its depositors, regardless of the project in which it invested. Namely, $\overline{R}_m \geqslant \overline{R}_i > r$ is assumed. If low project cash flows realize, since $r > \underline{R}_i \geq \underline{R}_m$ holds, the bank is unable to cover r and is considered failed.

Second-period project cash flows depend on the realization of the first-period cash flows in the following manner:

In case high cash flows are realized at date 1, the cash flows in the second period are equal to V, where V is independent from the chosen project. However, if the bank fails at date 1, cash flows at date 2 are a function of the cash flow realization at $t = 1$, defined by

$$R_{2j} \mid \underline{R}_{1j} \sim U\left(\underline{R}_{1j} - \varepsilon, \underline{R}_{1j} + \varepsilon\right) \tag{3.1}$$

for some small enough ε.

Path-dependance of cash flows in the low state makes bank continuation value in case of the failure dependent on the bank's realized value in failure. The greater severity of the failure, the lower the future cash flows. This is a reduced form of modelling the feature that bank's inability to repay its depositors may have consequence on the bank's future cash flows. One can think that bank's default harms bank's reputation or it imposes more stringent regulations on the bank after it had to rever to the regulator as the lender of last resort, all of which may affect the bank's continuation value. Also, I assume that failures are expensive, and that banks will be incurring certain costs of financial distress in the form of lower second-period cash flows, relative to the case where there was no failure. Thus, $V > R_{2j}$, for $j = I, m$

If the bank was able to repay depositors at date 1 or was given the adequate help by the regulator through the bailout intervention, it will be able to capture the second-period project cash flows. At date 0, bank i chooses between investing in a common or bank-specific project, by choosing $x_i = \{0, 1\}$, where $x_i = 0$ defined the investment in the market project, while $x_i = 1$, investment in a bank-specific project. The bank is trying to maximize the total expected value of project cash flows.

Outside Investors

Outside investors buy the failing banks' assets that are offered to them by the regulator. They are able to generate cash flows $L(k)$ per bank, where k denotes the total number of banks they buy. Consequently, $L(k)$ represents the liquidation value of a failing bank, given the fact that the regulator sells k banks to the outside investors.

I assume that outside investors have limited resources to operate the acquired banking assets, thus the liquidation value generated declines in the number of banks purchased from the regulator. The higher the number of the liquidated banks sold to outsiders, the lower the liquidation value of each bank i.e. $L'(k) < 0$.

Outsiders are rational, and the price they are willing to pay for the banking assets is less or equal to the value they are able to produce. In this model, outside investors always break even and their participation constraint binds:

$$p(k) = L(k) \tag{3.2}$$

where $p(k)$ represents the price they pay per bank bought, given that in total k banks are being liquidated through sales to outsiders. This makes it is obvious that $p(k)$ is also decreasing in k.

Regulator

At date 1, regulator observes bank failures and decides between bailing out the bank or selling it to the outsiders. Bank has failed if the cash flows generated by its project at date 1 are not sufficient to cover the promised return r to depositors. Since the deposits are insured, regardless of the chosen failure resolution, the regulator covers for deposit insurance. The regulator's objective function is to maximize the total expected output of the banking sector in the following period net of any bailout or liquidation costs.

Costs incurred by the regulator are the fiscal costs related to the coverage of deposit insurance. I assume the linear fiscal cost function is defined as $C(d) = d$, where d represents the number of units of funds required to cover deposit insurance. Fiscal costs associated with the provision of funds for deposit insurance can be explained by the standard distortionary effect that required increase in taxes may have. Also, other potential costs related to banking crises and bank failures that result from immediacy of providing these funds may be captured through this cost function.[1]

Bailout assumes that the regulator covers for the deposit insurance and the bank remains operational, thus capturing the second-period's project cash flows. Liquidation assumes that the bank and its project are sold to the outside investors. This implies that the bank gets nothing, and unrealized second-period project cash flows are lost, but the proceeds from the sale lower the regulator's costs of deposit insurance.

Since the liquidation values outside investors generate decrease in the number of liquidated banks, the loss from liquidations will be increasing in the number of liquidated banks. Thus, the Regulator is facing a trade-off between lowering the cost of deposit insurance through bank sales and incurring the social loss from selling the banking assets to potentially less efficient outside users.

If k banks in total are being liquidated, the payoff from bailing out the k -th bank is

$$E\left(R_{2j} \mid \underline{R}_{1j}\right) - \left(r - \underline{R}_{1j}\right)$$

while the payoff from liquidating this k-th bank through the sales to outsiders is

$$L(k) - \left(r - \underline{R}_{1j} - p(k)\right)$$

I assume that for any single bank failure, it is always optimal to liquidate the bank since $E\left(R_{2j} \mid \underline{R}_{1j}\right) < 2L(1)$, for any $j = m, I$ and outside investors paying the break-even price $p(1) = L(1)$.

Lemma 1 *Let f be the number of bank failures occuring at date 1. The regulator's optimal bailout policy at date 1 is defined by the marginal $k^* - th$ bank, where $k^* \leq f$ such that the following holds:*

$$E\left(R_{2j} \mid \underline{R}_{1j}\right) - L(k^*) = p(k^*)$$

where $E\left(R_{2j} \mid \underline{R}_{1j}\right) - L(k^*)$ represents the net loss from liquidating the $k^* - th$ bank, and $p(k^*)$ is the net gain from selling the bank to outside investors. Then, for any $k^* > 1$, it will be optimal to liquidate k^* banks, while bailout $f - k^*$ of the failing banks, given expressions in (3.3) hold:

[1] See Calomiris [1998] for a detailed discussion on fiscal costs associated with banking failures and bailouts

$$\begin{cases} E\left(R_{2j} \mid \underline{R}_{1j}\right) - L\left(k^* - 1\right) < p\left(k^* - 1\right) \quad and \\ E\left(R_{2j} \mid \underline{R}_{1j}\right) - L\left(k^* + 1\right) > p\left(k^* + 1\right) \end{cases} \tag{3.3}$$

This makes it obvious that the pace at which $L(k)$ decreases in the number of banks acquired by the outsiders determines how costly bank liquidations are. If the social loss from liquidation is too high relative to the reduction in deposit insurance costs obtained, this implies that there are 'too many banks to fail' as termed in Acharya and Yorulmazer [2007]. In such cases, the banking crisis is considered to be systemic.

Timeline

At date 0 depositors deposit their endowments in the banks and are promised return r at date 1. At date 0 each Bank i chooses to invest this one unit of depositors' endowment either in the market project or in a bank-specific investment project. At date 1 first-period project cash flows are realized. If the bank is not able to meet its liabilities towards depositors, the bank is considered failed. The Regulator has to choose between liquidating the bank through sales to outside investors or bailing it out.

If the bank is bailed out, the bank owners are allowed to continue operatig the bank and they capture second-period project cash flows. If the bank is sold to outsiders, initial bank owners get nothing in return and outside investors are only able to realize the bank's liquidation value.

3.3 'Too many to fail' benchmark

In order to analyse the effects of bailout policy on banks' risk-taking and investment decision, I start with a benchmark model that is supposed to capture the 'too many to fail' feature of the bailout policy.

In this setup, I assume that $\bar{R}_m = \bar{R}_i = \bar{R}$ and $\underline{R}_m = \underline{R}_i = \underline{R}$ holds. Namely, the market and bank-specific projects have identical cash flows. By investing in the market project common to all the banks, banks can achieve perfect correlation of their project cahs flows, while if investing in the bank-specific projects the correlation will be zero.

In case of failure, given the banks are homogeneous in failure, the regulator will be indifferent between banks to liquidate and bailout, once the total number of bailouts and liquidations is determined. Bank's bailout probability only depends on the total number of banks that failed together. This setup captures the feature of the 'too many to fail' bailout policy.

3.3.1 Solving the Model

Regulator's decision

The banks fail if the low project cash flows have realized at date 1. Since both the market and bank-specific projects have the same cash flow in the low state, the banks will be homogeneous in failure. Given that the regulator cannot observe banks' investment decision, but only realized cash flows, the bailout decision cannot be contingent on the banks' project choice. The bailout probability for each bank will only be contingent on the aggregate state, where aggregate state is defined by the total number of failures in the banking system.

According to Lemma 1, there will be some number of bank liquidations k^*, such that the regulator is indifferent between liquidating and bailing out the $k^* - th$ bank. Given f bank failed at date 1, k^*banks will be randomly selected and sold to the outside investors, while $f - k^*$will be bailed out. The optimal number of banks to be liquidated, k^*, is defined by the following expression

$$\underline{R} - L(k^*) = p(k^*) \tag{3.4}$$

Since outside investors are rational, and their participation constraint given in (3.2) binds, k^* is determined by

$$\underline{R} - L(k^*) = L(k^*) \tag{3.5}$$

Lemma 2 *Let k^*be determined by $L(k^*) = \frac{\underline{R}}{2}$ and $k^* < n$, where $n$is the total number of banks. Then, in any sub-game perfect equilibrium, if f is the number of banks that failed at date 1, Regulator's ex-post optimal bailout policy is defined as follows:*

- *when $f \leq k^*$, all failed banks get liquidated and no bailouts happen, implying $Pr(Bailout \mid f) = 0$*
- *when $f > k^*$, k^*banks are liquidated through the sales to outsiders, while $f - k^*$ banks are bailed out, implying $Pr(Bailout \mid f) = 1 - \frac{k^*}{f}$*

Bailouts occur only when enough banks fail together, thus generating systemic enough banking crisis. Ex ante, the bailout probability would be increasing in the total number of failures and each failing bank has the same probability of being bailed out.

Unless all banks have invested in the market project, the number of bank failures f will have a binomial distribution $B(n, 1-\alpha)$such that probability of f banks failing at date 1 is

$$Pr\left(f\right)=C\left(n,f\right)\alpha^{n-f}\left(1-\alpha\right)^{f}\quad for\,f\in\{0,1,...n\} \tag{3.6}$$

where $C\left(n,f\right)$is the number of combinations of f objects from a total of n.

Bank's decision

In the first period all banks choose between investing in the market project or the bank-specific project. The game between banks is a symmetric game, given that they are identical with the same set of available actions and assumed unable to distinguishing between the other players (Gale et al. [1950]).

Therefore, I analyze the choice of a representative bank i which takes the actions of all other banks as given. I define a symmetric pure strategy equilibrium, in which the optimal investment decision for the representative bank is also optimal for all other banks. When solving for the optimal strategy, I rely on the assumption that banks are homogeneous, thus if it is profitable for the representative bank i to deviate, all banks deviate.

When choosing its investment at $t=0$, Bank i takes the bailout probability as given. In equilibrium, each bank correctly infers the ex-post optimal regulator's bailout policy. Therefore, given the bailout policy and implied bailout probabilities, representative bank i decides between investing in the idiosyncratic, $x_i=1$, and the market project, $x_i=0$.

Let $E\left(\pi\left(0\right)\right)$ be the expected payoff given all banks invest in the common project. If the low cash flow realizes at date 1, all banks will fail together and the regulator would randomly pick $n-k^*$ banks to be bailed out, while liquidate the rest. Thus, the expected payoff from investing in the market project is given as:

$$E\left(\pi\left(0\right)\right)=\alpha\left(\overline{R}-r\right)+\alpha V+\left(1-\alpha\right)\left(1-\frac{k^*}{f}\right)\underline{R} \tag{3.7}$$

If the bank i thinks that all other banks will choose the market project, it is neccessary to check whether it is profitable for the bank i to deviate and invest in the bank-specific project. Let $E\left(\pi_i\left(1,\underline{0}\right)\right)$be the expected payoff of the bank i given it deviates to $x_i=1$, while all other banks choose $x_{-i}=0$:

$$E\left(\pi_i\left(1,\underline{0}\right)\right)=\alpha\left(\overline{R}-r\right)+\alpha V+\left(1-\alpha\right)\left(1-\alpha\right)\left(1-\frac{k^*}{f}\right)\underline{R} \tag{3.8}$$

Ex post optimal bailout policy of the regulator specified in Lemma 2, implies that the bank will always be liquidated when failing on its own, since $k^* \geq 1$ is assumed. and bailed out with some positive probability when failing with other banks.

By comparing (3.7) and (3.8), it is clear that Bank i never chooses to deviate when all other banks are investing in the common market project, since the expected bailout subsidy decreases, the lower the probability of the systemic crisis. Therefore, the following holds

$$E\left(\pi_i\left(1, \underline{0}\right)\right) - E\left(\pi\left(0\right)\right) = -\alpha\left(1-\alpha\right)\left(1 - \frac{k^*}{f}\right)\underline{R} < 0$$

If all banks choose to invest in the bank-specific projects, bank i's expected payoff from investing in the bank-specific project is:

$$E\left(\pi\left(1\right)\right) = \alpha\left(\overline{R} - r\right) + \alpha V + \left(1-\alpha\right)\sum_{f=k^*}^{n-1} Pr\left(j\right)\frac{f+1-k^*}{f+1}\underline{R} \tag{3.9}$$

Uncorrelated projects imply that bank failures will be scattered. In the states in which very few banks fail together, bank failures are resolved by the sales to outside investors. Only when enough failures occurs simultaneously, some banks will be bailed out.

Investing in the bank-specific or the market project when all other banks invest in their bank-specific projects, is payoff equivalent For the representative bank i since the bank remains equally uncorrelated with other banks. Given all projects are identical in terms of cash flows and success probabilities, then, for the same level of interbank correlation, payoffs from different strategies could be the same. Thus, there might be multiple Nash equilibria resulting in the same level of interbank correlation which are all payoff-equivalent.

Here I focus on the symmetric equilibria in which all banks take the same equilibrium action. Therefore, given the ex-post optimal bailout policy of the Regulator, defined in Lemma 2, banks always choose to invest in the market project. Herding allows them to maximize the bailout subsidies by maximizing the probability of bailouts happening. Increasing the probability of the systemic crisis is achieved by choosing the perfectly correlated investment portfolios.

Lemma 3 *Let $E\left(\pi\left(0\right)\right)$ be defined as in (3.7) and $E\left(\pi\left(1\right)\right)$ as in (3.9). If the Regulator implements the ex post optimal bailout policy, banks will always choose to invest in the common market project, rather than in the bank-specific projects. This is due to $x = 0$ being a weakly dominant strategy for each bank, i.e. $E\left(\pi\left(0\right)\right) > E\left(\pi\left(1\right)\right)$.*

Proof: See appendix.

Ex-post optimal bailout policy of the Regulator, defined in Lemma 2, combined with the optimal investment decision of the banks, gives the subgame perfect equilibrium described in Proposition 1.

Proposition 1 *Let k^* be determined by $L(k^*) = \frac{R}{2}$. Then, in the unique symmetric pure strategy subgame perfect equilibrium:*

If f is the number of failed banks at date 1, and $f > k^*$, the Regulator will liquidate at maximum k^* banks and bailout the rest of the failed ones, such that the bailout probability for each bank is equal across all failed banks.

Then, the optimal investment choice for each bank is to invest in the common market project and therefore maximize the expected bailout subsidy by maximizing the interbank correlation.

3.4 'Fail less' Model - Heterogeneity in Failure

In order to investigate how the banks' choice between systematic and idiosyncratic risk changes when the regulator cares about bailing out the banks that failed less, I introduce the heterogeneity in banks' failure through heterogeneity in projects' cash flows in the low state.

The bank-specific projects remain homogeneous and uncorrelated across banks, but now yield a higher cash flow than the market project in the low state, i.e. $\underline{R}_i > \underline{R}_m$. In the high state, the cash flows remain the same across projects, i.e. $\overline{R}_i = \overline{R}_m$.

Since in case of bank failure, the second-period cash flows are a function of the realized first-period cash flows as defined in (3.1), how bad the bank failed at date 1 determines the bank continuation value. Consequently, the value maximizing regulator is no longer indifferent between banks to bailout or liquidate.

3.4.1 Solving the Model

Regulator's decision

At date 1, for each bank that failed, the regulator compares payoffs from bailing out and liquidating the bank, given the total number of failures in the banking system.

Since the Regulator is maximizing the total banking output at date 2, net of the costs of his intervention, it follows that the bailout probability for each bank will be contingent on the aggregate state, where aggregate state is defined by the total number of failures in the banking system, but also on the bank's value (cash flow realized) in failure.

Let $j = I, m$, then for any bank that failed, regardless of the project in which it invested, the payoff from bailing out bank i is given as:

$$E\left(R_{2j} \mid \underline{R}_{1j}\right) - \left(r - \underline{R}_{1j}\right) = \underline{R}_{1j} - \left(r - \underline{R}_{1j}\right)$$

On the other hand, payoff from liquidating the Bank i, where the bank is $k-th$ bank to be liquidated is:

$$L(k) - \left(r - \underline{R}_{1j} - p(k)\right) = L(k) - \left(r - \underline{R}_{1j} - L(k)\right)$$

By comparing these payoffs, it follows that the social loss from selling the k-th bank, $\underline{R}_j - L(k)$, is now dependent on the bank's choice of the project j and increases in the bank continuation value. At the same time, the gain from selling the k-th bank to outside investors, given k banks were liquidated in total, is equal to $p(k)$ and only depends on the total number of banks liquidated.

For each project j there will be some number of bank liquidations k_j^*, such that the regulator is indifferent between liquidating and bailing out the $k_j^* - th$ bank, where $j = i, m$. For a bank which invested in the project j, the regulator's liquidation/bail out decision is defined by the indifference condition given in 3.10:

$$\underline{R}_j - L\left(k_j^*\right) = p\left(k_j^*\right) \tag{3.10}$$

Outsiders are rational, and their participation constraint binds, thus $p\left(k_j^*\right) = L\left(k_j^*\right)$ holds for any k_j^*. The price outsiders pay is only contingent on the total number of banks they purchase while independent of banks' values. On the other hand, the losses from bank liquidation will be increasing in the bank's value. This creates incentives for the regulator to preserve the higher value banks in the banking system, while liquidating the lower valued ones first. Consequently, if the regulator observes bank failures across both banks that invested in the market and idiosyncratic projects, he will always choose to liquidate the lower-value banks, in this case, banks that invested in the market project.

Lemma 4 *Let bank-specific projects have higher cash flow than the market project in case of failure, i.e.* $\underline{R}_I > \underline{R}_m$*, and* k_m^* *and* k_I^* *represent the maximum number of banks liquidated that invested in the market project, and the bank-specific project.*

In a symmetric equilibrium, the maximum number of liquidated banks that invested in the bank-specific projects will be lower than the number of liquidated banks that invested in the market project i.e. $k_m^* > k_I^*$ *holds.*

Proof: Since $\underline{R}_I > \underline{R}_m$ and outsiders participation constraint, it follows that $L(k_I^*) > L(k_m^*)$. Given $L(k)$ is decreasing in k, it follows that $k_m^* > k_I^*$.

Ex-post optimal bailout policy for the regulator depends on the total number of failures. If not enough banks fails at the same time, crisis is not systemic enough and even the high-value banks are sold to outsiders. Whenever the crisis is systemic enough for bailouts to happen and some of the failed banks invested in the bank-specific projects, while others invested in the market project, the banks that failed less have higher probability of being bailed out. The bailout probability, conditional on the intervention happening, increases in the bank's value in failure. This defines the 'fail less' bailout policy.

Proposition 2 *Let* k_j^* *be determined by* $L\left(k_j^*\right) = \frac{\underline{R}_j}{2}$, *where* $j = I, m$. *Then, in any sub-game perfect equilibrium, Regulator's ex post optimal bailout policy is defined as follows:*

If $n > k_I^*$ *and* f_j *is the total number of banks that failed at date* 1 *while investing in project* $\widetilde{R}_j$ *, then:*

- *when* $f_j \leq k_j^*$, *all failed banks* f_j *get liquidated and no bailouts happen*
- *when* $f_j > k_j^*$, k_j^* *banks are liquidated through the sales to outsiders, while* $f_j - k_j^*$ *banks are bailed out*

Then, Regulator's ex-post optimal bailout policy translates into the corresponding bailout probabilities as defined in Corollary 1.

Corollary 1 *Let* $f = f_I + f_m$, *where* f_m *is the number of failed banks that invested in the market and* f_I *is the number of failed banks that invested in the bank-specific project. The banks will face different bailout probabilities, following from Regulator's ex post optimal bailout policy, depending on the total number of failures, and their investment decision:*

1. *When* $f \leq k_I^*$ *no bailouts happen, and each failed bank gets liquidated regardless of its investment project*
2. *If* $f > k_I^*$, *such that*
    - $f_m \leq k_I^*$, *all* f_m *failed banks are liquidated, so that* $Pr\left(Bailout \mid f_{I,m}, \tilde{R}_m\right) = 0$, *while* $k_I^* - f_m$ *of* f_I *banks are liquidated , so that* $Pr\left(Bailout \mid f_{I,m}, \tilde{R}_I\right) = \frac{f_I - (k_I^* - f_m)}{f_I} = \frac{f - k_I^*}{f_I}$

- $k_I^* \leq f_m < k_m^*$, *all* f_m *banks are liquidated, so that* $Pr\left(Bailout \mid f_{I,m}, \tilde{R}_m\right) = 0$, *while all* f_i *banks are bailed out, so that* $Pr\left(Bailout \mid f_{I,m}, \tilde{R}_i\right) = 1$
- $f_m > k_m^*$, *then* k_m^* *out of* f_m *banks are liquidated, while the rest of the failed banks are bailed out, so that bailout probabilities are* $Pr\left(Bailout \mid f_{I,m}, \tilde{R}_m\right) = \frac{f_m - k_m^*}{f_m}$, *and for banks that invested in the idiosyncratic project* $Pr\left(Bailout \mid f_{I,m}, \tilde{R}_I\right) = 1$

Bank's decision

As in the benchmark model, banks are identical in the first period and they choose between investing in the market or in the bank-specific project. Following the definition and assumptions of symmetric games, as before, I analyse the investment choice of a representative bank i .

If all banks choose to invest in the market project, and low cash flows realize at date 1, all banks fail together. According to Proposition 2, the bailout probability for each bank is $1 - \frac{k_m^*}{n}$. Thus, the expected payoff from investing in the market project is given as:

$$E\left(\pi\left(0\right)\right) = \alpha\left(\overline{R}_m - r\right) + \alpha V + (1-\alpha)\left(1 - \frac{k_m^*}{n}\right)\underline{R}_m \tag{3.11}$$

If bank i deviates and chooses the bank-specific project, while others invest in the market, the bank's failure is no longer correlated with other banks' failures. Given $k_i^* \geq 1$, the bank will always be liquidated when failing on its own. However, if the low cash flow of the idiosyncratic project realizes, when the market project also yields the low cash flow, bank i will be bailed out with certainty, as it will be the bank with the highest value in failure.

Thus, the expected payoff given bank i deviates to $x_i = 1$, while all other banks choose $x_{-i} = 0$ is the following:

$$E\left(\pi_i\left(1, \underline{0}\right)\right) = \alpha\left(\overline{R}_I - r\right) + \alpha V + (1-\alpha)(1-\alpha)\cdot 1 \cdot \underline{R}_I \tag{3.12}$$

If the payoff from deviating is high enough, the bank will choose the idiosyncratic project, even when all other banks invest in the common project. Therefore, the condition that should hold is:

$$E\left(\pi_i\left(1, \underline{0}\right)\right) - E\left(\pi\left(0\right)\right) > 0$$

which translates into

$$(1-\alpha)\,\underline{R}_I > \left(1-\frac{k_m^*}{n}\right)\underline{R}_m \tag{3.13}$$

Condition (3.13) implies that, given failure, expected bailout subsidies have to be higher when the Bank i chooses the bank-specific project, than when it chooses the common project. From (3.13), I calculate the α_{FL}^* , the probability of projects yielding high cash flows, that makes the Bank i indifferent between the two projects, when all other banks invest in the market:

$$\alpha_{FL}^* = 1-\left(1-\frac{k_m^*}{n}\right)\frac{\underline{R}_m}{\underline{R}_I} \tag{3.14}$$

Then, if $\alpha < \alpha_{FL}^*$, it is profitable for Bank i to invest in the bank-specific project, even if all other banks choose the common project. Since banks are identical, this implies that in that case, all banks would choose to deviate and invest in the bank-specific project.

In case all banks choose to invest in the bank-specific projects, the expected payoff $E(\pi(1))$ is

$$E(\pi(1)) = \alpha\left(\overline{R_i}-r\right)+\alpha V+(1-\alpha)\sum_{f=k_i^*}^{n-1} Pr(f)\,\frac{f+1-k_i^*}{f+1}\underline{R}_i \tag{3.15}$$

Since bank-specific projects are uncorrelated, if only few banks fail together, Regulator can always liquidate them at the high enough price, such that the opportunity cost of bailout is too high. It is never profitable for the bank i to deviate and invest in the market project, when all other banks are investing in their bank-specific projects, since its expected bailout subsidy would be zero. This is because bank i would always be the lowest value bank in failure, therefore always the first to be liquidated. Therefore, if bank i believes that all other banks will choose to invest in the bank-specific projects, it is optimal for the bank i to invest in its bank-specific project as well, since that maximizes its expected bailout subsidies. The optimal investment strategy for banks, given the Regulator implements the ex post optimal 'fail less' bailout policy is summarized in Proposition 3.

Proposition 3 *Let α_{FL}^* be defined as in (3.14) and the ex post optimal bailout policy of the Regulator be defined as in Proposition 2.*

- *If $\alpha < \alpha_{FL}^*$ holds, in equilibrium all banks choose to invest in their bank-specific projects $x^* = 1$*
- *If $\alpha \geq \alpha_{FL}^*$ holds, there will be two pure strategy symmetric equilibria:*
  - *if Bank i believes that all other banks will choose the common project, it is optimal for Bank i to do the same, therefore $x^* = 0$*

– *if Bank i believes that all other banks will choose the bank-specific project, it is optimal for Bank i to choose its bank-specific project, therefore $x^* = 1$.*

In this model, α represents the probability of projects yielding high cash flows and no bank failures occuring which may represent an indicator of the aggregate economic conditions. For example, if aggregate economic conditions are poor, such that probability of high cash flows is low enough, banks will prefer to invest in their bank-specific projects. In other words, when probability of bank failure is high enough, such that systemic crisis will occur even when banks choose the uncorrelated investments, banks care to maximize their individual bailout probability by choosing project which entails higher values in failure. However, when the aggregate state of the economy is good, i.e. α is high enough and bank failures are less probable, banks prefer to invest in the correlated investment in order to maximize the probability of the systemic crisis happening. Therefore, the result described in Proposition 3 is aligned with the procyclicality of bank herding behaviour that has been established in the literature (Acharya and Yorulmazer [2008b]).

3.5 Ex ante optimal investment choice

In order to compare the optimality of different bailout policies from the ex ante standpoint, I analyze the expectation at date 0 of the total banking output given different possible bank investment decisions. Let $E(\Pi(x))$ represent the ex-ante banking output net of bailout/liquidation costs for the symmetric banks' investment choice x, where x stands represents a decision between the idiosyncratic ($x = 1$) or the common project ($x = 0$).

The total banking output in the high cash flow realization states is independent of the investment choice, since idiosyncratic and market project yield the same cash flows in the high state, by assumption. Differential in the expected total output between banks' different ex ante investment decisions is generated by differences in the low cash flow realization states and the corresponding optimal regulatory responses.

If all banks invest in the common project

$$E(\Pi(0)) = n \cdot \alpha \left(\overline{R}_m - r + V\right) + n \cdot (1-\alpha)\, \underline{R}_m - (1-\alpha)\, n\, (r - \underline{R}_m) \tag{3.16}$$

The first term represents the expected banking output in the high state, when no failures occur. Since the social loss from bank liquidation is perfectly offset by the decrease in the costs of deposit insurance obtained through bank sales, expected banking output in the low state is equivalent to the situation in which the regulator bails out all the failed banks, given they all invested in the common project.

Next, I consider the case in which all banks invest in the bank-specific projects. From the Proposition 2, it follows that the banking crisis will be systemic enough for the regulator to intervene, only when more than k_i^* banks fail simultaneously. In the states in which only few banks fail, the regulator is able to liquidate the banks such that the social loss from liquidation is lower than the gains from the reduction in the cost of deposit insurance. Conversly, when all banks fail together the gains from bank sales are always offset by the social loss from liquidation. The total net banking output when banks invest in the bank-specific projects is given in (3.17), while detailed derivations are provided in the Appendix.

$$\begin{aligned} E\left(\Pi\left(1\right)\right) &= n\alpha\left(\overline{R}_I - r + V\right) + \left(1-\alpha\right) n\underline{R}_I \\ &+\sum_{f=0}^{k_I^*} f Pr\left(f\right)\left(2L\left(f\right) - \underline{R}_I\right) \\ &-\left(1-\alpha\right) n\left(r - \underline{R}_I\right) \end{aligned} \tag{3.17}$$

The first row of (3.17) represents the expected banking output of the high and low cash flow realizations, assuming that banks are bailed out in failure. In this case, I exploit the feature of the binominal distribution, that the expected number of bank failures for n independent bank projects with failure probability $1-\alpha$ is equal to the sum of independent failure probabilities across these n realizations.

The second row represents the gains from bank liquidations in the states of the world in which there is few enough bank failures, such that the gains from bank sales are not entirely offset by the social losses from bank liquidation. Therefore, when the number of failed banks f is $f \in [0, k_I^*)$: the condition $\underline{R}_I - L\left(f\right) < p\left(f\right)$ holds and participation constraint of the outsiders binds for any f, $p\left(f\right) = L\left(f\right)$. This implies that $2L\left(f\right) > \underline{R}_I$ for every $f \in [0, k_I^*)$ representing the gains from bank liquidations at high enough values. When $f > k_I^*$ the crisis is systemic enough for the regulator to start bailing out the banks and the gains from bank sales are entirely offset by the social loss from bank liquidation. The third row represents the expected costs of deposit insurance.

When comparing equations in (3.16) and (3.17), additional component existing when banks invest in uncorrelated projects are the gains from no herding arising from the bank failures being uncorrelated. The gains from no herding are always strictly positive and defined by the expression $\beta = \sum_{f=0}^{k_I^*} f Pr\left(f\right)\left(2L\left(f\right) - \underline{R}_I\right)$

In order to determine the ex ante investment policy of banks that maximizes the net expected banking output, I compare the outcomes given in equations (3.16) and (3.17). The additional gains arising from the banks investment in their bank-specific projects consists of three components: (i) higher expected banking output when low cash flows realize; (ii) the lower cost of deposit insurance ;(iii) potential gains from no herding β.

Given previous assumptions on $\overline{R}_I = \overline{R}_m$ and the fact that gains from no herding are always positive, it follows that the expected total output of the banking sector at date 0, net of any costs of anticipated liquidations and bailouts is always higher when banks choose to invest in their uncorrelated investment projects. In this setting, the ex post optimal 'fail less' bailout policy, is also the bailout policy that induces banks to implement the ex ante optimal investment choice.

3.6 Heterogeneous banks

Here, I relax the assumption that bank-specific project is neccessarily more efficient than the market project and anlalyze the optimal investment choices of ex ante heterogeneous banks under regulator implementing the 'fail less' bailout policy. There are two types of banks, where the type is determined by the bank-specific project banks is endowed with. The good banks, similar to before, are endowed with the idiosyncratic project $\widetilde{R}_G$ which yields higher cash flows in the low state than the market project. The bad banks are endowed with the idiosyncratic project $\widetilde{R}_B$ which yields the lower cash flows relative to the market project in the low state. Both bank types also have access to the common market project $\tilde{R}_m$ defined as before. All projects yield the same cash flows in the high state, while heterogeneity comes from the low state realizations summarized in (3.18)

$$\begin{aligned} \bar{R}_m = & \quad \bar{R}_G = \bar{R}_B \\ \underline{R}_G > & \quad \underline{R}_m > \underline{R}_B \end{aligned} \tag{3.18}$$

Given that the economy is populated by n banks in total, now there will be g good banks and b bad banks, such that $g + b = n$. Apart from distinguishing the two bank types based on the quality of the bank-specific project in the low state, all other components of the model are the same. As before, bank fails in case of the low state realization since none of the projects has high enough cash flows to cover for the return promised to depositors.

Since now there are two types of banks, but banks are identical within the type, the heterogeneous bank game will be solved for the representative bank of each type. In other words, good banks may differ in the optimal investment decision than the bad, but all banks within the type invest in the same way. I solve the model for the heterogeneous bank case, with two bank types starting from date 1 and the Regulator's subgame.

Regulator's decision

Let j determine the project the bank has undertaken, where $j = B, G, m$. Then, for each project there will be some number of bank liquidations k_j^* such that the regulator is indifferent between liquidating and bailing out the $k_j^* - th$ bank that has invested in $\widetilde{R}_j$ project at date 0. Consequently, for each j, the following will hold:

$$\underline{R}_j - L\left(k_j^*\right) = p\left(k_j^*\right) \tag{3.19}$$

Also, the break even condition for the outsiders holds. Then, k_j^* is implicitly defined by $\underline{R}_j = 2L\left(k_j^*\right)$. Given the relation between cash flows stated in (3.18) holds, and $L(k)$ and $p(k)$ are decreasing in k, then:

$$k_B^* > k_m^* > k_G^* \tag{3.20}$$

This implies that the lower the cash flow of the bank's project , it will be less costly to liquidate the bank in failure. Therefore, the number of liquidated failed banks before any bailouts happen will be the highest among the bad banks that invested in the Bad idiosyncratic project, and the lowest among the good banks that invested in the good idiosyncratic project.

The price outsiders pay is only contingent on the total number of banks that are being sold, while the liquidation loss is increasing in the bank's value in failure. Thus, the regulator always liquidates the low-value banks first, while bailout the higher-value ones, if any bailouts are to happen. The extent of how systemic the crisis has to be for the regulator to intervene depends on the investment project the banks undertake and the number of banks with the same or worse project that failed together. Proposition 4 defines the bailout policy of the regulator in the setting with heterogeneous banks.

Proposition 4

Let f_j be the total number of failed banks that invested in project j where $j = B, G, m$. Let $f = \sum_j f_j$ be the total number of all failed banks. Then, in any sub-game perfect equilibrium, Regulator's ex-post *optimal bailout policy is defined as follows:*

- *If $f < k_G^*$, no bailouts happen at all.*
- *If $f_B > k_B^*$, then k_B^* of the failed bad banks that invested in the project B will be liquidated, while $f_B - k_B^*$ will be bailed out. In all other possible outcomes any failed bank that invested in project B will be liquidated.*
- *For any f and f_j realized, liquidations start with the lowest value banks until the Regulator's indifference condition given in (3.19) is satisfied for the last marginal bank to be liquidated. The rest of the failed banks with higher or equal values in failure are bailed out.*

Unless the total number of all bank failures is lower than k_G^*, good bank that invested in project G are always bailed out with some positive probability. The bad bank invested in the bank-specific project B has positive probability of a bail out only when the total number of bad banks that failed is greater than k_B^*.

Bad Bank's decision

Let $E(\pi_{Bi}(x_B, x_G))$ be the representative bad bank's expected payoff from the investment project over two periods, given bad banks choose x_B , while the good banks choose the investment x_G. Representative bad bank maximizes the expected payoff by taking into account regulator's optimal bailout policy and potential investment choice of the Good banks. In a symmetric pure strategy equilibrium, all bad banks invest like their representative bank.

For the bad banks, it is never optimal to invest in the bad bank-specific project since in this case the bank is bailed out only if enough of other bad banks invested in the idiosyncratic project fail simultaneously. For the bad banks it is always more profitable to invest in the market project, irrespective of what other banks do. This is because the common project increases the probability of bailout intervention happening and yields the higher value in failure relative to bad idiosyncratic project, thus making the liquidation of the bank more costly for the regulator. At the same time, the market project investment increases the overall probability of bailout intervention, and bad bank's individual bailout probability in the intervention.

Lemma 5

Given Regulator's ex post optimal 'fail less' bailout policy, it is a Bad banks' dominant strategy to invest in the common market project and therefore undertake systematic risk.

Proof: See Appendix.

Good Bank's decision

Good banks decide on the optimal investment by taking into account the regulator's optimal 'fail less' bailout policy, and the fact investing in the market project is a dominant strategy for the bad banks. Let $E\left(\pi_{Gi}\left(x_B, x_G\right)\right)$ be the expected payoff from the investment project over two periods of the Good bank i, given bad banks choose x_B , while the good banks choose investment x_G.

The expected payoff from investing in the common project, when all good banks invest in the common market project is:

$$E\left(\pi_{Gi}\left(0,0\right)\right) = \alpha\left(\bar{R}_m - r\right) + \alpha V + (1-\alpha)\left(1 - \frac{k_m^*}{n}\right)\underline{R}_m \tag{3.21}$$

Similar to the homogeneous case, the representative good bank deviates and invest in the idiosyncratic G project, only when the expected bailout subsidy from that investment is higher than the bailout subsidy from herding with all other banks. This implies that, for $\alpha < \alpha_{FL}^*$, where α_{FL}^* is defined in (3.14), the good bank deviates and invests in the bank-specific project, even when other good and bad banks choose to invest in the market.

If all good banks choose to invest in their bank-specific projects, the expected payof for the representative good bank is:

$$E\left(\pi_{Gi}\left(0,1\right)\right) = \alpha\left(\bar{R}_G - r\right) + \alpha V + (1-\alpha)\left[\alpha Pr\left(f_G \geq k_G^*\right) Pr\left(Bailout \mid f_G, \tilde{R}_G\right) + (1-\alpha)\cdot 1\right]\underline{R}_G \tag{3.22}$$

From equation (3.22), it follows that the expected bailout subsidy when investing in the idiosyncratic project G, consists of two parts. First, if the bad banks that invested in the market project do not fail, the expected bailout subsidy depends on whether enough of good banks fail together. Bailout happens only if the crisis is considered systemic among the good banks i.e. when there is more than k_G^* failures of good banks. Second, in the case when the market project yields low cash flow, simultaneous failures of all bad banks create the crisis systemic enough for the regulator to intervene. Then, any failed good bank is bailed out with certainty.

However, it is neccessary to check whether it is profitable for the good bank i to deviate and invest in the market project, while the rest of the good banks invest in their bank-specific projects. The payoff from this deviation is

$$E\left(\pi_{Gi}\left(0, x_{Gi}=0, x_{G-i}=1\right)\right)=\alpha\left(\bar{R}_m-r\right)+\alpha V+(1-\alpha)\left(1-\frac{k_m^*}{b+1}\right)\underline{R}_m \tag{3.23}$$

By comparing the expected payoffs of two investment strategies given in (3.22) and (3.23), it follows that there exists some α_{HFL}^* such that the expected bailout subsidies for the good bank i of two investment strategies are equal when $\alpha=\alpha_{HFL}^*$. In other words, α_{HFL}^* is derived from the condition in (3.24).

$$\alpha_{HFL}^* \sum_{f_G=k_G^*}^{g-1} Pr\left(f_G\right)\left(1-\frac{k_G^*}{f_G+1}\right)+\left(1-\alpha_{HFL}^*\right)\cdot 1=\left(1-\frac{k_m^*}{b+1}\right)\frac{\underline{R}_m}{\underline{R}_G} \tag{3.24}$$

where $Pr\left(f_G\right)=C\left(g, f_G\right)\left(\alpha_{HFL}^*\right)^{g-f_G}\left(1-\alpha_{HFL}^*\right)^{f_G}$.

By comparing the expected bailout subsidies from the two investment strategies for the representative good bank, it follows that investing in the market project, while all other good banks choose the bank-specific projects is profitable when $\alpha>\alpha_{HFL}^*$. Otherwise, there is no profitable deviation and all good banks invest in the bank-specific projects. The optimal investment strategy for the good banks, given bad banks' optimal investment and anticipated regulator's optimal bailout policy is summarized in Lemma 9.

Lemma 6

Let α_{FL}^* be defined as in (3.14) and α_{HFL}^* defined by the following expression:

$$\alpha_{HFL}^*\left(1-\Theta\left(\alpha_{HFL}^*\right)\right)=1-\left(1-\frac{k_m^*}{b+1}\right)\frac{\underline{R}_m}{\underline{R}_G} \tag{3.25}$$

where $\Theta\left(\alpha_{HFL}^*\right)=\sum_{f_G=k_G^*}^{g-1} Pr\left(f_G\right)\left(1-\frac{k_G^*}{f_G+1}\right)$, and f_G is the number of good banks that failed at date 1 and $f_G \sim B\left(g, 1-\alpha\right)$. Then, $\alpha_{FL}^*<\alpha_{HFL}^*$ and the optimal equilibrium investment strategies are:

- *If $\alpha<\alpha_{FL}^*$ the good banks choose to invest in the idiosyncratic project G, $x_G^*=1$*
- *If $\alpha>\alpha_{HFL}^*$ the good banks choose to invest in the market project, $x_G^*=0$*
- *If $\alpha_{FL}^* \leq \alpha \leq \alpha_{HFL}^*$, then there are two pure strategy symmetric equilibria:*

– *if Good bank i believes that all other good banks will choose the common project, it is optimal for Good bank i to do the same, therefore* $x_G^* = 0$

– *if Good bank i believes that all other good banks will choose the bank-specific project, it is optimal for Good bank i to choose its bank-specific project, therefore* $x_G^* = 1$.

Proof: See Appendix.

Ex ante optimal investment choice when banks heterogeneous

In order to establish whether the es post optimal 'fail less' bailout policy implements the ex ante optimal outcome when banking system consists of heterogeneous banks, I analyze the expectation at date 0 of the total banking output given different possible bank investment decisions. Let $E\left(\Pi\left(x_B, x_G\right)\right)$ represent the ex-ante banking output net of bailout/liquidation costs for the investment strategy of bad banks x_B and the investment strategy of good banks x_G .

Similar to the homogeneous bank setting, since all projects yield equal cash flows in the high state, it follows that the expected banking output of the high cash flows will be the same regardless of the investment strategies different banks undertake. Variation in the expected total output between banks' different ex ante investment decisions is generated by differences in the low cash flow realization states and related costs of deposit insurance, as well as the potential gains from no herding, denoted by $\beta_{x_B x_G}$, where x_B and x_G represent the investment choices of bad and good banks. Therefore, in order to maximize the expected net banking output regulator's bailout policy should induce bank investment decisions which maximizes the expected gains from no herding and the expected banking output in the low cash flow realizations net of the costs of deposit insurance.

Let $E\left(\Pi\left(0,0\right)\right)$ be the total welfare when all banks invest in the common project as defined in (3.26). Then bank failures are perfectly correlated and the regulator always liquidates the maximum number of banks, offsetting entire gains from reduced cost of deposit insurance by the social loss arising from bank liquidations. Thus in this case, there are no gains from no herding.

$$\begin{aligned} E\left(\Pi\left(0,0\right)\right) &= n\alpha\left(\bar{R}_m - r + V\right) + n\left(1-\alpha\right)\underline{R}_m \\ &\quad -n\left(1-\alpha\right)\left(r - \underline{R}_m\right) \end{aligned} \tag{3.26}$$

In case when good banks pick their bank-specific project, while the bad banks invest in the market, the expected value of the total banking output net of any intervention costs is:

$$
\begin{aligned}
E\left(\Pi\left(0,1\right)\right) &= b\alpha\left(\bar{R}_m - r + V\right) + g\alpha\left(\bar{R}_G - r + V\right) \\
&\quad +\beta_{01} \\
&\quad +b\left(1-\alpha\right)\underline{R}_m + g\left(1-\alpha\right)\underline{R}_G \\
&\quad -b\left(1-\alpha\right)\left(r-\underline{R}_m\right) - g\left(1-\alpha\right)\left(r-\underline{R}_G\right) \qquad (3.27)
\end{aligned}
$$

where β_{01} are the expected gains from no herding, defined in (3.28) and arising from the good banks choosing the uncorrelated bank-specific projects.

$$
\beta_{01} = \alpha \sum_{f_G=0}^{k_G^*} f_G Pr\left(f_G\right)\left(2L\left(f_G\right) - \underline{R}_G\right) \qquad (3.28)
$$

Whenever less than k_G* failures of good banks investing in projects G fail simultaneously, the regulator is able to capture gains from selling the failed banks to outsiders. Namely, the fewer banks being sold, the price outsiders are willing to pay is higher, and the reduction in deposit insurance cost outweighs the losses in banking output that occur due to bank liquidations.

If bad banks choose the bank-specific project, while the good banks invest in the common project, the expected value of the total banking output net of any intervention costs is:

$$
\begin{aligned}
E\left(\Pi\left(1,0\right)\right) &= b\alpha\left(\bar{R}_B - r + V\right) + g\alpha\left(\bar{R}_m - r + V\right) \\
&\quad +\beta_{10} \\
&\quad +b\left(1-\alpha\right)\underline{R}_B + g\left(1-\alpha\right)\underline{R}_m \\
&\quad -b\left(1-\alpha\right)\left(r-\underline{R}_B\right) - g\left(1-\alpha\right)\left(r-\underline{R}_m\right) \qquad (3.29)
\end{aligned}
$$

where gains from no herding when bad banks invest in the bank-specific project and generate states in which the regulator can capitalize on bank liquidations through the sales to outsiders are defined as

$$
\beta_{10} = \alpha \sum_{f_B=0}^{k_B^*} f_B Pr\left(f_B\right)\left(2L\left(f_B\right) - \underline{R}_B\right) \qquad (3.30)
$$

When both good and bad banks invest in their bank-specific project, the expected value of the total banking output net of any intervention costs is:

$$
\begin{aligned}
E\left(\Pi\left(1,1\right)\right) &= b\alpha\left(\bar{R}_B - r + V\right) + g\alpha\left(\bar{R}_G - r + V\right) \\
&\quad +\beta_{11} \\
&\quad +b\left(1-\alpha\right)\underline{R}_B + g\left(1-\alpha\right)\underline{R}_G \\
&\quad -b\left(1-\alpha\right)\left(r-\underline{R}_B\right) - g\left(1-\alpha\right)\left(r-\underline{R}_G\right) \qquad (3.31)
\end{aligned}
$$

where β_{11} captures the corresponding expected gains from no herding and is defined as follows:

$$
\begin{aligned}
\beta_{11} \; = \; & \sum_{f_B=0}^{k_G^*} Pr\left(f_B\right)\left[\sum_{f_G=0}^{k_G^*-f_B} Pr\left(f_G\right)\left(f_B\left(2L\left(f\right)-\underline{R}_B\right)+f_G\left(2L\left(f\right)-\underline{R}_G\right)\right)\right. \qquad (3.32) \\
& + \sum_{f_G=k_G^*-f_B}^{g} Pr\left(f_G\right)\left(f_B\left(2L\left(k_G^*\right)-\underline{R}_B\right)\right)\Big] \\
& + \sum_{f_B=k_G^*}^{k_B^*} Pr\left(f_B\right) f_B\left(2L\left(f_B\right)-\underline{R}_B\right)
\end{aligned}
$$

Expression (3.32) distinguishes between three different type of states of the world, defined by the number of bank failures, in which uncorrelated bank failures generate gains. The first row represents the gains realized in the states in which the number of bad bank failures is below k_G^*, implying that depending on the number of good bank failures, there can be at most k_G^* bank liquidations. In terms of welfare, if there are less than k_G^* failures in total, both bad and good banks will be selling at a higher price than the regulator's reservation price for either bank.

The second row represents the gains from bad bank liquidations at the higher price than the regulator's reservation corresponding to the bad banks. If the total number of failures is greater than k_G^*, but the number of bad banks failing is still lower than k_G^*, the regulator will liquidate good failing banks at the reservation price, while capture gains from bad bank liquidations.

Finally, the last term of (3.32) represents the net gains captured from the bad bank liquidations when the number of bad bank failures is between k_G^* and k_B^*, implying that liquidation of bad banks is still socially optimal, given the price outside investors are willing to pay.

In order to determine the ex ante optimal investment decisions, I compare the total banking outputs across different possible investment choices, focusing on the low cash flow state realizations and the possible gains from no herding.

It is straghtforward to see that $E\left(\Pi\left(0,1\right)\right) > E\left(\Pi\left(0,0\right)\right)$ always holds, since good banks choosing the bank-specific projects implies that they choose their more efficient project yielding higher cash flows, thus reducing the costs of deposit insurance, but also the uncorrelated project, thus reducing the occurence of the systemic bank failures.

Similarly, $E(\Pi(1,1)) > E(\Pi(1,0))$ since using the expressions defined in (3.31) and (3.29), it follows that

$$E(\Pi(1,1)) - E(\Pi(1,0)) = \beta_{11} - \beta_{10} + 2 \cdot g(1-\alpha)(\underline{R}_G - \underline{R}_m) \tag{3.33}$$

where $\beta_{11} = \beta_{10} + \Delta_\beta$ and Δ_β[2] captures the additional gains from no herding when all banks choose the uncorrelated investment, relative to no herding gains arising from only bad banks investing in their bank-specific projects.

Namely, the decision of good banks to invest in the bank-specific projects instead of the market project always improves the banking output, since it allows capturing the gains from no herding as well as higher cash flows. However, the optimal investment for the bad banks from the ex ante perspective is less straightforward. Bad bank's investment decision trades off the gains from no herding by undertaking the bank-specific projects with the lower cash flow realizations and higher cost of deposit insurance in the low state.

In order to determine ex ante value maximizing investment decision for the bad banks I analyze

In order to determine the conditions under which either investment decision of the bad banks maximizes the total banking output net of intervention costs, I assume that good banks choose the bank specific projects and analyze under what conditions bad banks investing in their bank-specific projects dominates the common project. Since good banks' investmetn in the bank-specific project is always welfare improving, this will be sufficient to determine the ex ante optimal investment decisions of both good and bad banks.

By comparing the net expected banking output $E(\Pi(1,1))$ and $E(\Pi(0,1))$, it follows that it is optimal for bad banks to invest in their bank-specific project is additional gains from less frequent systemic crisis outweigh the losses from higher costs of deposit insurance in the low state realizations:

$$\beta_{11} - \beta_{01} > b(1-\alpha)\,2(\underline{R}_m - \underline{R}_B) \tag{3.34}$$

This implies that there will be some lower-bound threshold on how bad the bank-specific project of

[2] $\Delta_\beta = \sum_{f_B=0}^{k_G^*} Pr(f_B)\left[\sum_{f_G=0}^{k_G^*-f_B} Pr(f_G)\left(f_B(2L(f) - \underline{R}_B) + f_G(2L(f) - \underline{R}_G)\right) + \sum_{f_G=k_G^*-f_B}^{g} Pr(f_G)\left(f_B\left(2L\left(k_G^*\right) - \underline{R}_B\right)\right)\right]$

the bad banks can be, in order for the bad bank's investment in the bank-specific project to be ex ante value maximizing. Proposition 5 defines the conditions under which the total banking output net of intervention costs is maximized when all banks choose their idiosyncratic projects versus when it is optimal for the bad banks to herd by investing in the common project.

Proposition 5 *If $\widetilde{R}_B$ represents the idiosyncratic project each bad bank is endowed with, such that $\underline{R}_B$ is the cash flow a project yields in the low state. Let $\Psi\left(\alpha, \underline{R}_G, k_j^*\right)$ and $\Omega\left(\alpha, k_j^*\right)$ be derived through algebraic manipulations of (3.32) and (3.28) when calculating $\beta_{11} - \beta_{01}$. Then, there will be some $\underline{R}_B^*$ defined as*

$$\Psi\left(\alpha, \underline{R}_G, k_j^*\right) - \Omega\left(\alpha, k_j^*\right) \underline{R}_B^* = 2b\left(1-\alpha\right)\left(\underline{R}_m - \underline{R}_B^*\right)$$

such that

- *If $\underline{R}_B > \underline{R}_B^*$, total welfare is maximized when all banks, good and bad, invest in their own bank-specific projects i.e. $E\left(\Pi\left(1,1\right)\right) > E\left(\Pi\left(0,1\right)\right)$*
- *If $\underline{R}_B \leq \underline{R}_B^*$, total welfare is maximized when bad banks invest in the market project, while the good banks invest in their bank-specific projects G, i.e. $E\left(\Pi\left(1,1\right)\right) \leq E\left(\Pi\left(0,1\right)\right)$*

Proof: See Appendix.

If bad banks are endowed with very poor bank-specific projects, $E\left(\Pi\left(1,0\right)\right) < E\left(\Pi\left(1,1\right)\right) \leq E\left(\Pi\left(0,1\right)\right)$ holds and 'fail less' bailout policy implements the ex ante value maximizing outcome. However, when bad projects are not sufficiently bad to offset the gains from no herding the 'fail less' is ex post optimal, but does not ensure the ex ante optimal investment choices are made. Bad banks under the 'fail less' policy still choose to invest in the common project, as it increases their individual bailout probability, while also increasing the probability of simultaneous failures. Optimal outcome would entail bad banks actually investing in their less efficient bank-specific projects in order to reduce the probability of the systemic crisis occuring and regulato's intervention happening at all. However, in comparison to the 'too many to fail' policy, since $E\left(\Pi\left(0,1\right)\right) > E\left(\Pi\left(0,0\right)\right)$ always holds, 'fail less' bailout policy always dominates by implementing the higher net banking output outcome.

3.7 Conclusion

In this paper I analyze one modification of the regulator's state-contingent bailout policy on the banks' choice between systematic and idiosyncratic risks. A bank's risk-taking decision is modelled as a decision to invest in a bank-specific project (capturing the idiosyncratic risk) or a common project wherein all banks have access to (systematic risk). State-contingent bailout policy is defined by the 'too many to fail' implicit bailout guarantees which capture the effect that bailouts are more probable when many banks fail simultaneously, i.e. the banking crises is systemic. This aspect of the regulator's policy affects the bank's risk-taking incentives ex ante by strengthening incentives to undertake correlated risks, thereby increasing the probability of systemic banking crises.

I argue that a bailout policy contingent on both the aggregate state and banks' individual characteristics may reduce their incentives to herd. For example, introducing the regulator who cares to bail out banks that failed less compared to their peers can mitigate the incentives of banks to herd by undertaking correlated projects.

The distinguishing feature of my model is that banks are heterogeneous in failure, as captured by the different cash flow realizations in default, depending on the bank's investment choice. Second, in case of a bank default, its continuation value is a function of this low cash flow realized in failure. This, paired with the regulator who maximizes the total output of the banking sector net of any intervention costs, endogenizes the 'fail less' bailout policy.

I show that when a bank's value in failure affects its bailout probability, banks may prefer to invest in an idiosyncratic project. In some states, this allows them to have a higher value and consequently, a higher bailout probability, conditional on the bailout intervention, compared to peers which have invested in a common project. In cases when a bank-specific project also entails a higher expected value, the 'fail less' bailout policy implements the ex ante optimal bank investment outcome.

The model also provides implications for cases where ex ante heterogeneous banks are endowed with different bank-specific projects. The results imply that the existence of the bad banks which always choose to invest in a common project, further mitigates the herding incentives for good banks and incentivizes them to invest in their efficient bank-specific projects more often. Finally, I demonstrate that a 'fail less' bailout policy always dominates the 'too many to fail' policy by implementing the ex ante investment outcome that is more efficient.

Appendix

Proof of Lemma 3 In order to find under which circumstances banks choose perfect or no interbank correlation, I need to compare $E(\pi(0))$ with $E(\pi(1))$. If $E(\pi(0)) > E(\pi(1))$ banks would choose to invest in the common project and by doing so, achieve the perfect interbank correlation, and consequently perfectly synchronized failure. Therfore, I check if the condition $E(\pi(0)) - E(\pi(1)) > 0$

holds.

$$E\left(\pi\left(0\right)\right)-E\left(\pi\left(1\right)\right)=\left(1-\alpha\right)\underline{R}\left(\left(1-\frac{k^{*}}{n}\right)-\sum_{j=k^{*}}^{n-1}Pr\left(j\right)\left(1-\frac{k^{*}}{j+1}\right)\right) \tag{3.35}$$

From (3.35) we observe that given $j\in\{k^{*},...n-1\}$ then $1-\frac{k^{*}}{j+1}\leq1-\frac{k^{*}}{n}$. Thus, the following has to hold:

$$\left(1-\frac{k^{*}}{n}\right)-\sum_{j=k^{*}}^{n-1}Pr\left(j\right)\left(1-\frac{k^{*}}{j+1}\right)\geq\left(1-\frac{k^{*}}{n}\right)-\left(1-\frac{k^{*}}{n}\right)\sum_{j=k^{*}}^{n-1}Pr\left(j\right)>0 \tag{3.36}$$

Since $\sum_{j=k^{*}}^{n-1}Pr\left(j\right)<1$, then inequality (3.36) always has to be positive. In other words, the bank will always choose to invest in the common project.

Ex ante banking output analysis - homogeneous case:

$$\begin{aligned}E\left(\Pi\left(0\right)\right) &= n\cdot\alpha\left(\overline{R}_{m}-r+V\right)+n\cdot\left(1-\alpha\right)\underline{R}_{m}\\ &\quad -k_{m}^{*}\left(1-\alpha\right)\left(\underline{R}_{m}-L\left(k_{m}^{*}\right)\right)\\ &\quad -\left(1-\alpha\right)\left(n\left(r-\underline{R}_{m}\right)-k_{m}^{*}\cdot p\left(k_{m}^{*}\right)\right)\end{aligned} \tag{3.37}$$

Derivation of $E\left(\Pi\left(1\right)\right)$

$$\begin{aligned}E\left(\Pi\left(1\right)\right) &= \sum_{f=0}^{n}Pr\left(f\right)\left(n-f\right)\left(\overline{R}_{I}-r+V\right)\\ &\quad +\sum_{f=0}^{k_{I}^{*}-1}Pr\left(f\right)\left(f\cdot\left(L\left(f\right)-\left(r-\underline{R}_{I}-p\left(f\right)\right)\right)\right)\\ &\quad +\sum_{f=k_{I}^{*}}^{n}Pr\left(f\right)\left(f\underline{R}_{I}-k_{I}^{*}\left(\underline{R}_{I}-L\left(k_{I}^{*}\right)\right)-\left(f\left(r-\underline{R}_{I}\right)-k_{I}^{*}\cdot p\left(k_{I}^{*}\right)\right)\right)\end{aligned} \tag{3.38}$$

In this case, I exploit the feature of the binominal distribution, that the expected number of bank failures for n independent bank projects with failure probability $1-\alpha$ is equal to the sum of independent failure probabilities across these n realizations.

Given that the expected number of failed banks $\sum_{f=0}^{n}fPr(f)$ represents the expected value of binomially distributed variable $f\sim B\left(n,1-\alpha\right)$, it follows that

$$\sum_{f=0}^{n} f Pr(f) = n\,(1-\alpha)$$

holds. Then the first term of (3.38) is transformed into:

$$\left(\overline{R}_I - r + V\right)(n - n\,(1-\alpha)) = n\alpha\left(\overline{R}_I - r + V\right) \tag{3.39}$$

Therefore (3.38) can be transformed into:

$$\begin{aligned} E\,(\Pi\,(1)) &= n\alpha\left(\overline{R}_i - r + V\right) + \\ &+ \sum_{j=0}^{k_i^*-1} jPr\,(j)\cdot L\,(j) - \sum_{j=0}^{k_i^*-1} jPr\,(j)\,(r - \underline{R}_i - p\,(j)) \\ &+ \underline{R}_i \sum_{j=k_i^*}^{n} jPr\,(j) - k_i^*\left(\underline{R}_i - L\,(k_i^*)\right)\sum_{j=k_i^*}^{n} Pr\,(j) \\ &- \sum_{j=k_i^*}^{n} Pr\,(j)\,(j\,(r-\underline{R}_i) - k_i^*\cdot p\,(k_i^*)) \end{aligned} \tag{3.40}$$

In equilibrium, in the states in which more than k_i^* banks fail together, the Regulator liquidates maximum number of banks such that $\underline{R}_i - L\,(k_i^*) = p\,(k_i^*)$ holds. Then (3.40) can be further simplified to the following:

$$\begin{aligned} E\,(\Pi\,(1)) &= n\alpha\left(\overline{R}_i - r + V\right) + \\ &+ \sum_{j=0}^{k_i^*} jPr\,(j)\cdot L\,(j) + \underline{R}_i \cdot \sum_{j=k_i^*+1}^{n} jPr\,(j) \\ &- (1-\alpha)\,n\,(r - \underline{R}_i) + \sum_{j=0}^{k_i^*} jPr\,(j)\cdot p\,(j) \end{aligned} \tag{3.41}$$

where again the formula for expected value of binomially distributed variable has been used. In order to obtain the expression (3.41), I used the following simplification:

$$(r-\underline{R}_i)\left(\sum_{j=0}^{k_i^*-1} jPr\,(j) + \sum_{j=k_i^*}^{n} jPr\,(j)\right) = (r-\underline{R}_i)\sum_{j=0}^{n} jPr\,(j) = (r-\underline{R}_i)\,(1-\alpha)\,n$$

Given that the participation constraint of the outsiders is binding $p\,(j) = L\,(j)$ for every number of liquidated banks j, and that $\sum\limits_{j=k_i^*+1}^{n} jPr(j) = \sum\limits_{j=0}^{n} jPr(j) - \sum\limits_{j=0}^{k_i^*} jPr(j)$, expression (3.17) follows.

Proof of Lemma 5 Proof that $x_B = 0$ is a dominant strategy, when $x_G = 0$:

Since $1 - \frac{k_B^*}{f_B+1} \leq 1 - \frac{k_B^*}{b}$ for all $f_B \leq b-1$. Then, it follows that:

$$\sum_{f_B=k_B^*}^{b-1} Pr(f_B)\left(1 - \frac{k_B^*}{f_B+1}\right) \leq \left(1 - \frac{k_B^*}{b}\right) \sum_{f_B=k_B^*}^{b-1} Pr(f_B) < 1 - \frac{k_B^*}{b}$$

Since $k_B^* > k_m^*$and as long as $g \approx b$, the following holds:

$$\frac{k_B^*}{b} \geq \frac{k_m^*}{g+1}$$

In other words, expected bailout subsidy from investing in the common project is always greater than the expected bailout subsidy of the bank-specific project, since the following holds:

$$1 - \frac{k_B^*}{b} \leq 1 - \frac{k_m^*}{g+1}$$

$$\sum_{f_B=k_B^*}^{b-1} Pr(f_B)\left(1 - \frac{k_B^*}{f_B+1}\right)\underline{R}_B \leq \left(1 - \frac{k_B^*}{b}\right) \sum_{f_B=k_B^*}^{b-1} Pr(f_B)\,\underline{R}_B < \left(1 - \frac{k_m^*}{g+1}\right)\underline{R}_m$$

Proof that $x_B = 0$ is a dominant strategy, when $x_G = 1$:

Since $k_m^* < k_B^*$ holds, then the following must be true

$$\sum_{f_B=k_m^*}^{b-1} Pr(f_B) > \sum_{f_B=k_B^*}^{b-1} Pr(f_B) > \sum_{f_B=k_B^*}^{b-1} Pr(f_B)\left(1 - \frac{k_B^*}{f_B+1}\right)$$

Thus, the expected bailout subsidy for the representative Bad bank i from investing in the market project is greater than the bailout subsidy from the bank-specific project, even when all other bad banks choose the bank-specific projects.

Proof of Lemma 6 In order to be optimal for the Good bank i to invest in the idiosyncratic project, while all other banks are investing in the market project, it would have to be:

$$E(\pi_{Gi}(0, x_{Gi} = 1, x_{G-i} = 0)) - E(\pi_{Gi}(0, 0)) > 0$$

where $E\left(\pi_{Gi}\left(0, x_{Gi}=1, x_{G-i}=0\right)\right)$ is defined as follows

$$E\left(\pi_{Gi}\left(0, x_{Gi}=1, x_{G-i}=0\right)\right)=\alpha\left(\overline{R}_G-r\right)+\alpha V+(1-\alpha)(1-\alpha)\cdot 1\cdot \underline{R}_G$$

Then, deviation is profitable as long as

$$(1-\alpha)\underline{R}_G>\left(1-\frac{k_m^*}{n}\right)\underline{R}_m \tag{3.42}$$

Therefore, for $\alpha<\alpha_{FL}^*$, where $\alpha_{FL}^*=1-\left(1-\frac{k_m^*}{n}\right)\frac{\underline{R}_m}{\underline{R}_G}$, it will be profitable to deviate and invest in the bank-specific project.

Then $x_G^*=1$ is an equilibrium strategy, for $\alpha<\alpha_{FL}^*$, if once all good banks go for the bank-specific project, it is not profitable for the representative Good bank to deviate from that and invest in the market project. In other words, as long as

$$\alpha\sum_{f_G=k_G^*}^{g-1}Pr\left(f_G\right)\left(1-\frac{k_G^*}{f_G+1}\right)+(1-\alpha)\cdot 1\geq\left(1-\frac{k_m^*}{b+1}\right)\frac{\underline{R}_m}{\underline{R}_G} \tag{3.43}$$

holds, $x_G^*=1$ is an equilibrium investment strategy. Since $b+1<n$, then $\left(1-\frac{k_m^*}{b+1}\right)\underline{R}_m<\left(1-\frac{k_m^*}{n}\right)\underline{R}_m$ always holds. Given that for $\alpha<\alpha_{FL}^*$, expression in (3.42) holds, then surely

$$\left(1-\frac{k_m^*}{b+1}\right)\underline{R}_m<\left(\alpha\sum_{f_G=k_G^*}^{g-1}Pr\left(f_G\right)\left(1-\frac{k_G^*}{f_G+1}\right)+(1-\alpha)\cdot 1\right)\underline{R}_G \tag{3.44}$$

holds. For $\alpha\geq\alpha_{FL}^*$ it is not profitable to deviate and invest in the bank-specific project, while all other banks are choosing the market project.

The payoff from investing in the bank-specific project is given in (3.22), while the payoff for the representative Good bank, from deviating is the following:

$$E\left(\pi_{Gi}\left(0, x_{Gi}=0, x_{G-i}=1\right)\right)=\alpha\left(\overline{R}_m-r\right)+\alpha V+(1-\alpha)\left(1-\frac{k_m^*}{b+1}\right)\underline{R}_m \tag{3.45}$$

Then, it follows that there will be some α_{HFL}^* for which the expected bailout subsidies are equated:

$$\alpha_{HFL}^*\sum_{f_G=k_G^*}^{g-1}Pr\left(f_G\right)\left(1-\frac{k_G^*}{f_G+1}\right)+\left(1-\alpha_{HFL}^*\right)\cdot 1=\left(1-\frac{k_m^*}{b+1}\right)\frac{\underline{R}_m}{\underline{R}_G}$$

This can further be written as

$$\alpha^*_{HFL}\left(1-\Theta\left(\alpha^*_{HFL}\right)\right)=1-\left(1-\frac{k^*_m}{b+1}\right)\frac{\underline{R}_m}{\underline{R}_G} \tag{3.46}$$

where $\Theta(\alpha)=\sum_{f_G=k^*_G}^{g-1} Pr(f_G)\left(1-\frac{k^*_G}{f_G+1}\right)$, and $Pr(f_G)=C(f_G,g)\,\alpha^{g-f_G}(1-\alpha)^{f_G}$.

Then, since $\Theta(\alpha)$ is a decreasing function in α, this implies that

$$\alpha\left(1-\Theta(\alpha)\right)<1-\left(1-\frac{k^*_m}{b+1}\right)\frac{\underline{R}_m}{\underline{R}_G}$$

holds whenever $\alpha>\alpha^*_{HFL}$. In other words, it will be optimal to deviate and invest in the market project whenever $\alpha>\alpha^*_{HFL}$.

In order to show that $x^*_G=0$ is the equilibrium strategy when $\alpha>\alpha^*_{HFL}$, it has to be that deviating from this back to investing in the bank-specific project is not profitable. This, indeed, is the case, since the expression

$$E\left(\pi_{Gi}\left(0,x_{Gi}=1,x_{G-i}=0\right)\right)-E\left(\pi_{Gi}(0,0)\right) \;=\; (1-\alpha)\,\underline{R}_G-\left(1-\frac{k^*_m}{n}\right)\underline{R}_m$$

is always negative, for $\alpha>\alpha^*_{HFL}$. This follows directly from the observation that

$$\alpha^*_{FL}<\alpha^*_{HFL} \tag{3.47}$$

The relation given in (3.47) comes from the definition of $\alpha^*_{FL}=1-\left(1-\frac{k^*_m}{n}\right)\frac{\underline{R}_m}{\underline{R}_G}$ and the implicit definiton of α^*_{HFL} given in (3.46). Since

$$\alpha^*_{FL}<1-\left(1-\frac{k^*_m}{b+1}\right)\frac{\underline{R}_m}{\underline{R}_G}$$

it follows that

$$\alpha^*_{FL}<\alpha^*_{HFL}\left(1-\Theta\left(\alpha^*_{HFL}\right)\right)<\alpha^*_{HFL}$$

Proof of Proposition 5 If $\beta_{11}-\beta_{01}>b(1-\alpha)\,2\left(\underline{R}_m-\underline{R}_B\right)$ holds, then the welfare is maximized when all banks invest in their own bank-specific projects. Using definitions of β_{11} as in (3.32) and β_{01}

as in (3.28), it is possible to calculate the lowest payoff of the bad banks' idiosyncratic project $\underline{R}_B^*$ for which it would be optimal for bad banks to choose their idiosyncratic project, although it is dominated by the market project ($\underline{R}_m > \underline{R}_B$).

$$\beta_{11} - \beta_{01} = 2b\left(1-\alpha\right)\left(\underline{R}_m - \underline{R}_B^*\right)$$

Then, by replacing β_{11} and β_{01} with their definitions

$$\begin{aligned}\sum_{f_B=0}^{k_G^*} Pr\left(f_B\right)[\sum_{f_G=0}^{k_G^*-f_B} Pr\left(f_G\right)\left(f_B\left(2L\left(f\right)-\underline{R}_B^*\right)+f_G\left(2L\left(f\right)-\underline{R}_G\right)\right) \\ +\sum_{f_G=k_G^*-f_B}^{g} Pr\left(f_G\right)\left(f_B\left(2L\left(k_G^*\right)-\underline{R}_B^*\right)\right)] \\ +\sum_{f_B=k_G^*}^{k_B^*} Pr\left(f_B\right)f_B\left(2L\left(f_B\right)-\underline{R}_B^*\right) \\ -\alpha\sum_{f_G=0}^{k_G^*} f_G Pr\left(f_G\right)\left(2L\left(f_G\right)-\underline{R}_G\right) &= 2b\left(1-\alpha\right)\left(\underline{R}_m-\underline{R}_B^*\right)\end{aligned}$$

This can be further transformed into

$$\begin{aligned}\sum_{f_B=0}^{k_G^*} Pr\left(f_B\right)\left[\sum_{f_G=0}^{k_G^*-f_B} Pr\left(f_G\right)f\cdot 2L\left(f\right)+\sum_{f_G=k_G^*-f_B}^{g} Pr\left(f_G\right)f_B\cdot 2L\left(k_G^*\right)\right]+ \\ \sum_{f_B=k_G^*}^{k_B^*} Pr\left(f_B\right)f_B\cdot 2L\left(f_B\right)-\alpha\sum_{f_G=0}^{k_G^*} f_G Pr\left(f_G\right)\left(2L\left(f_G\right)-\underline{R}_G\right) \\ -\left[\sum_{f_B=0}^{k_G^*} Pr\left(f_B\right)f_B\left(\sum_{f_G=0}^{g} Pr\left(f_G\right)\right)+\sum_{f_B=k_G^*}^{k_B^*} Pr\left(f_B\right)f_B\right]\underline{R}_B^* &= 2b\left(1-\alpha\right)\left(\underline{R}_m-\underline{R}_B^*\right)\end{aligned} \tag{3.48}$$

Then, I define $\Psi\left(\alpha,\underline{R}_G,k_j^*\right)$ and $\Omega\left(\alpha,k_j^*\right)$, as follows

$$\begin{aligned}\Psi\left(\alpha,\underline{R}_G,k_j^*\right) &= \sum_{f_B=0}^{k_G^*} Pr\left(f_B\right)\left[\sum_{f_G=0}^{k_G^*-f_B} Pr\left(f_G\right)f\cdot 2L\left(f\right)+\sum_{f_G=k_G^*-f_B}^{g} Pr\left(f_G\right)f_B\cdot 2L\left(k_G^*\right)\right]+ \\ &+ \sum_{f_B=k_G^*}^{k_B^*} Pr\left(f_B\right)f_B\cdot 2L\left(f_B\right)-\alpha\sum_{f_G=0}^{k_G^*} f_G Pr\left(f_G\right)\left(2L\left(f_G\right)-\underline{R}_G\right)\end{aligned} \tag{3.49}$$

$$\Omega\left(\alpha,k_j^*\right)=\left[\sum_{f_B=0}^{k_G^*} Pr\left(f_B\right)f_B\left(\sum_{f_G=0}^{g} Pr\left(f_G\right)\right)+\sum_{f_B=k_G^*}^{k_B^*} Pr\left(f_B\right)f_B\right] \tag{3.50}$$

Then equality (3.48) can be written as

$$\Psi\left(\alpha, \underline{R}_G, k_j^*\right) - \Omega\left(\alpha, k_j^*\right)\underline{R}_B^* = 2b\left(1-\alpha\right)\left(\underline{R}_m - \underline{R}_B^*\right) \tag{3.51}$$

Finally, the lowest cash flow that the bad idiosyncratic projects can yield, while still being welfare maximizing for the bad banks to undertake these idiosyncratic projects is given as

$$\underline{R}_B^* = \frac{\Psi\left(\alpha, \underline{R}_G, k_j^*\right) - 2b\left(1-\alpha\right)\underline{R}_m}{\Omega\left(\alpha, k_j^*\right) - 2b\left(1-\alpha\right)} \tag{3.52}$$

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