Sources of Financial Fragility: The Role of Debt Management

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DOCTOR OF PHILOSOPHY

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ABSTRACT

The main aim of this thesis is to investigate from both a theoretical and empirical point of view how debt management may affect the choice of the monetary and exchange rate regimes and ultimately influence the stability of financial systems.

The thesis is organised as follows. In Chapter 1, we develop a simple theoretical model to analyse how the choice of the maturity and denomination of public debt instruments affects the choice of the optimal monetary target. We then compare debt management to alternative institutional mechanism designs and find that delegation of monetary policy to an independent central banker is a better solution to inflationary temptations than the issuance of foreign or indexed debt.

Chapter 2 extends the analysis and shows that foreign currency debt may reduce the probability of a collapse of a fixed exchange rate regime. However, conditional on a currency crisis, countries with larger shares of foreign currency debt tend to experience sharper devaluations. Econometric results referring to the countries adhering to the Exchange Rate Mechanism of the European Monetary System from 1979 to 1995 confirm these theoretical findings.

In the second part of the thesis we look at the sources of financial vulnerability in a sample of emerging and developing countries from 1970 to 1997. In Chapter 3, we test the role of debt and exchange rate fragility in determining episodes of banking crises, while Chapter 4 extends the analysis of the causal link between currency and banking crises to episodes of *twin crises*. The results indicate that along with the increasing liberalisation and globalisation of the financial markets, banking and currency crises have become closely intertwined and driven by common fundamentals.

Finally, Chapter 5 contains a description of the econometric specifications and simulation-based estimation techniques adopted in the second part of the thesis.

DECLARATION

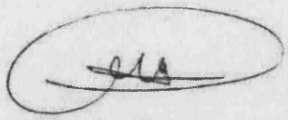
1. No part of this work has been presented to any University for any degree.
2. Chapter I, "The currency denomination of public debt and the choice of the monetary regime", was conducted as a joint work with Prof. Alessandro Missale when he was Houblon-Norman Fellow at the Bank of England (October, 1997- May 1998). My contribution in this paper was 50%. A statement from my co-author confirming this is given below.
3. Chapter IV, "What do Twins Share?. A Joint Probit Estimation of Banking and Currency Crises" was undertaken as a joint work with Maria Mercedes Tudela. My contribution to this paper was 50%. A statement from my co-author confirming this is given below.

- I confirm the above declaration (point 2) referring to joint work carried out with Elisabetta Falcetti.

Alessandro Missale 10/6/2001

Prof. Alessandro Missale

- I confirm the above declaration (point 3) referring to joint work carried out with Elisabetta Falcetti.



Maria M. Tudela

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INTRODUCTION

The focus of this thesis is on the sources of financial fragility. In particular, we investigate from both a theoretical and empirical point of view how debt management –i.e. the choice of the type, maturity and currency composition of debt instruments– may affect the choice of the monetary and exchange rate regimes and, ultimately, impact the stability of the financial systems.

This topic has received renewed attention in the 1990s, following the intensification of episodes of financial system distress in developed and emerging countries. Some of the most recent examples include the collapse of the European Exchange Rate Mechanism (ERM) in 1992-93, the devaluation of the Mexican peso in 1994, the Asian crises in 1997-98, the devaluation of the Russian rouble in 1998, the Brazilian crisis in 1998, Argentina's default in 2001 and the Turkish crisis in 2002.

In most of these cases, the forced abandonment of a fixed exchange rate regime and the sharp devaluation of the domestic currency that followed, undermined the stability of the financial sectors and led to concurrent episodes of systemic banking failures. The Mexican and Russian crises also showed that financial sector problems can be exacerbated by a sudden reversal of capital inflows, a large stock of short-term external debt, and domestic liabilities denominated in foreign currency.

Self-fulfilling, bond-led crises were formerly described by Calvo (1988), who showed that the presence of a large stock of short-term debt may lead to a crisis of confidence in public debt that can be self-fulfilling. Lately, this argument has been

revitalised by Obstfeld (1994) within the 'second generation' models of currency crises to highlight how debt refinancing problems may trigger a self-fulfilling speculative attack on the currency.

The same theoretical literature on sovereign debt management and currency crises has shown that the choice of the maturity and currency of denomination of public debt can influence the likelihood of a confidence crisis. Debt indexation and foreign currency denomination can be used as commitments devices against inflationary expectations and can help delay, if not avoid, the occurrence of a crisis.

Despite these policy prescriptions, debt managers seem to be reluctant to issue indexed or foreign currency debt. On the contrary, the share of long-term, fixed-rate debt in OECD countries has increased on average since the 1980s. Furthermore, the Mexican crisis of 1994 has shown that the markets might react negatively to this choice, by attacking the currency and imposing further strains on already fragile banking systems. One of the lessons learned from the crises in Sweden (1992) and Mexico (1994) is that the decision to issue large amounts of debt in foreign currency not only did not help the governments withstand a confidence crisis but also exacerbated the balance sheets effect of the devaluation, leading to banking sector problems.

At first sight, the facts seem to contradict the main findings of the theoretical literature on debt management and financial crises. The research presented in this thesis was inspired by the desire to reconcile economic theory and empirical evidence. The common thread to the various chapters of the thesis is indeed the role of debt (public or external) as a potential source of financial sector fragility.

The first part of the thesis is dedicated to the analysis of the interaction between the choice of the optimal monetary and exchange rate regimes and debt management.

In Chapter 1, we examine the relative role of institutional design and debt management for monetary policy. In particular, we show how the choice of the maturity and currency denomination of public debt interacts with the choice of the optimal monetary target. We compare debt management to institutional design mechanisms —like delegation of monetary policy to an independent central banker or the adoption of inflation targeting— as alternative solutions to credibility problems.

Our aim is to bridge the gap between the time inconsistency literature, which points to policy delegation as the best solution to the inflationary bias, and the debt management theory that suggests the use of indexed and foreign currency debt to enhance the credibility of an anti-inflationary policy. The original contribution of our work is to look at the interaction between the two by using a modified version of the Barro and Gordon (1983a) model where output is affected by tax distortions and these, in turn, depend on the type of debt issued by the government.

We find that the effectiveness of indexed debt instruments as an anti-inflationary device depends on the type of monetary regime. If delegation of monetary policy to an independent central banker or an inflation contract are viable, they are a better solution to inflationary temptations than issuing foreign or indexed debt. By issuing long-term nominal debt the government can increase the sensitivity of taxes and output to unexpected inflation, and thus minimise the inflationary surprise needed to counteract supply shocks.

This result is important for the following reasons. First, it explains the reluctance of debt managers towards indexed-debt instruments by supporting the conventional idea that central bank independence is the best form of commitment to a disinflationary policy and little is gained from increasing the cost of inflation by issuing indexed or foreign currency denominated debt. Second, it offers a justi-

fication for the concomitant increase in the degree of central bank independence and in the shares of long-term nominal debt observed in OECD countries since the 1980s.

In Chapter 2, we extend the previous analysis and investigate the role of debt management in the context of a fixed exchange rate regime, where the monetary authority is not fully independent or the policymaker and the private sector have asymmetric information.

Under these circumstances, we show that debt management and, in particular, the issuance of debt denominated in foreign currency or with a short maturity may enhance the credibility of an anti-inflationary policy by increasing the cost of surprise inflation. We make this point with the help of a stylised model that shares with the 'second generation' models of currency crises the feature of generating self-fulfilling multiple equilibria. However, we focus here on public debt and its characteristics, rather than external debt as in Velasco (1996).

Within this framework, foreign currency denominated debt can insulate the government budget from the effect of high interest rates associated with devaluation expectations, thus preventing the occurrence of a self-fulfilling currency crisis. However, if there are other benefits deriving from unexpected inflation than the simple reduction of the real debt stock, foreign currency debt can not completely eliminate the probability of a devaluation. Conditional on a devaluation taking place, countries with larger shares of foreign currency denominated debt have to devalue more than those that rely more on long-term nominal debt.

This result is important because it explains why private agents may react negatively to the decision to issue large stocks of debt denominated in foreign currency, anticipating a worse devaluation than in the presence of nominal debt.

In the second part of Chapter 2, we provide some empirical evidence that supports these theoretical results with reference to the European countries adhering to the Exchange Rate Mechanism (ERM) of the European Monetary System (EMS) during the period 1979-95.

We focus on the effect of fiscal and debt variables on the likelihood of an official realignment within the ERM. Interestingly, we find that the issuance of foreign currency debt reduced the probability of a realignment. However, conditional on a realignment taking place, those countries with larger shares of foreign currency debt experienced sharper devaluations.

In the second part of the thesis we look at the causal links between debt, exchange rate fragility and systemic banking failures in emerging and developing countries. We show that debt variables play an important role in determining banking and twin crises.[1]

In Chapter 3, we test empirically the role of debt and exchange rate fragility in determining episodes of banking crises using panel data estimation techniques on a new sample of developing and emerging markets from the early 1970s to 1997.

Contrary to most existing studies that estimate static logit/probit models on pooled observations, we assess the probability of banking crises by applying simulation-based estimation techniques on panel data. In particular, we adopt the method of maximum smoothly simulated likelihood (MSSL), in conjunction with the GHK simulator, to estimate a multiperiod dynamic probit model with unobserved heterogeneity and autocorrelated errors.

This approach has several advantages. First, the use of panel data analysis would allow us to capture the information deriving from both the cross-country as well

[1] This term refers to the joint occurrence of currency and banking crises.

as across-time variation of our data. This choice is motivated by the belief that financial crises are inter-temporal events that should be analysed within a dynamic framework.

Second, the dynamic feature of our econometric model would help us understand the dynamics leading to, accompanying and following a crisis. In particular, it would allow us to test for the existence of *state dependence* among episodes of banking crises, i.e. if past occurrences of banking crises influence the probability of observing another banking crisis in the future. Moreover, we would be able to test if there is a significant leading effect from currency to banking crises.

Third, the relaxation of the traditional assumption of serially uncorrelated errors would account for the possibility of unobserved heterogeneity and autocorrelated errors. The first element may reflect historical or institutional factors, which are time-invariant and country-specific, that may not be fully captured by the set of explanatory variables in our model. The second error component would capture serially correlated unobserved determinants of the probability of banking crises. The explicit consideration of these two error terms in the model specification is necessary to avoid *spurious state dependence* in the estimation of the lagged dependent variable.

The empirical analysis presented in Chapter 3 focuses on three main objectives. First, the identification of a set of domestic and global variables that are potential determinants of banking crises. In particular, we would look at the role played by debt instruments in triggering or averting such crises. Second, we would test for the presence of leading effects from currency to banking crises. Third, we would consider alternative error structures and show the importance of using panel data estimation techniques and allowing for a flexible serial correlation structure in the unobservables.

The main results of our analysis reveal that macroeconomic fundamentals and debt vulnerability indicators are important determinants of the probability of banking crises. Developing countries seem also very sensitive to changes in global macroeconomic conditions, like an increase in international interest rates or an adverse terms-of-trade shock. Countries that have experienced a banking crisis in the past are more prone to experience other crises, while there is mixed evidence that currency crises lead to banking crises.

After controlling for a large number of explanatory variables, we find evidence of unobserved heterogeneity and autocorrelation in the error term, supporting our hypothesis of a flexible error term structure. The omission of the autocorrelated error component introduces *spurious state dependence* in the estimates of the lagged banking dependent variable, which is even stronger once we omit the panel structure and pool together all the observations. This finding is important because it questions the robustness of the conclusions reached by previous studies that make use of static probit/logit models to estimate the likelihood of banking crises.

Chapter 4 extends the analysis of the previous chapter by examining the determinants of *twin crises*. The joint occurrence of banking and currency crises has increasingly attracted the attention of theorists who have tried to explain the causal link between the two. Despite the growing interest, few empirical studies have tried to assess the determinants of *twin crises* and detect the direction of causality between banking and currency crises since the seminal work of Kaminsky and Reinhart (1999). The results presented in Chapter 4 are an attempt to fill this gap in the empirical literature.

We estimate by maximum smoothly simulated likelihood a system of two dynamic probit equations (similar to the one used in Chapter 3), one for banking and another for currency crises. The probability of each type of crisis is modelled

as a function of a set of explanatory variables encompassing banking or currency specific indicators, as well as a set of common determinants that includes debt variables. We test for the existence of a causal link from banking to currency crises by allowing a leading and contemporaneous effect of the banking dummy variable in the currency crisis equation. We thus overcome one of the limitations of the model estimated in Chapter 3 by fully endogenising the occurrence of banking crises. In addition to the error term structure described above, with unobserved heterogeneity and autocorrelated errors, we assume the existence of some unobserved contemporaneous correlation between banking and currency crises. This last effect would allow for the possibility that twin crises are driven by omitted common factors.

The results presented in Chapter 4 suggest that, along with the increasing liberalisation and globalisation of the financial markets, banking and currency crises have become closely intertwined and driven by common fundamentals.

Currency crises seem to lead banking crises, at least during the nineties, but a causal link between the two types of crisis cannot be determined unambiguously over the whole sample period. Banking and currency crises share some common factors but which crisis surfaces first is ultimately a matter of circumstances.

The final chapter of this thesis contains a brief overview of the principal simulation-based estimation methods for limited dependent variable models (LDV). The main aim of this methodological chapter is to illustrate why we need to use simulation techniques to overcome the computational problems associated with the estimation of the multiperiod dynamic probit models of banking and twin crises used in Chapter 3 and Chapter 4 of this thesis. We would also derive the application of the GHK simulator to these two estimation problems.

1. DEBT MANAGEMENT, CENTRAL BANK INDEPENDENCE AND THE CREDIBILITY OF MONETARY POLICY

1.1 Introduction

In the 1990s the share of long-term nominal debt —i.e. non-indexed debt denominated in domestic currency— increased in almost all OECD countries. In the same period the governments of these countries have made their central banks more independent in order to strengthen the commitment to price stability.

This chapter examines the relative merits of public debt management and institutional design as commitment devices to an anti-inflationary monetary policy. The literature on public debt management suggests that inflation-indexed debt enhances the credibility of monetary policy. The argument has been made by Back and Musgrave (1941) and later formalised by Lucas and Stokey (1983), Bohn (1988), Calvo (1988), and Calvo and Guidotti (1990). The same role for foreign currency debt has been suggested by Bohn (1990a), Bohn (1991) and Watanabe (1992). This literature, however, implicitly assumes that the government cannot delegate monetary policy to an independent institution.

On the other hand, the literature on central bank independence points to policy delegation as the best way to reduce the inflationary bias. Some attention is given to the implications of public debt, but not to its composition. Cukierman (1994) argues that the larger the debt, the more likely it is that politicians will delegate authority to the central bank, and the more independent the bank will

be. Beetsma and Bovemberg (1997) show that delegation of monetary policy to a properly conservative central banker achieves the second-best inflation tax on money balances without distorting debt accumulation, but they confine attention to indexed debt.

As a matter of fact the interaction between the choice of debt instruments and the design of monetary institutions remains largely unexplored. This chapter compares institutional design and debt management as alternative solutions to credibility problems, showing that the best solution to inflationary temptations is to delegate monetary policy to an independent central bank. The point is made within a standard rules-versus-discretion framework where output is affected by tax distortions and, thus, by the type of debt that the government issues.

We argue that the role of the currency of denomination and indexation of public debt depends on the monetary regime. If monetary policy can be delegated to an independent, inflation-averse institution, or an inflation contract is viable, then indexed or foreign currency debt are not necessary for anti-inflationary purposes. The government should instead provide the monetary authority with the largest possible share of nominal debt to support output stabilisation.

Intuitively, a greater share of nominal debt implies lower taxes and tax distortions for any given unexpected inflation. By increasing the sensitivity of output to inflation, nominal debt makes monetary policy more effective: less unexpected inflation is needed to counter supply shocks. Although nominal debt may give rise to inflationary expectations, credibility problems are dealt more effectively by monetary policy delegation.

This result is important for two reasons. First, it supports the conventional wisdom that institutional design and, in particular, central bank independence is the best way to avoid the inflationary bias, while little is gained by increasing the

cost of inflation with indexed or foreign currency debt. Secondly, it provides an explanation for the lengthening of debt maturities observed in OECD countries since the late 1980s.

This chapter is organised as follows. In Section 1.2, we describe the theoretical framework and analyse the role of debt management when the government retains full discretion over the choice of the monetary policy target. The results are discussed in Section 1.3 in light of alternative specifications of the social loss function. The following sections examine the role of debt management when monetary policy is delegated to an independent institution. Section 1.4.1 focuses on delegation to a weight-conservative central banker. Section 1.4.2 considers an inflation contract, while Section 1.4.3 reviews inflation targeting. Section 1.5 presents evidence on the debt structure, central bank independence and inflation in OECD countries which suggests that the normative arguments derived from the theory have some positive content. Finally, Section 1.6 concludes.

1.2 The Theoretical Framework

1.2.1 The Government Problem

We examine the interaction between debt management and monetary policy by using a modified version of the Barro and Gordon (1983a) model in which distortionary taxation creates a wedge between the first-best level of output and its natural rate. We explicitly model this output loss which is the source of time inconsistency in the rules-versus-discretion literature.[1]

Following Barro and Gordon, we assume that the output loss depends on the tax rate but extend the analysis to consider that the tax rate varies with the real value of public debt and the tax base. A higher debt level would increase taxes and tax distortions, thus reducing the level of output. In turn, the value of debt

[1] Along with imperfectly competitive goods and labor markets.

is determined by its composition and unexpected inflation, which arises from the policy response to external shocks.[2]

The government's objective is to minimise a loss function that weighs the costs of expected inflation against the cost of output deviations from its optimal level in the absence of distortions. The expected social loss is equal to[3]

$$E_0 L = \theta E_0 \pi^2 + E_0(y - \bar{y} - k\tau)^2 \tag{1.1}$$

where the parameter θ reflects the social preferences, i.e. the cost of inflation relative to output deviations, π denotes the inflation rate, y is the logarithm of actual output, $\bar{y}$ is its natural rate, τ is the tax rate and k a positive constant.[4]

A time consistency problem arises because the government aims at the level of output $y^T = \bar{y} + k\tau$ higher than the natural rate, $\bar{y}$, because of tax distortions.[5]

For analytical tractability the output loss, $k\tau$, is modelled as a linear function of the tax rate, but linearity could be formally derived from labor market equilibrium as in Beetsma and Bovemberg (1997).[6] The social loss function is further discussed in Section 1.3.

[2] Alternatively, unexpected inflation reduces real interest payments on public debt and thus frees resources from the budget that can possibly be used for counter-cyclical fiscal policy.

[3] For the same specification, or specifications where output is replaced by the unemployment rate or the level of employment see Barro and Gordon (1983a), Rogoff (1985), Svensson (1997) and Walsh (1997), among others. For a microfoundation see Herrendorf and Neumann (1998).

[4] More precisely, as in Barro (1979), the deadweight loss H is an homogeneous function of total revenues τY and output Y, so that $H = Yk(\tau)$. Then, defining potential output as Y^T, the natural output level is $\bar{Y} = Y^T[1 - k(\tau)]$. Taking the log of $\bar{Y}$ yields the output target $y^T = \bar{y} + k(\tau)$ in the loss function.

[5] In the literature, an output target greater than the natural rate is justified by the existence of either tax or labor market distortions or simply by political pressure (see Eijffinger and Haan (1996) and Walsh (1998)). In what follows we shall focus on tax distortions.

[6] Assume that output (in the absence of shocks) is given by $Y = L^a (0 < a < 1)$ where L is labor, so that the maximisation of after-tax profit yields the labor demand $L = [Pa(1 - \tau)/W]^{1/(1-a)}$ where W is the nominal wage. Assume that workers aim at a target real wage,

Output is given by an expectations augmented Phillips curve:

$$y = \bar{y} + b(\pi - E_0\pi) - u \tag{1.2}$$

where b is the output sensitivity to unexpected inflation and u is an adverse output shock distributed on the compact support $[u^l, u^h]$, with mean $E_0 u = 0$ and variance $E_0 u^2 = \sigma^2$.

Following the literature, we assume that the output loss depends on the tax rate, but extend the analysis to allow the tax rate to vary with the real value of public debt. The latter is affected by unexpected inflation depending on its currency composition, indexation and maturity structure.[7]

Assuming that the entire debt and public spending are repaid at the end of the following period and using a linear approximation for the impact of inflation, the tax rate is equal to:[8]

$$\tau = G + [1 + r - m(\pi - E_0\pi)]B \tag{1.3}$$

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the log of which is normalised to zero, and contracts are signed one period in advance based on inflation expectations. It follows that the log of output is given by $y = (a/(1-a))(\pi - E\pi - \tau + lna)$, and the output loss is $k\tau = (a/(1-a))\tau$.

[7] It is worth noting that, as the tax rate and thus distortions vary, so does the natural rate of output, $\bar{y} = y^T - k\tau$. This suggests that debt management may have implications for monetary policy even if the authorities target the natural rate of output.

[8] Note that, due to the linear approximation, unanticipated inflation may turn the real value of the debt negative, clearly a nonsense since the most inflation can do is to cancel the debt. In order to rule out negative real payments, an upper bound on the distribution of u must be imposed such that

$$u \leq u^h \equiv (1+r)(kB + \frac{b}{m} + \frac{\theta}{mb + m^2 kB})$$

If we assume that the government can raise funds in nominal bonds to lend in inflation-indexed bonds, then m tends to infinity, but a positive upper bound would still exist and be equal to $u^h = (1+r)kB$.

where G and B are the ratios of government spending and public debt to the natural rate of output, respectively, and r is the constant real interest rate.[9]

The important variable here is m, which measures the impact of unexpected inflation on the real value of the debt. Notionally, m is the share of debt that can be devalued by inflation; it excludes both inflation-indexed debt and foreign currency debt insofar as monetary policy does not systematically affect the real exchange rate.[10]

Although the model does not allow to distinguish between debt of different maturities, whether m includes nominal debt of any maturity or only long-term debt is important for policymaking. In a multi-period framework m would be the share of debt which matures after the next monetary policy decision. Certainly, m would include fixed-rate debt with a maturity longer than three months and probably shorter maturities than that, but whether one-month or one-week debt would qualify it is difficult to say.[11]

In practice, there are two other reasons for further restricting the definition of long-term debt. First, because of price stickiness, monetary policy decisions may not immediately develop into higher inflation. Second, inflation may turn out to be higher than currently anticipated over a long period ahead and strongly affect the value of long-term debt, while short-term debt would be rolled-over at interest rates which reflect the revision in expectations.

[9] Note that G and B should be in terms of actual output which would make the tax rate depend on the realisation of the output shock, u. We shall discuss this approximation in Section 1.3.

[10] This is certainly the case if Purchasing Power Parity holds. In that case the value of foreign currency debt would depend on unexpected foreign inflation.

[11] In the case of floating-rate debt the choice would depend on how frequently coupons are revised.

In what follows we refer to m as nominal debt —i.e. debt other than inflation-indexed and foreign currency debt—, but in the empirical analysis of Section 1.5 we shall consider an alternative definition of m which excludes debt with a maturity shorter than one year and floating-rate debt.

The sequence of events is as follows: (i) the government designs monetary institutions and chooses the debt composition; (ii) private agents form rational inflation expectations; (iii) the output shock is realised; (iv) the monetary authority sets the inflation rate.

In the next section we derive the basic insights from the model when monetary policy is not delegated to an independent central bank. In Section 1.3 we shall discuss microfoundations and robustness when alternative specifications of the social loss function are considered.

1.2.2 A Dependent Central Bank

Consider a government that does not delegate monetary policy and retains full discretion over the choice of the inflation rate. After observing the realisation of the shock, u, the government chooses inflation so as to minimise the social loss

$$E_0 L = \theta E_0 \pi^2 + E_0[(\pi - E_0\pi)(b + kmB) - u - k(G + B + rB)]^2 \qquad (1.4)$$

that is obtained by substituting the values of y and τ from equations (1.2) and (1.3) in (1.1).

Assuming rational expectations, inflation and output are given by

$$\pi = \frac{Z}{\theta}(D + \lambda u) \qquad (1.5)$$

$$y = y^T - D - \lambda u \qquad (1.6)$$

where $Z = b + kmB$ denotes the marginal output gain from unexpected inflation, $D = k(G + B + rB)$ is the expected output loss due to tax distortions, and

$\lambda = \theta/[\theta + (b + kmB)^2]$ is decreasing with the share of nominal debt, m.

In this setting, inflation allows the government to dampen the impact of output shocks — the more so, the lower is λ or the larger is the share of nominal debt, m. However, a larger share of nominal debt leads to higher expected and equilibrium inflation, because the private sector anticipates the incentive to inflate. This, in turn, increases the government loss.

At time 0, when the government chooses the indexation and currency denomination of the debt, the government's expected loss is:

$$E_0 L^D = \frac{D^2}{\lambda} + \lambda\sigma^2 \tag{1.7}$$

The government would clearly be better off if it could 'precommit'; i.e. if it could credibly commit to follow a 'state-contingent inflation rule' with zero average inflation $\pi = Z\lambda u/\theta$. Then, the expected loss would be equal to

$$E_0 L^D = D^2 + \lambda\sigma^2 \tag{1.8}$$

Equation (1.8) shows that with precommitment the government should issue the largest possible amount of nominal debt while lending in inflation-indexed or foreign currency debt. Intuitively, nominal debt makes taxes and output sensitive to unexpected inflation thus minimising the inflation needed to offset output shocks. A large, possibly infinite, share of nominal debt would make the social loss tend to the global minimum D^2.[12]

However, since a state-contingent inflation rule is difficult to implement, the government's choice is between discretion and a 'fixed rule' of zero inflation and depreciation. When the government credibly commits to the 'fixed rule' $\pi = e = 0$, the expected loss is equal to

$$E_0 L^R = D^2 + \sigma^2 \tag{1.9}$$

[12] See Calvo and Guidotti (1990).

This loss can be contrasted with the discretionary solution (1.7). Noting that $0 \leq \lambda \leq 1$, equations (1.7) and (1.9) show that under the fixed rule the government loses flexibility in reacting to output shocks but avoids the costs of expected inflation (or depreciation). Indeed, the expected loss (1.7) depicts the trade off between credibility and flexibility that is at the heart of the rules-versus-discretion literature. This trade off is spanned by $\lambda = \theta/[\theta + (b + kmB)^2]$ varying between zero and one, and thus by the share of nominal debt, m.

In general, the government can do better than the fixed rule by choosing a proper, possibly negative, m, so as to select the optimal point on the credibility-flexibility spectrum.[13] The optimal share of nominal debt increases with output variability, σ^2, while it decreases with the temptation to inflate. The latter depends on tax distortions, D, and thus on the level of government expenditure and debt, as in Bohn (1988) and Calvo and Guidotti (1990). Therefore, with a dependent central bank, inflation-indexed debt and/or foreign currency debt are optimal if the impact of tax distortions on inflationary expectations is large relative to the variance of output shocks.

1.3 The Social Loss Function: A Motivation

In this section we discuss the motivation behind the choice of the loss function (1.1) and examine whether the trade off between credibility and flexibility, which emerges in our basic set-up, can be generalised to other specifications.

The choice of the loss function is important because it defines a particular policy

[13] In fact, if the government can choose any debt combination, including the possibility of raising funds with one type of debt to lend in the other type, the expected loss under discretion can be made no greater than the loss under a fixed rule. This conclusion follows immediately from the fact that the zero inflation rule is equivalent to setting a negative m such that $b + kmB = 0$ and hence $\lambda = 1$. However, the government can do no better than a fixed rule when $D^2 > \sigma^2$.

regime. For example, it characterises the preferences, the nature, and extent of independence of the institution in charge of monetary policy. We adopted the loss function (1.1) which is standard in the literature on central bank independence[14] and model the output loss as a function of the tax rate.

A possible objection to this approach is that the marginal cost in welfare terms of tax distortions is relatively higher in bad states of nature, i.e. when adverse output shocks occur so that $y - \bar{y} < 0$ (as shown by equation (1.1)). This partly reflects the assumption that society has a preference for stabilising output fluctuations arising from nominal rigidities.[15]

However, the implication that the marginal cost of tax distortions is countercyclical is quite strong from the viewpoint of real business-cycle theory of output fluctuations, where distortionary taxation is the only source of inefficiency. In fact, in utility-based models where the output loss reflects disincentives to work induced by proportional taxation of labor income (as opposed to losses from tax collection), the relation between the marginal cost of taxation and the level of output is uncertain.[16] Intuitively, taxation could be less distortionary in bad output states as labor could be supplied more inelastically.

In the absence of nominal rigidities, a possible motivation for equation (1.1) is that a greater marginal cost in bad output states would capture the higher tax rates that are required to ensure fiscal solvency.[17] In fact, the same implications can be derived from a specification of the loss function where the marginal cost of tax distortions is independent from the state of nature.

[14] See Walsh (1998).

[15] See e.g. Walsh (1998) and Herrendorf and Neumann (1998).

[16] See Chari, Christiano, and Kehoe (1999).

[17] Chari, Christiano, and Kehoe (1999) show that, for reasonable parameter values, in bad states of nature it is optimal to cover most of the financing needs in contingent markets for debt even when raising tax rates is efficient.

The formal argument is as follows. Suppose that society cares about output expansions rather than output stabilisation, as in Barro and Gordon (1983b) and Cukierman and Meltzer (1986).[18] Then, the social loss is linear in output and tax distortions:

$$E_0 L = \theta E_0 \pi^2 + E_0(\bar{y} - y) + c E_0 \tau^2 \tag{1.10}$$

where the output loss from distortions is assumed to be quadratic in the tax rate.

Although the marginal cost of taxation is independent from the output shock, u, the dependence of the tax rate from the level of output implied by the budget constraint may lead to the same specification as in equation (1.4). While this is easily verified in a one-period framework where tax revenues, τY, must cover spending commitments and debt repayments, a negative relation between output shocks and the tax rate also emerges over longer horizons if the government smooths taxes.

For instance, using the linear approximation around a zero output growth of the intertemporal budget constraint suggested by Bohn (1990b), it can be shown that tax-smoothing implies the following tax rule:

$$\tau_t = G_t^{P*} + i(1+i)^{-1}[1 + i - m(\pi_t - E_{t-1}\pi_t)]B_{t-1}^* - \bar{\tau}\Sigma_{i=0}^{\infty}(1+i)^{-i}E_t\hat{y}_{t+i}$$

where $G_t^{P*} = G_t^P \bar{Y}/Y_{t-1}$ is permanent (or normal) public expenditure relative to time $t-1$ output, $B_{t-1}^* = B_{t-1}\bar{Y}/Y_{t-1}$ is the debt-to-output ratio, and $\hat{y}_{t+i} = y_{t+i} - y_{t+i-1}$ is the rate of output growth. Finally, $\bar{\tau} = iB_{t-1}^* + G_t^{P*}$ is the point of linearisation for the tax rate. Assuming that the initial output level corresponds to its natural level, i.e. $y_{t-1} = \bar{y}$, and that output shocks are not persistent, so that $E_t y_{t+i} = \bar{y}$ for $i = \{1, 2, 3...\infty\}$, the tax rate is equal to:

$$\tau_t = \bar{\tau} - \frac{i}{1+i}[(\pi_t - E_{t-1}\pi_t)mB_{t-1} + \bar{\tau}(y_t - \bar{y})] \tag{1.11}$$

which can be substituted for τ_t in equation (1.10) to yield a similar specification as equation (1.4).

[18] The argument goes through independently of the presence of output in the loss function.

This motivation for equation (1.1) hinges, however, on tax-smoothing as the rule for fiscal policy. In fact, a series of negative output shocks will eventually force the government to raise taxes independently of the fiscal rule. If the government does not smooth taxes, then the persistence of shocks, the level of debt, and the length of time intervals between monetary policy decisions, are all relevant aspects to consider.

If tax rates are invariant to economic activity, i.e. if $\tau = G+[1+r-m(\pi-E_0\pi)]B$, both output stabilisation and tax variability are irrelevant for welfare. In this case raising funds in inflation-indexed (or foreign currency) debt to lend in nominal debt —i.e. a negative m— can completely remove the inflationary bias at no cost. Hence, an argument for institutional design would have to be based on the existence of practical constraints to this funding policy.

To conclude, our analysis requires either that the government cares about output stabilisation (i.e. because of nominal rigidities) and taxes affect output, or that it wants to stabilise tax rates that vary in response to output changes.

Acknowledging that our analysis is not fully general, in what follows we maintain the motivating hypothesis that a trade-off between credibility and flexibility exists, which depends on tax distortions, and can be improved upon by designing institutions besides choosing the debt composition. In Section 1.5 we shall provide evidence of a negative relation between central bank independence and the shares of foreign currency and indexed debt which is consistent with the existence of such a trade-off.

In the next section we consider the choice of debt instruments and highlight the role of the monetary regime in this decision. In particular, we study the case of a weight-conservative central banker and compare this solution to an inflation contract and to inflation targeting.

1.4 An Independent Central Bank

The merits of foreign currency and inflation-indexed debt as commitment devices that can possibly enhance the credibility of anti-inflationary policy are well known in the literature on debt management. The new interesting issue that we address in this section is how debt policy interacts with, and compares to, institutional design as a solution to credibility problems.

1.4.1 A Weight-Conservative Central Banker

The time-inconsistency literature views delegation of monetary policy to an independent central bank as the natural solution to inflationary temptations. Rogoff (1985) shows that the appointment of a central banker with preferences characterised by a stronger aversion to inflation than society —i.e. by a parameter $\theta_B > \theta$ — increases social welfare. In principle, society could choose the degree of conservativeness, θ_B, of the central banker so as to attain the desired combination of credibility and flexibility.[19]

The first issue we want to address is whether delegation of monetary policy to an independent central bank produces a better outcome than the choice of debt instruments.

Noting that any value of $\lambda = \theta/[\theta + (b + kmB)^2]$ is consistent with alternative combinations of the policymaker's preferences, θ, and nominal debt, m, equation (1.7) seems to suggest the substitutability of debt management and policy delegation. However, we can show that institutional design is a better solution to the credibility-flexibility trade-off than debt management.

[19] The central bank has both goal and instrument independence. However, an alternative interpretation is that society delegates monetary policy to an instrument independent central banker that is assigned a particular loss function.

Proposition 1: *Monetary policy delegation increases social welfare even if the share of nominal debt can be chosen optimally.*

To prove this result, consider the expected social loss, that is, the government loss when the central bank is goal independent:

$$E_0 L = \theta E_0 \pi_B^2 + E_0(y_B - \bar{y} - k\tau)^2 = -(\theta_B - \theta) E_0 \pi_B^2 + E_0 L_B \qquad (1.12)$$

where π_B and y_B are the inflation and output chosen by the central banker whose loss function is denoted by L_B. Note that π_B and y_B follow from the minimisation of L_B and thus depend on the preferences, θ_B, of the central banker. Define with m^* the share of nominal debt that minimises the expected loss under discretion (equation (1.7)) and the corresponding $\lambda^* = \theta / [\theta + (b + km^* B)^2]$.

It is possible to show that the social loss is reduced by choosing a greater share of nominal debt, $m > m^*$, and a central banker with a degree of conservativeness $\theta_B > \theta$ which imply the same $\lambda = \lambda^*$ as the optimal debt policy.

By choosing $\theta_B = \lambda^*(b + kmB)^2/(1 - \lambda^*)$, the welfare loss for society is equal to

$$E_0 L^{*b} = -(\theta_B - \theta) E_0 \pi_B^2 + \frac{D^2}{\lambda^*} + \lambda^* \sigma^2 \qquad (1.13)$$

that is lower than the loss obtained with the optimal debt policy since the central banker is more inflation averse than society; i.e. $\theta_B > \theta$. This result shows that delegation endows the government with an additional control mechanism and enlarges the space of possible outcomes.

The second interesting issue is how the possibility to use both institutional design and debt management affects the selection of the central banker and debt instruments. We can show that:

Proposition 2: *The optimal delegation policy involves the choice of an extremely conservative central banker and the use of an infinitely large share of nominal debt.*

To prove this result, note that the expected welfare loss (1.12) can be written as

$$E_0 L = \left(D^2 + \lambda_B^2 \sigma^2\right)\left[1 + \theta\left(\frac{Z}{\theta_B}\right)^2\right] \qquad with \quad \lambda_B = \frac{\theta_B}{\theta_B + Z^2} \tag{1.14}$$

where $Z = b + kmB$ denotes the marginal output gain from unexpected inflation, and $D = k(G + B + rB)$ is the expected output loss due to tax distortions.

From equation (1.14) it is clear that any increase in Z and θ_B which increases the ratio Z^2/θ_B (and thus lowers λ_B), while reducing Z/θ_B, reduces the social loss. This is possible if θ_B increases at a faster rate than Z but at a slower rate than Z^2.

For example, if we set $Z = (\theta_B)^\alpha$, with $1/2 < \alpha < 1$, the social loss tends to the global minimum D^2 as θ_B tends to infinity. Hence, if there are no constraints on the choice of nominal debt, m, monetary policy delegation approximates the 'state-contingent rule' solution (1.8) in the limit, that is, in the case of an extremely conservative central banker.

The intuition for this result is as follows. A higher share of nominal debt widens the inflation tax base and thus allows for lower conventional taxes and tax distortions for any given unexpected inflation rate.[20] By increasing the sensitivity of output to inflation, nominal debt makes monetary policy more effective in stabilising output fluctuations: less unanticipated inflation is needed to counter negative supply shocks. It follows that more nominal debt, i.e. a lower λ_B, helps to stabilise both output and inflation as shown by equations (1.5) and (1.6).

[20] Alternatively, as shown by Bohn (1990a) and Bohn (1990b), nominal debt reduces the need for a higher tax rate when negative supply shocks occur (see equation (1.11)).

On the other hand, nominal debt gives rise to inflationary temptations that, in the absence of institutional arrangements, would lead to a greater inflation bias. This can be avoided if the government appoints an independent, weight-conservative central banker.

Equations (1.5) and (1.6) show that even when inflation aversion, θ_B, goes to infinity and inflation tends to zero, the government does not need to give up output stabilisation. This requires the share of nominal debt to increase so that λ_B goes to zero (i.e. Z^2/θ_B goes to infinity), though at a slower rate than inflation aversion (i.e. Z/θ_B goes to zero).

In practice, the optimal policy is unfeasible. Realistically, the government would not be able to over-fund in nominal debt and invest the proceeds in foreign currency or indexed assets; there is a limit to the amount of nominal debt that can be issued. Then, we can show that:

Proposition 3: *If there is a limit to the share of nominal debt, welfare is maximised by issuing the largest possible amount of nominal debt and appointing a correspondingly conservative central banker.*

To see this, define with θ_B^* the preferences of the central banker who minimises the social loss function for any given share, $\bar{m}$, of nominal debt. The corresponding λ is $\lambda_B^* = \theta_B^*/[\theta_B^* + (b + k\bar{m}B)^2]$. Then, the social loss (1.12) can be re-written as:

$$E_0 L = \left(\frac{D^2}{\lambda_B^*} + \lambda_B^* \sigma^2\right)\left[\lambda_B^* + \frac{\theta}{\theta_B^*}(1 - \lambda_B^*)\right] \tag{1.15}$$

It is clear that a share of nominal debt, m, lower than $\bar{m}$ cannot reduce the social loss. If it could, θ_B^* would not be optimal since an increase in θ_B, that achieves the same effect on λ_B as $m > \bar{m}$, further reduces the second term of

(1.15). On the contrary, the social loss can always be reduced by a higher m. Any increase in θ_B and m, which leaves $\lambda_B = \lambda_B^*$ unaffected, reduces the second term in equation (1.15).

Therefore, the expected loss for society is minimised by issuing the largest possible amount of nominal debt and appointing a correspondingly 'very' conservative central banker. Intuitively, central bank independence is more effective in containing inflationary expectations and should be used to enhance the credibility of anti-inflationary policy, while nominal debt increases the sensitivity of output to surprise inflation and thus reduces the need for flexibility.

This is an important result that supports the conventional wisdom that institutional design and, in particular, central bank independence is the effective solution to inflationary expectations while very little is gained by increasing the cost of inflation with indexed and foreign currency debt.[21] This may also provide a rationale for the conventional belief that foreign currency debt is a sign of weakness of monetary policy rather than an incentive for low inflation.

1.4.2 An Inflation Contract

In this section, we examine the role of debt denomination and indexation when the delegation mechanism takes the form of an inflation contract between the government and the central bank. The linear contract proposed by Walsh (1995) and extended by Persson and Tabellini (1993) removes the inflationary bias at no cost in terms of output stability, thus providing the best solution to the problem

[21] This conclusion is immediate if one accepts the view of McCallum (1995) that a central banker targets the natural rate of output. Indeed, in such event monetary policy delegation completely removes the credibility problem making the choice of debt instruments depend only on risk considerations, as argued by Miller (1997a).

of establishing the credibility of monetary policy without losing flexibility.[22] [23] The optimal contract delegates monetary policy to a central banker with the same preferences as society (equivalently, it assigns to the central banker the social loss function) but imposes upon the monetary authority a linear cost to inflation. The instrument independent, but not goal independent, central banker minimises

$$E_0 L^C = \theta E_0 \pi^2 + E_0(y - \bar{y} - k\tau)^2 + C E_0 \pi \tag{1.16}$$

where C is the linear penalty associated with inflation.

Except for the cost, C, the central banker faces the same problem as the government under discretion. After observing the shock u, the monetary authority chooses inflation so as to minimise the loss L^C subject to (1.2) and (1.3).

Assuming rational expectations, expected inflation is given by

$$E_0 \pi = \frac{1}{2\theta}(2ZD - C)$$

and the inflation bias can be eliminated by imposing a linear cost to inflation equal to

$$C = 2ZD = 2(b + kmB)D \tag{1.17}$$

Since the temptation for inflationary financing increases with nominal debt, the cost C imposed on the central banker must increase with the share of such debt. Using this result, the solution to the government problem is equal to

$$\begin{aligned} \pi &= \frac{Z}{\theta}\lambda u \\ y &= y^T - D - \lambda u \end{aligned} \tag{1.18}$$

[22] This result requires that the authorities and the private sector share the same information (see Herrendorf and Lockwood (1997)) and that output shocks are not persistent (see Lockwood, Miller, and Zhang (1998)).

[23] McCallum (1997) and Jensen (1997) have challenged this result, by arguing that the Walsh approach does not solve the time inconsistency problem but simply relocates it, because the government will always have the temptation to renege on its choices and change the monetary institution. See Persson and Tabellini (1999) and Driffill and Rotondi (2003) for a reply to these critiques.

that implies an expected loss for society equal to

$$E_0 L^C = D^2 + \lambda\sigma^2 \tag{1.19}$$

The expected loss (1.19) is equal to the loss (1.8) obtained under precommitment, when the government follows a 'state-contingent rule'. An increase in the share of nominal debt (i.e. a decrease of λ) reduces the impact of output shocks and, thus, the social loss. Intuitively, nominal debt makes taxes and output sensitive to unexpected inflation, thus minimising the inflation needed to offset output shocks.

As in the case of a weight-conservative central banker, a large (possibly infinite) share of nominal debt would be optimal; the social loss would tend to the global minimum D^2 as it does in Rogoff's solution when both the degree of conservativeness of the central banker and the share of nominal debt go to infinity.

However, as the amount of nominal debt that can be issued is limited, the inflation contract produces a better outcome. By comparing equation (1.19) to equation (1.14) or (1.15) and assuming that there is no constraint on the choice of the penalty, C, it is possible to show that

Proposition 4: *If there is a limit to the amount of nominal debt that can be issued, then the inflation contract is a better solution than the appointment of a weight-conservative central banker.*

It is, however, worth noting that the central bank contract requires a penalty for inflation that increases with the share of nominal debt, as shown by equation (1.17). Imposing such a cost can be problematic even if justified by the objective of avoiding income redistribution from debt holders to taxpayers or simply by the objective of defending the real value of wealth.

1.4.3 Inflation Targeting

Finally, it is important to ask how previous results relate to inflation targets, as they currently operate in the United Kingdom and elsewhere. In effect, inflation targets can be seen as the practical counterpart of either delegating policy to a weight-conservative central banker (Canzoneri, Nolan, and Yates (1996) and Haldane (1995)) or choosing the contract solution (Svensson (1997)).

Adopting Svensson's interpretation of an inflation targeting regime, the central bank is given operational independence to minimise the following loss function

$$E_0 L^T = \theta E_0(\pi - \pi^T)^2 + E_0(y - \bar{y} - k\tau)^2 \tag{1.20}$$

where π^T denotes the inflation target. Hence, the central bank is assigned a loss function with a target for inflation different from the one which is socially optimal, say, $\pi^* = 0$. It is easy to show that by fixing a target equal to

$$\pi^T = -\frac{1}{\theta}(b + kmB)D \tag{1.21}$$

the targeting regime yields the same solution as the inflation contract. In particular, the expected loss for society, $E_0 L^T = D^2 + \lambda\sigma^2$, is equal to the loss under the contract.

While implications for debt management are the same as in the contract solution, it is worth noting that a high share of nominal debt would imply an inflation target that, if not negative, could lie much below the socially optimal rate of inflation, thus creating problems for the implementation of the optimal policy.[24]

[24] Haldane (1995) uses the same argument to cast doubts on the relevance of Svensson's interpretation to the UK's monetary regime.

1.5 *Independence and Debt Structure: The Evidence*

In the previous section we have shown that delegation of monetary policy to an independent central bank is the best solution to inflationary temptations, while nominal debt should be issued to support output stabilisation. If this normative argument has a positive content, the share of such debt should increase with the independence of the central bank.

A positive relation between central bank independence and the fixed-rate, long-term component of nominal debt is also suggested by an informal interpretation of our model. As argued in Section 1.2, the maturity of the nominal debt should be sufficiently long for inflation to have a significant impact on the debt value and, hence, for nominal debt to enhance the stabilisation role of monetary policy. We discussed a number of reasons, from price stickiness to revisions in expectations, that could explain why the impact of inflation on the value of long-term debt could be stronger than on short-term and floating-rate debt.

In what follows we look at two measures of debt composition: (i) the share of nominal debt; and (ii) the share of fixed-rate, long-term nominal debt (long-term nominal debt in what follows). The former is defined as the percentage of bonds and loans denominated in domestic currency that are not indexed to the price level. The latter is the percentage of fixed-rate bonds and loans denominated in domestic currency with an initial maturity longer than one year.[25]

Table 1.1 reports data on the composition of debt for a sample of 20 OECD industrial countries. The sample includes Australia, Austria, Belgium, Canada, Denmark, Finland, France, Germany, Greece, Ireland, Italy, Japan, the Nether-

[25] Nominal debt excludes ECU-indexed bills and bonds. Long-term nominal debt excludes floating-rate debt but includes extendible bonds and bonds with an option for early redemption if the period preceding the earliest possible maturity is longer than one year.

lands, New Zealand, Portugal, Spain, Sweden, Switzerland, the UK and the US.[26]

In the late 1990s the share of nominal debt varied from 60 per cent in Finland to about 70 per cent in Ireland and Sweden, up to 100 per cent in Germany, Japan, the Netherland, Switzerland and in the United States until the introduction of inflation-indexed bonds in 1997.

Differences across countries can partly be explained by institutional aspects. In a number of countries foreign currency debt is not used for deficit financing but only for the purpose of managing foreign exchange reserves. This is now the case in Canada, Denmark and Britain. Sweden followed this rule until 1993.

However, in 1998 the share of nominal debt was greater than 80 per cent in all countries except for Finland, Ireland, Portugal and Sweden. Differences in debt compositions were thus relatively minor and certainly smaller than in the 1980s. Table 1.1 shows that, while in most countries the share of nominal debt remained relatively stable over the last two decades, in eight countries —Australia, Austria, Belgium, Finland, Greece, Ireland New Zealand and Portugal— such share grew substantially with an average increase of 15 percentage points between 1985 and 1997.

In line with the analysis of the previous section, this evidence could be explained by the increasing independence enjoyed by central banks during this period. The share of nominal debt has fallen significantly (by about 10 percentage points) only in Sweden and in Britain. Interestingly, the Bank of England was granted operational independence only in 1997.

[26] The sample excludes Norway because of data availability and Luxembourg which has a monetary union with Belgium. Data refer to gross central government debt, with the exception of Germany, for which only general government debt data are available.

Tab. 1.1: Change in Nominal Debt Shares – 1985–1997

Increase in the Share of Nominal Debt, $m1$			
$\Delta m1 < -5\%$	$-5\% \leq \Delta m1 < 0\%$	$0\% \leq \Delta m1 \leq 10\%$	$10\% < \Delta m1$
Sweden [78; 67]	Canada [93; 92]	Austria [80; 86]	Australia [82; 95]
UK [91; 83]	France [96; 95]	Denmark [77; 80]	Belgium [80; 92]
	Italy [96; 92]	Germany [100;100]	Finland [45; 60]
	Spain [92; 91]	Japan [100;100]	Greece [61; 79]
	US [100; 99]	Netherl. [100;100]	Ireland [55; 74]
		Portugal [69; 78]	New Zeal. [54; 80]
		Switz. [100;100]	

Notes: The share of nominal debt, $m1$, is the percentage of domestic-currency debt which is not indexed to the price level. The two numbers in brackets are the shares at the end of 1985 and 1997, respectively, or at the end of March 1986 and 1998 for fiscal years ending in March. Nominal debt excludes debt indexed to the ECU. Total debt for the US includes debt in Government Accounts.

Source: Missale (1999).

The increase in the share of nominal debt recorded by the small open economies in our sample of OECD countries may also reflect past difficulties and relatively higher costs faced by these countries when raising funds on their domestic markets. In the case of less developed countries, Eichengreen and Hausmann (1999) and Hausmann and Panizza (2002) have advanced the idea that '...the domestic currency cannot be used to borrow abroad or to borrow long-term, even domestically.'. Many emerging markets borrow, instead, in foreign currency, a situation that the authors describe as the *original sin* of international finance.

Stronger evidence in support of the model comes from the evolution of long-term nominal debt over the last two decades. As shown in Table 1.2, the share of such debt increased sharply since the mid 1980s almost everywhere except that in the United States and in those countries, such as Germany, Japan, the Netherlands, Switzerland and Britain, where it was already above 70 per cent. Indeed, while in 1985 only nine countries had a share of long-term nominal debt greater than 50 per cent, in 1997 this group included sixteen countries. During this period, the average increase in the share of long-term nominal debt was 13 percentage points for the entire sample and 24 points for the eleven countries with an initial share lower than 50 per cent.

Although economists agree that in this period central banks have enjoyed an increasing independence in the conduct of monetary policy[27] and the Maastricht Treaty established the full independence of European banks, no time series are available on the evolution of independence. Thus, the prediction of a positive relation between independence and nominal debt is tested in this section using cross-sectional evidence for the 20 industrial OECD countries in our sample.

[27] See Eijffinger and Haan (1996) and King (1994).

Tab. 1.2: Change in Long-Term Debt Shares – 1985–1997

Increase in the Share of Long-Term Nominal Debt, $m2$			
$\Delta m2 < -5\%$	$-5\% \leq \Delta m2 < 0\%$	$0\% \leq \Delta m2 \leq 10\%$	$10\% < \Delta m2$
UK [71; 59]	Germany [93; 90]	Australia [65; 75]	Austria [41; 61]
	Japan [88; 83]	Denmark [67; 72]	Belgium [51; 71]
	Netherl. [99; 94]	Ireland [41; 49]	Canada [40; 61]
	Switz. [72; 67]	Sweden [48; 52]	Finland [41; 55]
	US [54; 50]		France [29; 71]
			Greece [0; 31]
			Italy [11; 42]
			New Zeal. [42; 57]
			Portugal [4; 34]
			Spain [13; 62]

Notes: The share of long-term nominal debt, $m2$, is the percentage of fixed-rate bonds and loans denominated in domestic currency with initial maturity longer than one year. The two numbers in brackets are the shares at the end of 1985 and 1997, respectively, or at the end of March 1986 and 1998 for fiscal years ending in March. Long-term nominal debt includes extendible bonds and bonds with coupons adjustable after a period longer than one year. Total debt for the US includes debt in Government Accounts.

Source: Missale (1999).

Central bank independence is measured by three main indexes available from the literature: the index of political independence developed by Alesina (1989), (AL); the total index of political and economic independence of Grilli, Masciandaro, and Tabellini (1990), (GMT); the legal index of Cukierman (1992), (CU). The macroeconomic variables used in the estimations are from the OECD.

Table 1.3 reports pairwise and rank correlations between the share of nominal debt in 1985 and the three indexes of central bank independence listed above. We choose 1985 as the reference year since the indexes of independence refer to legal and institutional arrangements of the 1980s, but results are robust to the choice of other dates or the use of period averages.

The simple correlation between the share of nominal debt and the indexes of central bank independence is positive, as expected, and significant at the 10 per cent level for the AL index and at the 5 per cent level for the GMT index. The correlation is not significant in the case of the CU index. Stronger evidence in support of the theory comes from the rank correlations in Table 1.3. The Spearman correlation coefficient is significant at the 5 per cent level for both the AL and the GMT indexes.

The last three columns of Table 1.3 report the correlation coefficients with the share of long-term nominal debt, which may better reflect actual inflation incentives than short-term and floating-rate nominal debt. In fact, a short maturity or variable interest rates limit the time for the impact of unexpected inflation on the debt value.

The correlations with the share of long-term nominal debt are strong and significant at the 5 per cent level for both the AL and GMT indexes, while there is no evidence of correlation with the CU index. The same results hold true for rank correlations.

Tab. 1.3: Correlations of Debt Shares and Central Bank (CB) Independence

	Nominal Debt			Long-Term Nominal Debt		
Index of CB Independence	AL	GMT	CU	AL	GMT	CU
Simple correlations	0.45	0.58	0.15	0.57	0.62	0.24
	(0.07)	(0.01)	(0.53)	(0.02)	(0.01)	(0.31)
Rank correlations	0.60	0.58	0.16	0.60	0.60	0.21
	(0.01)	(0.01)	(0.51)	(0.01)	(0.01)	(0.39)
Observations	16	18	19	16	18	19

Notes: Pairwise correlation coefficients and Spearman rank correlation coefficients. P-Values are in parentheses. The index by Alesina (AL) is not available for Austria, Greece, Ireland and Portugal. The index by Cukierman (CU) is not available for Portugal. The Grilli-Masciandaro-Tabellini (GMT) index is not available for Finland and Sweden.

To examine whether the relation between central bank independence and debt structure is robust to the introduction of other variables, we estimate regressions of debt shares on independence indexes and a set of control variables. We focus our attention on the AL and GMT indexes for which a significant relation has been detected. We take debt shares as the dependent variable, even though the choice of debt composition and bank independence has been modelled as a joint decision taking place contemporaneously at the institutional stage of the game.[28]

Table 1.4 shows that the relation between debt shares and the AL and GMT indexes remains significant after controlling for the fiscal stance, the openness of the economy and the adoption of an exchange rate peg. Columns 1–4 show that the ratios of government consumption and gross debt relative to GDP in 1985 have no impact on debt composition. Incidentally, this result is quite robust; it holds for different periods, for the use of period averages and for regressions with government deficits and interest payments.

In the second part of Table 1.4, we control for an exchange-rate peg and for the openness of the economy, as measured by the sum of imports and exports relative to GDP in 1985.[29] The consideration of the exchange rate regime is important since a peg provides further commitment to low inflation because of the costs associated with the realignments of the fixed parity (Giavazzi and Pagano (1988)), and the greater transparency of the exchange rate (Herrendorf (1999)). Openness is suggested by the greater use of foreign currency debt by open economies. Furthermore, a larger tradable sector facing international competition may imply less distortions and thus lower inflationary temptations, as shown by Lane (1997).

[28] This choice reflects less frequent and more costly changes in institutional arrangements and central bankers compared to changes in the debt structure.

[29] Peg is a dummy variable taking the value of one for those countries that were part of the Exchange Rate Mechanism (ERM) of the EMS in 1985, namely Belgium, Denmark, France, Ireland, Italy and the Netherlands. The inclusion of Spain (that joined the ERM in 1989) and/or Austria, Finland and Sweden (*de facto* adopting a peg), does not change the results.

Tab. 1.4: Debt Shares, CB Independence, Fiscal Variables and Openness

Dep. variable	Nominal		Long-Term Nominal		Nominal		Long-Term Nominal	
	AL	GMT	AL	GMT	AL	GMT	AL	GMT
Constant	77.1**	81.4**	18.0	5.58	74.2**	74.1**	7.76	-5.56
	(3.29)	(4.45)	(0.50)	(0.16)	(6.18)	(7.62)	(0.41)	(0.27)
CB Independence	8.31*	3.07**	16.6**	6.81**	9.65**	3.15**	15.4**	5.95**
	(1.84)	(2.57)	(2.40)	(3.07)	(2.34)	(3.28)	(2.40)	(2.98)
Government Consumption	-0.82	-0.83	-0.15	-1.06				
	(0.91)	(0.86)	(0.11)	(0.59)				
Debt Ratio	0.13	-0.09	0.08	0.17				
	(0.80)	(0.62)	(0.31)	(0.64)				
Peg					16.5*	10.7	-9.51	-2.39
					(1.76)	(1.45)	(0.65)	(0.15)
Openness					-0.42	-0.51**	0.56	0.31
					(1.50)	(2.29)	(1.28)	(0.67)
Observations	16	18	16	18	16	18	16	18
Adjusted R^2	0.29	0.39	0.34	0.41	0.39	0.52	0.41	0.41

Notes: t-statistics are in parentheses. *Significant at the 10% level. **Significant at the 5% level.

For the AL and GMT indexes see Notes to Table 1.3.

Columns 5–8 of Table 1.4 show that the AL and GMT indexes of independence perform better than the peg and openness; controlling for exchange rate pegging even enhances the significance of the AL index in explaining the variation in nominal debt. This is because exchange rate pegging provides a substitute for independence. When the GMT index is considered, openness appears to reduce the share of nominal debt. There is instead no evidence that either openness or exchange rate pegging affect the share of long-term nominal debt.

We then examine the effect of political instability on the composition of public debt. Miller (1997b) finds that political instability reduces significantly the share of long-term nominal debt, possibly because of an inflation-risk premium on long-term debt induced by higher inflation uncertainty. Columns 1–4 of Table 1.5 show, however, that independence performs better than instability in three out of four cases: when nominal debt (of any maturity) is considered, and when independence is measured by the AL index. Political instability has a significant negative impact on the share of long-term debt only with the GMT index.

Columns 5 to 8 of Table 1.5 consider size and openness as determinants of the debt composition, drawing from evidence of a greater use of foreign currency debt by small open economies. The log of GDP in 1985 (in US dollars) accounts for most of the variation in nominal debt across OECD economies leaving no significant role for central bank independence. The last two columns of Table 1.5 show, however, that when long-term nominal debt is considered, the AL and GMT indexes remain significant at the 5 per cent and 10 per cent level, respectively, while size does not have a statistically relevant effect.

If GDP is viewed as an indicator of the size of the security markets and their liquidity, this evidence suggests that the dimension of the market affects the cost and thus the choice between alternative instruments to commit to low inflation.

Tab. 1.5: Debt Shares, CB Independence, Political Instability and Country Size

Dep. variable	Nominal		Long-Term Nominal		Nominal		Long-Term Nominal	
	AL	GMT	AL	GMT	AL	GMT	AL	GMT
Constant	95.1**	65.3**	-13.3	-6.57	14.9	26.6*	3.33	-41.4
	(5.75)	(5.71)	(0.54)	(0.37)	(0.74)	(2.00)	(0.08)	(1.13)
CB Independence	11.0**	3.08**	12.1*	2.85	1.52	0.93	15.8**	4.35*
	(2.54)	(2.10)	(1.86)	(1.27)	(0.40)	(1.09)	(2.14)	(1.84)
Political Instability	3.03*	0.35	-4.11	-3.72**				
	(1.83)	(0.31)	(1.67)	(2.16)				
Openness					0.36	0.17	0.45	0.66
					(1.47)	(0.94)	(0.92)	(1.33)
Log of GDP					10.7**	9.02**	0.76	7.06
					(3.38)	(4.08)	(0.12)	(1.16)
Observations	15	16	15	16	16	18	16	18
Adjusted R^2	0.38	0.29	0.46	0.50	0.60	0.75	0.39	0.46

Notes: t-statistics are in parentheses. *Significant at the 10% level. **Significant at the 5% level.

For the AL and GMT indexes see Notes to Table 1.3.

Although there may be a preference for short-term and variable-rate debt, in the mid 1980s debt managers could rely on deep markets for such instruments only in large economies, while for small countries borrowing on foreign markets was more convenient.

The overall impression is that a relation between debt composition and independence exists which gives a potentially positive content to the theory developed in the previous sections. There are other important predictions regarding output variability and inflation that can be examined.

A stronger testable implication of our theoretical model is that a greater share of nominal debt helps to reduce output variability by making the stabilisation policy of the monetary authority more effective (see equation (1.6)). To test this prediction we follow the standard procedure in the empirical literature stemming from Grilli, Masciandaro, and Tabellini (1990) and Alesina and Summers (1993). We estimate regressions of the standard deviation of output growth on the AL and GMT indexes, introducing the two measures of debt composition as additional explanatory variables. We consider the standard deviation of output growth for the period 1986-1997 so as to avoid potential endogeneity problems between output growth and the debt structure.

The results shown in columns 1 and 2 of Table 1.6 are striking: a greater initial share of nominal debt significantly decreases output variability. The effect is significant at the 5 per cent level for both the AL and the GMT indexes and still holds when openness and log of GDP are introduced in the regression as control variables (see columns 5 and 6).

The evidence on the impact of the debt structure is however mixed: when the share of long-term nominal debt is considered, no significant effect on output variability is found (see columns 3, 4, 7 and 8).

Tab. 1.6: Variability of Output Growth, Debt Shares and CB Independence

Dep. Variable	Standard Deviation of Output Growth 1986-97							
	AL	GMT	AL	GMT	AL	GMT	AL	GMT
Constant	4.46**	3.19**	1.96**	2.08**	4.89**	3.29**	4.27**	2.76**
	(8.13)	(5.69)	(4.04)	(6.70)	(7.59)	(4.34)	(3.96)	(3.56)
CB Independence	0.25*	0.003	0.003	-0.06	0.25*	0.002	0.21	-0.04
	(2.01)	(0.08)	(0.01)	(1.28)	(2.10)	(0.06)	(0.88)	(0.69)
Nominal Debt	-0.04**	-0.02**			-0.04**	-0.03*		
	(5.29)	(2.25)			(4.61)	(1.91)		
Long-Term Nominal Debt			-0.003	0.002			-0.001	0.003
			(0.38)	(0.43)			(0.17)	(0.67)
Openness					-0.01	0.001	-0.02*	-0.01
					(1.22)	(0.10)	(1.81)	(0.54)
Log of GDP					0.06	0.11	-0.39**	-0.15
					(0.42)	(0.65)	(2.28)	(1.16)
Observations	16	18	16	18	16	18	16	18
Adjusted R^2	0.68	0.33	0.01	0.11	0.77	0.35	0.34	0.20

Notes: *t*-statistics are in parentheses. *Significant at the 10% level. **Significant at the 5% level.

For the AL and GMT indexes see Notes to Table 1.3.

Finally, we examine the relation between average inflation for the period 1986–1997, central bank independence and debt composition. Since monetary policy delegation does not fully eliminate the inflation bias and the share of nominal debt is limited, inflation is expected to decrease with independence and rise with the share of nominal debt or, in an inflation targeting, bear no relation to it.

The empirical evidence reported in Table 1.7 contradicts this prediction: the coefficient of the share of long-term nominal debt is negative and significant with both the AL and the GMT index. This result is robust to the introduction of a dummy variable for exchange rate pegging (see columns 3 and 4) and the consideration of the debt-to-GDP ratio (see columns 7 and 8). As expected, both independence and exchange rate pegging significantly reduce inflation.

The negative relation between inflation and long-term nominal debt may reflect inverse causality running from inflation to the composition of debt. A high inflation environment is likely to be associated with high expected inflation and inflation variability, making it more costly to issue fixed-rate long-term debt.

Alternatively a lower share of long-term nominal debt may reflect a policy reaction to high inflation in an attempt to reduce inflationary expectations, as suggested by King (1994) and Mandilaras and Levine (2000). In either case the estimated relation suffers from an endogeneity problem that the use of initial-period debt shares cannot solve, since average future inflation is typically correlated with long-term interest rates.

To conclude, the observed debt structures in industrial OECD countries are consistent with the prediction that more independent central banks allow governments to issue a larger share of long-term nominal debt.

Tab. 1.7: Inflation, Debt Shares and CB Independence

Dep. Variable:	Average Inflation 1986-1997							
	AL	GMT	AL	GMT	AL	GMT	AL	GMT
Constant	5.23**	11.4**	6.07**	8.68**	5.91**	15.7**	6.23**	10.6**
	(3.36)	(3.85)	(10.7)	(6.68)	(4.09)	(4.40)	(7.03)	(5.28)
CB Independence	-1.03**	-0.39*	-0.66**	-0.23	-0.94**	-0.42*	-0.64*	-0.30
	(3.62)	(1.82)	(2.56)	(1.17)	(2.91)	(2.06)	(2.05)	(1.46)
Nominal Debt	0.01	-0.04			0.001	-0.07		
	(0.46)	(1.10)			(0.06)	(1.66)		
Long-Term			-0.02*	-0.05**			-0.02	-0.05**
Nominal Debt			(2.02)	(2.43)			(1.61)	(2.27)
Peg	-1.14**	-1.94*	-1.07**	-1.82*				
	(2.31)	(1.75)	(2.59)	(1.87)				
Debt Ratio					-0.01	-0.05**	-0.01	-0.03
					(1.15)	(2.21)	(1.14)	(1.70)
Observations	16	18	16	18	16	18	16	18
Adjusted R^2	0.60	0.48	0.70	0.60	0.48	0.53	0.57	0.59

Notes: t-statistics are in parentheses. *Significant at the 10% level. **Significant at the 5% level.

For the AL and GMT indexes see Notes to Table 1.3.

However, the negative relation between inflation and long-term nominal debt suggests an alternative explanation to the commitment motivation. The positive relation between independence and nominal debt may simply reflect the lower inflation environment that characterises countries with more independent central banks. So far we have been unable to construct a test that allows to distinguish between these two competing but related explanations. We leave the investigation of this issue to our future research agenda.

1.6 Conclusions

While the role of central bank independence in securing low and stable inflation is undisputed, the idea that indexed and foreign currency debt may create incentives and expectations for low inflation is not always accepted.

This chapter argued that the efficacy of debt characteristics as incentives for anti-inflationary policy depends on the type of monetary regime. We showed that delegation of monetary policy to an independent central bank is a better solution to credibility problems than increasing the costs of inflation by issuing indexed debt, foreign currency debt and short-term debt. Furthermore, an independent central bank may benefit from nominal debt, possibly of a long maturity, since such debt increases the sensitivity of taxes and output to unexpected inflation, thus minimising the unexpected inflation needed to counter supply shocks.

This explanation is consistent with the decline in the share of debt denominated in foreign currency and the lengthening of debt maturity that has taken place since the late 1980s in many OECD countries, with the establishment of increasingly independent central banks.

2. DEBT MANAGEMENT AND THE SUSTAINABILITY OF FIXED EXCHANGE RATE REGIMES

2.1 Introduction

Chapter 1 shows that delegation of monetary policy to either an independent central banker or inflation targeting is a superior solution to a 'fixed rule' of zero inflation and depreciation if the authorities and the private sector share the same information. On the other hand, a fixed exchange regime may fare better if information is asymmetric or the monetary authority is not granted full independence.

Herrendorf (1998) finds that joining a fixed exchange rate regime can be a better solution to credibility problems if the private sector lacks the ability to distinguish the relative impact of economic policies and exogenous shocks on the inflation rate, i.e. when actual inflation is a noisy signal of monetary policy performance.[1]

A fixed exchange rate regime can make the commitment to zero-inflation more visible and enhance the credibility of monetary policy by increasing the cost of inflation. This is the case if the decision to abandon the exchange rate parity involves political and reputational costs.[2] The main benefit is to avoid inflationary expectations that arise if the government is expected to behave opportunistically.

[1] See also Herrendorf (1997) and Walsh (1997).

[2] See Giavazzi and Pagano (1988).

Obstfeld (1991) shows that pegging the exchange rate to a foreign currency can be interpreted as a 'fixed rule with an escape clause'. This solution parallels the possibility of removing (at a fixed cost) a conservative central banker in the literature on bank independence.[3]

In this chapter, we would examine the implications of a fixed exchange regime on debt policy using a model which shares relevant insights with the *second generation* models of currency crises.[4] We would also test the main predictions of the model by looking at the experience of the European countries participating in the Exchange Rate Mechanism (ERM) of the European Monetary System (EMS) during the period 1979–1995.

The rest of this chapter is organised as follows. In Section 2.2, we selectively review the literature on self-fulfilling confidence crises by focusing on those contributions where debt management plays a key role in triggering or averting a financial crisis. In Section 2.3, we extend the simple theoretical framework used in Chapter 1 to show how debt management may affect the sustainability of a fixed exchange rate regime. In Section 2.4, we describe in a snapshot the different phases of the ERM, from its foundation in 1979 to 1995 when the band of fluctuation of the participating currencies was enlarged to $\pm 15\%$ around the central parity. Section 2.5 describes the dataset that we use to empirically test the main theoretical conclusions arising from Section 2.3. The estimation results are presented in Section 2.6. Finally, Section 2.7 concludes.

[3] See Flood and Isard (1989) and Lohmann (1992).

[4] See Drazen and Masson (1994) and Velasco (1996).

2.2 *Debt Management and Self-Fulfilling Confidence Crises: A Partial Review of the Literature*

The EMS crisis of September 1992 —which led to the abandonment of the ERM system by Great Britain and Italy, and the speculative attack on the French franc thereafter— inspired a new strand of literature on the causes of currency crises. These new theories are grouped under the common heading of 'second generation' models of currency crises, or models with an 'escape clause'.[5]

Until the early 1990s, the prevailing theoretical framework used to explain the occurrence of currency crises was the speculative attack model à la Krugman (1979), which inspired the 'first generation' models of currency crises. According to this approach, the abandonment of a fixed exchange rate regime is the result of a run on the foreign exchange reserves of the central bank orchestrated by speculators with rational expectations of a devaluation. The crisis is thus the result of the arbitrage by speculators that anticipate the full depletion of the central bank's stock of foreign reserves. The conflict between an expansionary fiscal or monetary policy and a fixed exchange rate regime is what triggers the loss of reserves that eventually forces the authorities to abandon the exchange rate peg.

The 1992 EMS crisis revealed the inadequacy of the 'first generation' models in explaining crises on the basis of bad fundamentals.[6] Indeed, while an excessive fiscal or monetary policy expansion may explain the collapse of the Italian lira or the Spanish peseta, the same argument cannot be applied to the devaluation of the British pound or the French franc. The credibility of the French and British governments to defend a fixed parity was eroded by their perceived incentives to devalue in order to ease the effects of the high unemployment and interest rates

[5] For a critical review of the currency crises literature and an assessment of the predictability of currency crises see, among others, Jeanne (1999), Chui (2002) and Berg and Pattillo (1998).

[6] As pointed out by Jeanne (1999), by bad fundamentals we mean here an expansionary monetary or fiscal policy that makes the devaluation inevitable.

imposed by Germany after its reunification. These domestic factors increased the temptation to devalue and made the choice to increase interest rates to defend the currency even more painful, because of self-fulfilling devaluation expectations.

These considerations led to the development of an alternative theoretical approach to speculative attacks that takes into account economic fundamentals but also the self-fulfilling nature of currency crises and the possibility of multiple equilibria. The devaluation is no longer the result of a shortage of foreign reserves, but the *ex-post* optimal response of policy makers faced with the incentive to devalue the currency. A fixed exchange rate is thus a commitment device to an anti-inflationary policy but with an 'escape clause' to devalue if the costs associated with this commitment outweigh its benefits.

In the seminal paper by Obstfeld (1994), the costs of the commitment to a fixed exchange rate are measured in terms of higher unemployment. However, another reason why policymakers may be tempted to an inflationary surprise is to inflate away the value of the outstanding public debt. The policymaker's choice is thus reduced to a problem of optimal taxation, where the choice is between monetary seigniorage and taxes.

In what follows, we would review some selected contributions from this last group of models. The main aim is to highlight the role that debt management can play in triggering or averting a confidence crisis.

Using a model where debt repudiation can be either open or through inflation, Calvo (1988) was the first to show that the presence of a large debt stock may generate multiple equilibria and self-fulfilling sovereign debt crises. This is because the expected debt repudiation will tend to be reflected in higher interest rates paid on government bonds. Higher interest rates, in turn, will add to the debt burden, increasing the likelihood of a debt default.

This circularity generates multiple equilibria: one with low interests and no repudiation, and another with high interests and debt default. Calvo also shows that in a monetary economy, where inflation is the only possible form of repudiation, indexation of public debt can offer a solution to the inflation bias because it removes the inflationary incentive associated with a high debt burden.

In the model by Calvo (1988), the incentive to repudiate the debt by creating an inflationary surprise is increasing in the total debt burden, no matter what its term structure is. The paper by Alesina, Prati, and Tabellini (1990) extends the previous argument by focusing on the role played by the maturity structure of public debt.

Contrary to Calvo (1988), the model by Alesina, Prati, and Tabellini (1990) has an infinite horizon, in which the optimal policy of the government is to roll-over its debt forever. A bad equilibrium, or confidence crisis, originates from a coordination failure among investors who refuse to buy the debt rolled over in the anticipation that others will behave likewise in future periods. As no investor buys public debt, the government is forced to default, validating the expectations of investors.

Multiple equilibria are a feature of this model too, depending on the cost associated with the government's default. Moreover, the authors show that the likelihood of a confidence crisis is higher the shorter and more concentrated are the maturities of public debt. It follows that a way of averting a crisis is to increase the maturity profile of the debt by issuing long-term public debt.

Giavazzi and Pagano (1990) extend the previous analysis by focusing on a small open economy with a fixed exchange rate regime and imperfect information on the government's preferences. In this set-up, a confidence crisis does not necessarily lead to a devaluation of the currency. The authors show that the ability of the

government to withstand a crisis depends on the stock of debt outstanding, its average maturity and maturity structure. The policy prescriptions that follows from this model are clear: the government should smooth the time pattern of the debt reaching maturity and possibly index or issue debt in foreign currency. The (real) return on the latter is insensitive to expected exchange rate movements and thus to confidence crises.

The self-fulfilling debt crises model of Cole and Kehoe (2000) shows how fundamentals, such as the level and composition of government debt, can lie in a 'crisis zone' where multiple equilibria are possible. The policy response to avoid or contrast a crisis is similar to that suggested by the previous studies, i.e. to reduce the stock of debt or lengthen its maturity.

Obstfeld (1994) finds inspiration in the strand of literature on 'bonds-led currency crises' initiated by Calvo (1988) for his model of the 1992 EMS crisis. The author extends the findings by Giavazzi and Pagano (1990) by modeling the intertemporal decisions of a government that faces a trade-off between a fixed exchange rate policy and the financing of its fiscal deficit using distortionary taxation. In his setting, the government chooses the currency composition of public debt first, and decides on whether or not to devalue the currency in the second period.

Multiple equilibria and self-fulfilling currency crises arise in this framework because devaluation expectations tend to raise the nominal interest rate and the debt burden. The higher the debt burden, the stronger the incentive of the government to devalue in the second period, validating expectations of a devaluation.

A similar argument is presented by Velasco (1996) and Sachs, Tornell, and Velasco (1996) with reference to the Mexican crisis in 1994. The focus of these studies is on the relationship between debt management, credibility and the sustainability

of fixed exchange rates. These models contain elements of both first and second generation models of currency crises. They share with Obstfeld (1994) the presence of an optimising policy maker that chooses whether or not to devalue on the basis of a cost-benefit analysis and reputational considerations.[7] However, fundamentals also matter in determining under what circumstances a self-fulfilling outcome is possible.

Velasco (1996) shows that only for sufficiently high levels of external debt there can be multiple equilibria. Moreover, the level of the debt stock influences in each point in time the incentive of the policymaker to devalue and thus the trade-off between flexibility and credibility. The cost-benefit analysis is influenced not only be the level of the debt stock but also by devaluation expectations. These, in turn, are influenced by the debt stock and by the probability assigned to the likelihood of a surprise devaluation. While a high stock of debt increases devaluation expectations, a surprise devaluation in $t = 1$ has an ambiguous effect on subsequent devaluation expectations.

The last finding sheds some light on the Mexican crisis. Contrary to conventional wisdom, not devaluing in the presence of bad fundamentals and adverse external shocks may have been detrimental to credibility. On the other hand, devaluing in the presence of bad fundamentals could have improved expectations and the government's credibility. This is because in Velasco (1996), the expectations of devaluation depend not only on the policymaker's reputation but also on the level of fundamentals, i.e. the debt stock. If fundamentals are bad and the government resists the temptation to devalue, devaluation expectations can raise more than they would have, had the government devalued in the first place.

[7] In the two-periods extension of the model, Velasco (1996) assumes that a government that devalues in $t = 1$ is never believed again. This implies that agents will expect a devaluation with probability one in the second period.

2.3 Exchange Rate Pegging

The analysis presented in this section follows Velasco (1996), extending his work in two directions. First, it considers domestic public debt as opposed to external debt. Secondly, it focuses on the choice of the currency denomination of debt, a problem which does not arise when only external debt is considered. Within the present framework the government must solve an additional problem, which is to choose the share of domestic debt denominated in local currency.

The government's problem is set as in Chapter 1. The loss function of the policy maker can be written as follows:

$$E_0 L = \theta E_0 e^2 + E_0(y - y^T)^2 \tag{2.1}$$

where θ reflects the social preferences, i.e. the cost of depreciation relative to output deviations, e denotes the exchange rate depreciation, y^T is the output target and y is actual output, lower than optimal because of tax distortions.

If the exchange rate parity is abandoned, the monetary authority decides the extent of the devaluation of the currency, e, (and thus inflation since PPP holds) so as to minimise (2.1) subject to:

$$y - y^T = Z(e - E_0 e) - D - u \tag{2.2}$$

where $Z = (b + kmB)$ denotes the marginal output gain from unexpected depreciation, $D = k(G + B + rB)$ is the expected output loss due to tax distortions, and u is an adverse output shock. The parameter b measures the sensitivity of output to surprise inflation (depreciation), G and B are the ratios of government spending and public debt to the natural rate of output, r is the constant real interest rate, and m is the share of nominal debt, which can be devalued by inflation (depreciation).

At normal times, under a fixed exchange rate regime, the authority does not devalue and maintains inflation equal to zero, so that its loss is equal to

$$L^{fx} = (D + u + ZE_0e)^2 \tag{2.3}$$

However, for sufficiently large adverse shocks to output, the government devalues and incurs the reputational and political costs of its action. Denoting with C the fixed cost associated with a devaluation, the loss from devaluing is equal to

$$L^d = \lambda(D + u + ZE_0e)^2 + C \tag{2.4}$$

It follows that the government will devalue for shocks such that $L^{fx} > L^d$, or

$$\lambda(D + u + ZE_0e)^2 + C < (D + u + ZE_0e)^2$$

that can be solved for u to yield

$$u + D > \Phi - ZE_0e \tag{2.5}$$

where $\Phi = [C/(1-\lambda)]^{1/2}$ is decreasing in $Z = b + kmB$ and thus in the share of nominal debt.

Equation (2.5) shows that the decision to devalue or to maintain the fixed parity depends on the devaluation expectations of the private sector, a fact which gives rise to multiple equilibria.

This can be easily illustrated for a simple distribution of output shocks. Suppose that u can take only two values: it can be bad and equal to $\bar{u}$ with probability p, or good and equal to $\underline{u}$ with probability $(1-p)$. Assume also a zero mean shock; i.e. $E_0u = p\bar{u} + (1-p)\underline{u} = 0$. Then, three possible equilibria may exist depending on the importance of tax distortions (and thus on the level of debt) and the magnitude of the shocks: (i) a *no devaluation* equilibrium; (ii) a *contingent devaluation* equilibrium; (iii) a *devaluation* equilibrium.

In a no devaluation equilibrium the private sector expects the government to maintain the exchange rate fixed even when the bad shock occurs, so that $E_0 e = 0$ and the government never devalues. This is the case if

$$D + \bar{u} < \Phi$$

the level of debt is low or the fixed cost of devaluation is high.

In a contingent devaluation equilibrium the private sector expects the government to devalue only if a bad shock occurs and the government behaves as expected; it maintains the exchange rate fixed, $e = 0$, for good shocks while it devalues for bad shocks, $u = \bar{u}$. In the latter case the government chooses an exchange rate equal to

$$Ze = (1 - \lambda)(D + \bar{u} + ZE_0 e)$$

It follows that the expected depreciation is:

$$ZE_0 e = \frac{p(1 - \lambda)(D + \bar{u})}{1 - p(1 - \lambda)} \tag{2.6}$$

Using this result in condition (2.5), it can be shown that a contingent devaluation is an equilibrium if the following inequalities are satisfied

$$\Phi[1 - p(1 - \lambda)] < \bar{u} + D \tag{2.7}$$

$$\bar{u} + D < (\Phi + \bar{u} - \underline{u})[1 - p(1 - \lambda)]$$

These conditions ensure that the government devalues for bad shocks, since $L^d(\bar{u}) + C < L^{fx}(\bar{u})$, while it maintains the fixed parity for good shocks, since $L^d(\underline{u}) + C > L^{fx}(\underline{u})$.

Finally, in a devaluation equilibrium the policymaker is expected to abandon the fixed parity even for good shocks, so that $E_0 e = ZD/\theta$. The government does so at very high levels of debt and tax distortions. Devaluation is an equilibrium if

$$D > \lambda(\Phi - \underline{u}) \tag{2.8}$$

Within this framework, the expectation that the government will devalue can be self-fulfilling because pessimistic expectations lead to higher interest rates and nominal wages, thus increasing output distortions and the cost of resisting a speculative attack. For some range of parameter values the equilibrium can be 'no devaluation' or 'contingent devaluation' depending on the private sector's expectations. For other parameter values, private sector's expectations determine whether devaluation is a sure outcome or is contingent on the output shock. Focusing on the former possibility, 'no devaluation' and 'contingent devaluation' are both possible outcomes if the following condition holds:

$$\Phi[1 - p(1 - \lambda)] < \bar{u} + D < \Phi \tag{2.9}$$

As mentioned in the previous section, the potential of fixed-rate nominal debt with a short maturity to generate multiple equilibria is known since the seminal work by Calvo (1988), Giavazzi and Pagano (1990) and Alesina, Prati, and Tabellini (1990) and has recently been revived in the literature on currency crises by Obstfeld (1994). In that literature the choice of the currency denomination and the maturity of the debt are shown to play a crucial role: the issuance of foreign currency debt can rule out a debt crisis, that is, the 'bad equilibrium'.

In the present framework the use of foreign currency debt can eliminate the contingent devaluation outcome. Foreign currency debt may insulate the government budget from high nominal interest rates and thus prevent expectations from having any impact on the decision to hold the exchange rate fixed. Formally, the condition for a contingent devaluation may not hold — i.e. $\bar{u}+D < \Phi[1-p(1-\lambda)]$ — for a high share of foreign currency debt, since both Φ and λ increase as conventional debt is reduced.

Although the merits of foreign currency debt arise quite naturally in most models of currency crises, a less favorable picture emerges when we turn to the facts. Large issuances of foreign currency debt have neither prevented the emergence

nor improved on the outcome of currency crises, such as in Sweden and Finland in 1992, and Mexico in 1994. Even more challenging for the theory is that foreign currency debt is usually not well received by private investors. There is thus little sign of the credibility bonus associated with foreign debt that most theoretical models predict.

In an effort to reconcile theory and evidence Obstfeld (1994) relies on the following explanation. If reducing the debt burden provides the only motivation for surprise devaluation and inflation, then foreign currency debt is effective in ruling out currency crises. However, if there are other benefits from unexpected inflation that are unrelated to public debt, then foreign currency debt helps to avoid some bad equilibria but may not eliminate the possibility of a crisis. If a crisis nevertheless materialises, it would be worse than had foreign debt not been issued. This is because foreign debt reduces the inflation tax base and thus the cost for the government of any given expected inflation. As a result, expected and realised depreciation and inflation must be higher for an equilibrium to exist where such expectations are self-validating.

This explanation can be formalised as follows. Suppose that the sensitivity of output to surprise depreciation, b, is high enough to make contingent devaluation a possible outcome even if all the debt is denominated in foreign currency, i.e. $m = 0$, and

$$\Phi[1 - p(1 - \lambda)] < \bar{u} + D$$

Then, the effect of domestic currency debt can be evaluated by examining the government loss when the 'contingent-devaluation' equilibrium prevails.[8]

When the private sector expects the decision to devalue to be contingent on

[8] We focus on this particular outcome because in the 'no-devaluation' equilibrium the loss is equal to $D^2 + \sigma_u$ and is thus independent from the debt composition.

the shock, the expected loss of the government is equal to:

$$E_0 L^{cd} = pC + p\lambda(D + \bar{u} + ZE_0e)^2 + (1-p)(D + \underline{u} + ZE_0e)^2 \qquad (2.10)$$

where the cost from pessimistic expectations, ZE_0e, increases with the share of nominal debt, m.[9] High interest rates on nominal debt add to the government's costs in both output states, but, since λ is decreasing in the share of nominal debt, the effect of debt policy is uncertain.

Rearranging terms, and using the value of E_0e from equation (2.6), yields

$$E_0 L^{cd} = pC + (1-p)(\bar{u} - \underline{u}) + (D - \bar{u})(D + \bar{u} + ZE_0e) \qquad (2.11)$$

which shows that the effect of nominal debt on the government loss depends on the difference $D - \bar{u}$. If the adverse output shock, $\bar{u}$, is larger than the output loss due to tax distortions, D, nominal debt reduces the government's expected loss.

Intuitively, domestic currency debt carries a cost in terms of higher interest payments and output distortions (increasing in the level of debt) but provides an insurance against adverse output shocks. For a large enough shock relative to distortions the latter effect prevails and nominal debt should be issued up to the point where it does not lead to a full devaluation.[10]

What is crucial for the result is that nominal debt does not alter the equilibrium outcome since there are other reasons, such as standard price-output effects captured by b, which lead to a devaluation. On the contrary, it should be noted

[9] This can be easily seen by noting that $Z = b + kmB$ is increasing with m and ZE_0e is equal to

$$ZE_0e = \frac{p(D + \bar{u})Z^2}{\theta + (1-p)Z^2}$$

[10] Formally, the optimal share, m, can be found by solving equation (2.8) with an equality.

that this result does not imply that discretionary policy is optimal; i.e. it is consistent with a fixed rule being a better policy than discretion (see equation (2.7)). Indeed, using the fact that $p\bar{u} + (1-p)\underline{u} = 0$, the variance of output shocks is equal to $\sigma_u = \bar{u}^2 p/(1-p)$, and the condition for a fixed rule to be preferable becomes

$$(1-p)D^2 > \lambda p\bar{u}^2 \tag{2.12}$$

which can be satisfied while some nominal debt is still optimal, i.e. $D < \bar{u}$, for a low probability of a bad shock to output.

Therefore, a fixed exchange rate regime can be preferred to a floating regime and domestic currency to foreign currency debt if a large adverse shock to output may occur but with a small probability.

Indeed, domestic currency debt is not only a valuable hedge against bad output shocks but, in such events, it can also lead to a lower rate of devaluation. This is the case if the cost of devaluing, θ, is low relative to the sensitivity of output to unexpected devaluation (and inflation), as shown by the derivative of e with respect to m

$$\frac{\partial e}{\partial m} = \frac{kB(D+\bar{u})}{[\theta + (1-p)Z^2]^2}[\theta - (1-p)Z^2]$$

The reason is that an increase in the inflation tax base may reduce the inflation rate needed to offset an adverse output shock.

This explanation captures the idea that if the likelihood of a devaluation is unaffected by the funding policy of the debt — that is, if the incentives set by foreign currency debt do not alter the government's decision to devalue —, the consequences of a currency devaluation in the presence of foreign debt can be worse than with conventional debt. Expectations may even react negatively to the issuance of foreign debt since a worse outcome, say a higher rate of devaluation, may be expected in the event of a crisis.

In the remaining of this chapter, we would present some empirical evidence based on the experience of the countries within the Exchange Rate Mechanism of the European Monetary System from 1979 to 1995 that provides support to these theoretical results.

2.4 The Exchange Rate Mechanism of the EMS

The European Monetary System was launched in March 1979 by the member states of the then called European Economic Community (EEC), now European Union (EU). The main aim of the EMS was to achieve a greater monetary integration among its member countries, including the creation of a European Central Bank and the introduction of a single common currency.

The key pillars of the agreement were:

- The introduction of the European Currency Unit (ECU), defined as a weighted average of the currencies of the EEC member states.
- The Exchange Rate Mechanism (ERM), which allowed the exchange rate of each member nation to fluctuate within a band of 2.5 per cent on either side of its parity against the ECU. Italy, a founding EMS member, as well as the late comers, i.e. the United Kingdom, Portugal and Spain, were initially granted a wider margin of ± 6 per cent around the central parity. Countries were also allowed to maintain capital controls and modify their central parities, should they become inconsistent with their long-term equilibrium exchange rate.

The ERM was, therefore, only one of the elements defining the EMS. Moreover, not every member country of the European Monetary System adhered to the ERM from the beginning, but only Belgium Denmark, France, Germany, Ireland, Italy, Luxembourg and the Netherlands. The ECU, instead, was a basket of all the EEC currencies, including the pound sterling and the Greek dracma.

As observed by Giavazzi and Giovannini (1989), the EMS was inspired by the Bretton Woods system and of the latter it mimicked the principle of adjustable pegs and bilateral intervention to support the fixed exchange rate parities. The central banks of the ERM member countries committed to keep their exchange rates within bands of fluctuation around their bilateral central parities. Bilateral interventions on the foreign exchange market were compulsory once the spot exchange rate of one currency against another had hit the margin of the fluctuation band. Intra-marginal interventions were let at discretion of the national authorities and did not have to be co-ordinated because they were unilateral.

Following Giavazzi and Giovannini (1989), we can subdivide the life of the Exchange Rate Mechanism in three different periods:

- An initial phase from March 1979 to January 1987, characterised by a large number of official realignments;
- A second 'tranquil' phase from February 1987 to August 1992, with only one realignment in correspondence of the adoption of the narrow band of $\pm 2.5\%$ by Italy;
- A third phase, which followed the forced abandonment of the Italian lira and British pound in September 1992 and lasted until 1995, when the enlargement of the band of fluctuation to $\pm 15\%$ in August 1993 ended *de facto* the European experiment of a fixed exchange rate system.

Table 2.1 shows the chronology of the official realignments within the ERM from March 1979 to 1995, the end-year for the econometric analysis presented in this chapter. The currencies involved in each realignment and the variation of the official parities are reported in the second and third column of the table, respectively. A positive sign indicates an appreciation of the central parity, whereas a negative sign means that the central parity was devalued.

Tab. 2.1: Official Realignments within the ERM I

Date	Country	Realignment
March 1979	Belgium franc, Danish krone,	±2.25% Band
	DM, French franc, Irish punt	
	Luxembourg franc and Dutch guilder	
	Italian lira	±6% Band
24 September 1979	DM	+2%
	Danish krone	−2.9%
30 November 1979	Danish krone	−4.8%
22 March 1981	Italian lira	−6%
5 October 1981	DM and Dutch guilder	+5.5%
	French franc and Italian lira	−3%
22 February 1982	Danish krone	−3%
	Belgian franc	−8.5%
14 June 1982	DM and Dutch guilder	+4.25%
	Italian lira	−2.75%
	French franc	−5.75%
21 March 1983	DM	+5.5%
	Dutch guilder	+3.5%
	Danish krone	+2.5%
	Belgian franc	+1.5%
	French franc and Italian lira	−2.5%
	Irish punt	−3.5%
21 July 1985	All ERM I countries but Italy	+2%
	Italy	−6%
7 April 1986	DM and Dutch guilder	+3%
	Belgian franc and Danish krone	+1%
	French franc	−3%
4 August 1986	Irish punt	−8%
12 January 1987	DM and Dutch guilder	+3%
	Belgian franc	+2%
7 January 1990	Italian lira	−3.75%
	Italian lira	±2.25% Band
14 September 1992	Italian lira	−3.5%
	All other currencies	+3.5%
17 September 1992	British pound abandons ERM I	
18 September 1992	Italian lira abandons ERM I	
	Spanish peseta	−5%
23 November 1992	Portuguese escudo and Spanish peseta	−6%
30 January 1993	Irish punt	−10%
14 May 1993	Spanish peseta	−8%
	Portuguese escudo	−6.5%
2 August 1993	DM and Dutch guilder	±2.25% Band
	All other currencies	±15% Band
6 March 1995	Spanish peseta	−7%
	Portuguese escudo	−3.5%

Notes: +(−) = Nominal appreciation (depreciation) of the official parity.

As shown in Table 2.1, the first three realignments in the first phase of the ERM were driven by unilateral decisions by Germany, Denmark and Italy to realign their currencies. From October 1981 onwards, official realignments involved more than one currency. Typically, during this first phase, high inflation countries, like France and Italy, had to devalue their currencies to try to regain competitiveness against the strongest currencies of the EMS, like the DM and the Dutch guilder. The other currencies —the Belgian franc, the Danish krone and the Irish pound— depreciated in the early years and appreciated thereafter. The United Kingdom refused to join the ERM until October 1990; the Spanish peseta joined in June 1989 and the Portuguese escudo in April 1992.

The 'tranquil' period of the ERM, from February 1987 to August 1992, was characterised by only one realignment, that of the Italian lira when it entered the narrow band of $\pm 2.5\%$. The empirical evidence reported in Giavazzi and Giovannini (1989) shows that, during this second phase, the countries of the EMS achieved a greater degree of convergence in their inflation and interest rates, as well as fiscal balances and debt ratios. Moreover, the authors find that member countries were characterised by a lower variation in the real exchange rates and the money supply than non-EMS member countries.

Other positive institutional developments that occurred during this period were the elimination of all forms of restrictions to capital movements within the EEC; the creation of the European Monetary Institute (a precursor of the European Central Bank); and the abolishment in 1992 of all remaining restrictions on the movement of goods, services, capital and labour among member nations that led to the creation of a single European market.

Until September 1992, the EMS was largely regarded as a success, having promoted the convergence of the inflation rates of its member countries towards the low level of Germany and limited considerably the number of official realign-

ments. However the events of September 1992 highlighted a big inconsistency of the EMS system, i.e. the presence of fixed exchange rate regimes combined with perfect capital mobility and limited monetary policy coordination. The system worked well in the absence of external shocks, but did not survive an asymmetric demand shock that affected only some of its member countries.

In September 1992, the United Kingdom and Italy abandoned the ERM following strong speculative pressures on their currencies. In the presence of high unemployment and economic recession, the cost of maintaining a fixed exchange rate regime was too high. Britain and Italy thus opted for the 'escape clause' of abandoning the ERM.[11] This decision was followed by another four realignments that involved the Irish pound, the Spanish peseta and the Portuguese escudo.

After Britain and Italy, it was the turn of the French franc to withstand a speculative attack. The currency survived September 1992 thanks to massive bilateral interventions by the Banque de France and the Bundesbank. In August 1993, when the French franc was under renewed speculative pressures, the finance ministers of the EU agreed to abandon the narrow band and allow the fluctuation of their exchange rates within a 15% band on either side of the central parity. Only the Dutch guilder retained the narrow band vis-à-vis the Deutsche Mark. For all the other countries, the establishment of a 30 per cent wide band of fluctuation meant, *de facto*, the shift to a floating exchange rate system.

[11] For these reasons, the 1992 crisis has been interpreted as a typical example of 'second generation' currency crisis episode à la Obstfeld (1994).

2.5 *The Data*

Our dataset includes the countries within the Exchange Rate Mechanism of the European Monetary System in the period 1979-1995. These are: Belgium, Denmark, France, Germany, Ireland, Italy, the Netherlands, Portugal, Spain and the United Kingdom. The frequency of the data is annual due to difficulties in collecting observations on the debt composition and denomination at a higher frequency for all the countries within the ERM. The set of explanatory variables has been derived from the theory and encompasses monetary and debt variables, as well as an indicator of central bank independence to control for institutional differences among EMS countries.

The first subset of variables includes net foreign assets growth and domestic credit growth. These are key variables in the 'first generation' models of currency crises that relate speculative attacks to unsustainable economic fundamentals.[12] The idea is that countries experience balance-of-payments crises because of monetary and fiscal policies which are inconsistent with a fixed exchange rate regime. According to this view we should observe an acceleration in domestic credit creation and a slowdown in the rate of accumulation of foreign reserves in the period preceding an attack.[13]

We consider Germany as the 'core' of the system. We thus take the short-term interest rate differential with Germany as a proxy for the anticipated component of a devaluation. In order to test if the probability of a realignment was affected by Germany's reaction to the appreciation of the US dollar, we include the rate of depreciation of the Deutsche Mark (DM) versus the US dollar as an additional control variable.

[12] See Krugman (1979) and Flood and Garber (1984).

[13] For an empirical assessment of the role of fundamentals in generating speculative pressures on European currencies, see for example Eichengreen, Rose, and Wyplosz (1995) and Otker and Pazarbaşioğlu (1997).

The analysis in Chapter 1 suggested that the choice of a fixed exchange rate regime may depend on both the degree of independence of the central bank and the characteristics of debt instruments. Therefore, we add the legal index of central bank independence developed by Cukierman (1992) to control for institutional differences among EMS countries. The index refers to the 1980s and varies between zero (minimal central bank independence) and one (maximum central bank independence). Germany is classified near the top, with an index value of 0.69, whereas Belgium has the lowest value in our sample.[14]

We also consider a second group of regressors that includes public debt variables. These are the shares of debt by currency of denomination and term to maturity, the debt-to-GDP ratio, and the growth rate of the debt denominated in foreign currency. In fact, the issuance of foreign currency debt, besides its level, can be crucial to minimise roll-over costs and to signal the government intentions at the time of a crisis.[15] By including these variables in the estimation, we can directly test for the effects of debt management on the sustainability of a fixed exchange rate regime.

The main data sources are the International Financial Statistics (IFS) by the International Monetary Fund (IMF) for the monetary indicators; the OECD Economic Outlook for GDP and interest rate series; national sources for public debt data.[16]

[14] As showed in Chapter 1, the index of central bank independence by Cukierman exhibits the lowest correlation with the debt variables. We preferred this index to those of Alesina and Grilli-Masciandaro-Tabellini to avoid multicollinearity among the regressors.

[15] See Giavazzi and Pagano (1990).

[16] See Appendix A for the full list of variables' definitions and sources.

2.6 Estimation Methods and Results

This section reports the main results of our empirical investigation on the interaction between debt management and exchange rate policy. As mentioned in Section 2.5, we look at the experience of countries within the Exchange Rate Mechanism (ERM) of the European Monetary System (EMS) in the period 1979-1995. The focus is on the official realignments of the central parities listed in Table 2.1, and on other episodes of speculative pressure defined below.

The first step in our analysis is to examine how the choice of debt denomination and maturity affected the decision to realign the exchange rate within the ERM. Following the mainstream empirical literature on currency crises, we first estimate by maximum likelihood the probability of an official realignment within the ERM by using an ordinary binary probit model.[17]

The dependent variable, y_i, is discrete and takes the value of one in correspondence of an official realignment of the national currencies within the ERM, and zero when the currencies were under speculative pressure but resisted an attack.[18]

The *control episodes* of speculative pressure are identified by fixing a cut-off level of 1 per cent on the monthly change in the nominal exchange rate (measured in units of national currency per DM).[19]

[17] The choice of this estimation approach is motivated by two main considerations. First, the desire to obtain results that could be compared to those of existing empirical studies like Eichengreen, Rose, and Wyplosz (1996). Second, the small number of observations and the short time span of our sample, somewhat prohibited the use of more sophisticated panel data estimation techniques. For a discussion of the limitations of this approach, we refer the reader to Chapter 3 and Chapter 4 of this work.

[18] Depreciations resulting from an official realignment of the DM are however excluded.

[19] For countries that entered the ERM with a wider band of 6 per cent above and under the central parity, we applied a 1.5 per cent threshold.

This approach differs from Eichengreen, Rose, and Wyplosz (1996) who define episodes of speculative pressure on the basis of an Exchange Market Pressure (EMP) index constructed as a weighted average of the exchange rate depreciation, the variation in the stock of international reserves and the interest rate differential with Germany. As the interest rate differential and the change in foreign assets appear on the right hand side of our probit equation, we decided to use a cut-off measure rather than an EMP index to define our dependent variable.

We exclude from the control sample cases of speculative pressure recorded in the same year of an official realignment of the domestic currency, because they would represent unsuccessful defenses of the parity. Finally, consecutive violations of the threshold occurred in the same year are counted as a single episode. In this way, we identify a sample of 75 total observations, with 43 official realignments.

We model the conditional probability of an official realignment in country i, P_i, as the expectation of the crisis event, $y_i = 1$, conditional on a certain information set, Ω_i, which contains exogenous and predetermined explanatory variables:

$$P_i \equiv Pr(y_i = 1 \mid \Omega_i) = E(y_i \mid \Omega_i) \tag{2.13}$$

In binary probit models, like the one estimated here, this conditional probability is obtained by applying the cumulative standard normal distribution function, Φ, to a linear index function that depends on the explanatory variables, x_i, and the parameters to be estimated, β:

$$P_i \equiv E(y_i \mid \Omega_i) = \Phi(x_i'\beta) \tag{2.14}$$

This is because the realignments within the ERM can be thought as the observed outcome of an unobservable latent, variable y_i^*. Assume that:

$$y_i^* = x_i'\beta + u_i \tag{2.15}$$

where u_i is normally distributed. The latent variable, y_i^*, is not directly observable. What we observe is the binary variable, y_i, that in our model takes on the value of one if a realignment takes place and zero otherwise. The relationship between y_i and the latent variable, y_i^*, is modelled as follows:

$$y_i = \begin{cases} 0 & \text{if} \quad y_i^* \leq 0 \\ 1 & \text{if} \quad y_i^* > 0 \end{cases}$$

Since we observe whether a realignment has taken place or not, we ultimately observe only the sign of y_i^*. We can thus normalise the variance of u_i to be unity.

It follows, that the probability of an official realignment, i.e. $y_i = 1$, is:

$$\begin{aligned} Prob(y_i = 1) &= Prob(y_i^* > 0) \\ &= Prob(x_i'\beta + u_i) > 0 \\ &= 1 - Prob(u_i \leq -x_i'\beta) \\ &= 1 - \Phi(-x_i'\beta) = \Phi(x_i'\beta) \end{aligned}$$

The likelihood function associated with this problem can be defined as the joint probability of observing a sequence of realignments and episodes of speculative pressure. Assuming that the y_i are independent and distributed according to the standard normal distribution function, the joint density is simply the product of the individual probabilities for each observation.

The likelihood function can be defined as follows:

$$L = Prob(Y_1 = y_1, Y_2 = y_2, \cdots, Y_n = y_n) = \prod_{y_i=0} [1 - \Phi(x_i'\beta)] \prod_{y_i=1} [\Phi(x_i'\beta)]$$

that can be written as

$$L = \prod_{i=1}^{n} [\Phi(x_i'\beta)]^{y_i} [1 - \Phi(x_i'\beta)]^{1-y_i} \tag{2.16}$$

The maximum likelihood estimation results are presented in Table 2.2. Since probit coefficients are not immediately interpretable, we report the effects of a unitary change in the regressors on the probability of a realignment (measured in percentage points), evaluated at the mean of the data. We also indicate, in parenthesis, the associated z-statistics that test the null hypothesis of no effect, and the χ^2 statistic which tests for the joint significance of the regressors.

All the regressors are lagged one period to avoid endogeneity problems.

As shown in column 1 of Table 2.2, both the growth of net foreign assets and the growth of domestic credit have a strong impact on the likelihood of a crisis and are significant at the 5 per cent level. This finding is in line with the predictions of the first generation models of currency crises, which focus on misalignments in fundamentals to explain speculative attacks. The interest rate differential with Germany is instead not significant, though its coefficient is positive as expected. Interestingly, the likelihood of a realignment within the ERM increases when the DM was under pressure: the coefficient of the rate of depreciation of the DM with respect to the US dollar is positive and strongly significant.[20]

Focusing on the debt variables, we find a strong and significant effect of the growth rate of foreign currency debt. An increase of such debt significantly reduces the probability of a devaluation. The impact of the debt-to-GDP ratio and of the share of foreign currency debt is also as expected, though not significant; a higher debt ratio increases the likelihood of a devaluation while a higher share of foreign currency debt reduces it.

[20] Most of the official realignments are concentrated in the first phase of the EMS, which was characterised by a strong appreciation of the US dollar. At the same time the Bundesbank was tightening monetary policy, thus undermining the exchange rate stability of the periphery countries.

Tab. 2.2: Probit Estimates

Explanatory Variables	(1)	(2)	(3)	(4)
Net foreign assets growth	−0.954**	−0.960**	−0.960**	−0.695**
	(−3.18)	(−3.19)	(−3.19)	(−2.55)
Domestic credit growth	2.694**	2.751**	2.895**	0.618
	(2.01)	(2.04)	(2.20)	(0.53)
Short-term interest rate differential	0.038	0.040	0.078**	0.058*
	(1.21)	(1.29)	(2.23)	(1.74)
Depreciation of the DM against the US$	1.771**	1.773**	1.774**	0.988*
	(3.18)	(3.19)	(3.13)	(1.83)
Cukierman index of CB independence	−0.174	−0.096	−2.314**	−1.164
	(−0.20)	(−0.11)	(−1.96)	(−1.15)
Public Debt to GDP ratio	0.215	0.244	0.284	0.181
	(−2.74)	(−2.57)	(−1.37)	(−1.47)
Foreign currency debt growth	−0.853**	−0.848**	−1.135**	−0.718**
	(−2.46)	(−2.45)	(−2.98)	(−2.08)
Foreign currency debt share	−0.240	−0.354		
	(−0.30)	(−0.45)		
Long-term fixed rate debt share			1.091**	0.724*
			(2.15)	(1.69)
Number of observations	72	72	72	61
Pseudo R^2	0.22	0.22	0.27	0.23
Ho: Slopes=0 $\chi^2(8)$	22.04	22.15	26.96	17.46
P-value	0.00	0.00	0.00	0.02

Notes: The table reports estimated probit derivatives, which measure the effect of a unitary change of each regressor on the probability of observing an official realignment. Associated z-statistics are reported in parenthesis.

The dependent variable takes the value of 1 in correspondence of an official realignment within the ERM, zero in cases of speculative pressure on the currency not followed by an official realignment. The foreign currency share in column (2) includes indexed debt. Column (4) is estimated over a restricted control sample that excludes episodes of speculative pressure contemporaneous to an official realignment of the DM.

* = 10% significance level. ** = 5% significance level.

As shown in column 2, the estimation results are invariant to the addition (for the United Kingdom) of price-indexed debt to foreign currency debt in order to determine the share of debt which is not affected by inflation. Again, such a share is not significant but an increase in the rate of growth of foreign and indexed debt has the effect of reducing the probability of a realignment.

So far, the evidence on the role of debt variables is mixed, with little effect arising from the currency composition of the debt whereas an important role is played by foreign currency financing in the period preceding a crisis. These findings may reflect the fact that actual inflation incentives depend on the maturity of conventional debt, in addition to the currency denomination. As discussed in Chapter 1, debt duration is the relevant concept for the effect of inflation on the real value of the debt. This consideration suggests to look at the share of fixed-rate long-term debt denominated in the domestic currency.

The third column of Table 2.2 reports estimation results when the share of long-term conventional debt replaces the share of foreign currency debt. The effect of long-term debt on the probability of a devaluation is positive and significant at the 5 per cent level. This finding is consistent with the predictions of the model in Section 2.3. Countries with a lower share of long-term conventional debt, and accordingly with a lower inflation-tax base, are characterised by a lower probability of realignment of the official parity.

The last result is reinforced by the fact that a greater reliance on foreign currency financing has the effect of reducing the probability of a crisis. Indeed, the coefficient on the rate of growth of the foreign currency debt is still significant at the 5 per cent level.

Interestingly, the substitution of long-term conventional debt for foreign currency debt results in a better specification of the probit. In particular, the coefficient

of the interest rate differential with Germany becomes significant as well as the coefficient of the Cukierman index. The probability of resisting a speculative attack increases with central bank independence. It is worth noting that these empirical findings are robust to the model specification and persist even if we correct the gross figures from the effect of exchange rate depreciation.[21]

Finally, the last column of Table 2.2 reports the estimates of the specification with long-term conventional debt based on a restricted control sample that does not include episodes of speculative pressures which were contemporaneous to realignments of the DM. Clearly, the results do not depend on the specification of the control observations. The share of fixed-rate long-term debt in domestic currency and the increase in the foreign currency denominated debt are still significant at the 10 and 5 per cent level, respectively. The likelihood of an official realignment within the ERM is greater, the larger the interest rate differential with Germany, the weaker the DM and the lower the rate of growth of net foreign assets.

The somewhat weak results of the probit estimations in terms of R^2 may be the consequence of omitted variables. We explored different specifications of the probit model. However, the results do not change substantially when the following variables are considered: (i) the standardised unemployment rate in levels or differences to the average of OECD countries; (ii) the structural primary surplus, to capture the ability of governments to generate future fiscal revenues; (iii) lagged inflation or its differential with Germany; (iv) the change in the fixed-rate long-term debt instead of foreign currency debt.

[21] We ran the same probit regression with the growth of the debt denominated in foreign currency net of the change of the nominal exchange rate with respect to the DM, in order to get a measure of the effective increase (decrease) of the debt. The results did not differ significantly from those reported here.

In brief, according to this first set of results, the decision to issue foreign currency debt by EMS countries seems to have reduced the probability of a devaluation of the official parity, while a higher share of long-term, conventional debt appears to have increased it.

So far, we estimated the probability of an official realignment within the ERM by using a binary probit model, where the alternative to an official realignment of the currency ($y_t = 1$) are episodes of successful defense of the central parity, i.e. cases of speculative pressure that have not been followed by an official realignment ($y_t = 0$). By doing so, we excluded from the estimated sample all the *tranquil periods*, in which the ERM currencies were not under speculative pressure. If the determinants of the choice between attacking or not a currency, in the expectations of an official realignment, are correlated with the set of determinants of the decision to realign the central parity once the currency is under pressure, then the estimates of the binary probit model presented in Table 2.2 would be biased.

To avoid this risk, we can model the official realignments within the ERM as the worse outcome of a sequence of ordered events that would also include tranquil periods and unsuccessful speculative attacks, i.e. cases of speculative pressure on the currency not followed by an official realignment.

A common way or dealing with ordered response data is to use an ordered probit model, which is built around a latent regression in the same manner as the binomial probit model estimated before. Let

$$c_i^* = x_i'\beta + \epsilon_i \tag{2.17}$$

be a latent dependent variable. What we would observe is a discrete variable c_i that can take on only three values:

$$c_i = \begin{cases} 0 & \text{if } c_i^* < \gamma_1 \\ 1 & \text{if } \gamma_1 \leq c_i^* < \gamma_2 \\ 2 & \text{if } \gamma_2 \leq c_i^* \end{cases}$$

The parameters to be estimated are β and $\gamma \equiv [\gamma_1, \gamma_2]$. The γ_i's are thresholds that determine what value of c_i a given value of c_t^* will map into. Assuming that ϵ is normally distributed across observations, with zero mean and variance equal to one, the probability that $c_i = 0$, i.e. a tranquil period is observed, is equal to:

$$\begin{aligned} Prob(c_i = 0) &= Prob(c_i^* < \gamma_1) \\ &= Prob(x_i'\beta + \epsilon_i < \gamma_1) \\ &= Prob(\epsilon_i < \gamma_1 - x_i'\beta) \\ &= \Phi(\gamma_1 - x_i'\beta) \end{aligned}$$

Similarly, the probability that $c_i = 1$, or a currency is under pressure, is equal to:

$$\begin{aligned} Prob(c_i = 1) &= Prob(\gamma_1 < c_i^* < \gamma_2) \\ &= Prob(\epsilon_i < \gamma_2 - x_i'\beta) - Prob(\epsilon_i < \gamma_1 - x_i'\beta) \\ &= \Phi(\gamma_2 - x_i'\beta) - \Phi(\gamma_1 - x_i'\beta) \end{aligned}$$

and the probability that $c_i = 2$, or an official realignment takes place, is equal to:

$$\begin{aligned} Prob(c_i = 2) &= Prob(c_i^* \geq \gamma_2) \\ &= Prob(x_i'\beta + \epsilon_i \geq \gamma_2) \\ &= Prob(\epsilon_i \geq \gamma_2 - x_i'\beta) \\ &= \Phi(x_i'\beta - \gamma_2) \end{aligned}$$

The log-likelihood function associated with this ordered probit model is thus:

$$\begin{aligned} l(\beta, \gamma_1, \gamma_2) &= \sum_{c_i=0} log(\Phi(\gamma_1 - x_i'\beta)) \\ &+ \sum_{c_i=1} log(\Phi(\gamma_2 - x_i'\beta) - \Phi(\gamma_1 - x_i'\beta)) \\ &+ \sum_{c_i=2} log(\Phi(x_i'\beta - \gamma_2)) \end{aligned}$$

The results of the estimation of the ordered probit model defined above are presented in Table 2.3. As for the binomial probit model, we report the marginal effects of each of the regressors on the probability of an official realignment within the ERM, i.e. the probability that $c_i = 2$. We also indicate the associated z-statistics (in parenthesis), which test the null hypothesis of no effect, and the χ^2 statistic which tests for the joint significance of the regressors.

As it can be seen in Table 2.3, the best model specifications are those in columns 3 and 4, where the share of long-term fixed-rate debt in domestic currency is substituted for the share of foreign currency or indexed debt. As in the binary probit estimations, an increase in the debt stock denominated in foreign currency reduces the probability of an official realignment within the ERM. However, the latter increases with the stock of debt that is denominated in domestic currency.

According to this new set of estimates, monetary variables seem to play a minor role in determining the likelihood of a realignment of the central parities. The interest rate differential with Germany is instead strongly significant at the 5 per cent confidence level. This variable clearly reflects expectations of a realignment.

Overall, the only robust result that emerges from the estimation of both the binary and ordered probit models is that debt management and, in particular, the choice of the currency denomination of public debt, seems to have played an important role in averting realignments within the ERM. The effect of other macroeconomic fundamentals is less robust to the model specification.

The next step of our empirical investigation is to look at the effects of debt management conditionally on the occurrence of a crisis. To this end, we restrict the sample to the episodes of official realignment and focus on the cumulative devaluation — per year and country — of the official parity with respect to the ECU, (PAR), and on its determinants.

Tab. 2.3: Ordered Probit Estimates

Explanatory Variables	(1)	(2)	(3)	(4)
Net foreign assets growth	−0.032	−0.033	−0.035	−0.718
	(−0.40)	(−0.41)	(−0.52)	(−0.94)
Domestic credit growth	0.803	0.801	0.792	1.302*
	(1.25)	(1.25)	(1.47)	(1.92)
Short-term interest rate differential	0.061**	0.061**	0.063**	0.058**
	(3.14)	(3.18)	(4.27)	(3.64)
Depreciation of the DM against the US$	0.175	0.174	0.123	0.566
	(0.52)	(0.51)	(0.44)	(1.62)
Cukierman index of CB independence	−0.182	−0.190	−0.539	−0.610
	(−0.30)	(−0.32)	(−1.30)	(−1.30)
Public Debt to GDP ratio	−0.137	−0.141	−0.125	−0.068
	(−0.57)	(−0.61)	(−0.91)	(−0.46)
Foreign currency debt growth	−0.205	−0.206	−0.216*	−0.384**
	(−1.53)	(−1.53)	(−1.67)	(−2.00)
Foreign currency debt share	−0.139	−0.129		
	(−0.26)	(−0.25)		
Long-term fixed rate debt share			0.275*	0.268
			(1.67)	(1.34)
Number of observations	106	106	106	106
Pseudo R^2	0.09	0.09	0.09	0.09
Ho: Slopes=0 $\chi^2(8)$	20.52	20.59	22.03	19.83
P-value	0.01	0.01	0.00	0.01

Notes: We report estimated ordered probit derivatives, which measure the effect of a unitary change of each regressor on the probability of observing an official realignment. Associated z-statistics reported in parenthesis.

The dependent variable takes on the value of 0 in correspondence of tranquil periods, 1 in instances of speculative pressure on the currency, and 2 in correspondence of an official realignment within the ERM. The foreign currency share in column (2) includes indexed debt. Column (4) is estimated over a restricted control sample that excludes episodes of speculative pressure contemporaneous to an official realignment of the DM.

$*$ = 10% significance level. $**$ = 5% significance level.

We first look at some descriptive statistics, by dividing the sample of official realignments according to the size of the nominal devaluation of the official parity with respect to the ECU. Values of PAR higher than the sample average (0.04) characterise the observations in the *Large* devaluations sub-sample, while cumulative devaluations below the sample mean are included in the *Small* devaluations sub-sample.

Table 2.4 reports the simple averages of the key macroeconomic fundamentals and explanatory variables in our probit model, computed over these two sub-samples of observations. As it can be seen, big realignments of the official parity within the ERM are characterised by a higher ratio of debt denominated in foreign currency over GDP and a faster rate of growth of the same debt component. Moreover, the *Large* devaluations sub-sample stands out for having larger interest rate differentials with Germany and faster money growth. These results are in line with the findings of Eichengreen, Rose, and Wyplosz (1996).

Table 2.4 also shows the stabilising effect of the share of public debt that is denominated in domestic currency. *Small* devaluation events are characterised by a comparatively higher share of debt denominated in domestic currency and more independent central banks, as shown by the higher average of the Cukierman index.

To be able to draw some conclusions on the real determinants of the size of the exchange rate adjustments we must supplement this qualitative characterisation of the episodes of realignment within the ERM with the result obtained using multivariate analysis. The simple averages presented in Table 2.4 are indicative of a potential relationship between episodes of *Large* devaluations and some of the explanatory variables in our dataset. What remains to be checked is if these relationships still hold true once we simultaneously control for other potential determinants of PAR. In order to do so, we have to revert to regression analysis.

Tab. 2.4: Cumulative Devaluations and Fundamentals.

Explanatory Variables	*Large*	*Small*
Net foreign assets growth	0.05	0.00
Domestic credit growth	0.13	0.11
Short-term interest rate differential	6.46	3.65
Cukierman index	0.29	0.33
Foreign currency debt growth	0.21	0.07
Foreign currency debt share	10.6	9.86
Long-term fixed-rate debt	32.23	57.09
Number of observations	24	33

Notes: Simple averages of the key explanatory variables.

The *Large* sub-sample contains all the realignment observations characterised by a cumulative yearly percentage devaluation of the central parity with respect to the ECU larger than the sample average (0.04). The *Small* sub-sample contains all the realignment observations characterised by a cumulative yearly percentage devaluation of the central parity with respect to the ECU smaller than the sample average

Table 2.5 presents the results of simple OLS regressions. The dependent variable is the cumulative devaluation of the official parity, PAR, which is regressed on a constant and the two sets of monetary and debt indicators used before. All the regressors are lagged one period.

The estimates of the benchmark regression are presented in column 1. According to our results, countries with more expansionary monetary policies and less independent central banks experienced larger devaluations. The coefficients on domestic credit growth and the Cukierman's index of legal central bank independence are both significant at the 10 and 5 per cent, respectively.

More interestingly, the currency denomination of public debt has a significant effect on the size of the devaluation. The coefficient of the share of foreign currency debt is indeed positive and significant at the 5 per cent level. This implies that, conditional on a realignment taking place, the EMS countries with a higher share of foreign denominated debt experienced larger devaluations of their parities with respect to the ECU.

This last result seems to support the theoretical argument that expected and actual inflation (depreciation) may be higher when the authorities are forced to devalue and foreign denominated debt has been issued. A positive growth of foreign currency debt, though not significant, tends to reinforce the effect of a high share of such debt.

The debt-to-GDP ratio is also significant and the estimated coefficient is negative. This somehow counterintuitive result is not completely at odds with the theory because, for a given composition of debt instruments and financial needs, countries with a higher debt ratio, and therefore a larger tax base, ex-post need to devalue less.

Tab. 2.5: Cumulative Devaluations: OLS Estimates

Explanatory Variables	(1)	(2)	(3)	(4)
Net foreign assets growth	−0.32	−0.50	0.04	0.38
	(−0.11)	(−0.17)	(0.01)	(0.17)
Domestic credit growth	28.77*	29.03*	18.36	8.37
	(1.98)	(1.96)	(1.25)	(0.84)
Short-term interest rate differential	−1.05	2.67	−5.81	−0.26
	(−0.04)	(0.10)	(−0.19)	(−0.01)
Depreciation of the DM against the US$	−4.71	−4.87	−4.50	2.41
	(−1.00)	(−1.03)	(−0.94)	(0.73)
Cukierman index of CB independence	−23.29**	−22.32**	3.55	−5.84
	(−3.14)	(−2.99)	(0.36)	(0.76)
Public Debt to GDP ratio	−8.82**	−8.24**	−3.20	−2.61
	(−2.74)	(−2.57)	(−1.37)	(−1.47)
Foreign currency debt growth	2.81	2.82	5.41*	3.87**
	(1.07)	(1.06)	(1.91)	(2.21)
Foreign currency debt share	16.55**	15.05**		
	(2.48)	(2.29)		
Long-term fixed rate debt share			−9.34**	−8.37**
			(−2.22)	(−2.65)
Constant	8.47**	7.78**	4.44	6.58**
	(2.37)	(2.20)	(1.50)	(2.91)
Number of observations	40	40	40	54
Pseudo R^2	0.35	0.34	0.33	0.26
Ho: coefficients=0	$F(8,31) = 3.68$	$F(8,31) = 3.49$	$F(8,31) = 3.42$	$F(8,45) = 3.39$
P-value	0.00	0.00	0.00	0.00

Notes: OLS estimated coefficients and associated t-statistics in parenthesis. The dependent variable is PAR, the total percentage devaluation of the central parity with respect to the ECU. * = 10% significance level. ** = 5% significance level.

In column 3 of Table 2.5, we substitute once again the share of fixed-rate long-term debt denominated in domestic currency for the share of foreign currency debt. Consistently with the previous result, the share of long-term debt has a stabilising effect, since it significantly reduces the size of the realignment. Interestingly the growth rate of foreign debt becomes significant in this case, though at the 10 per cent level.

Finally, we take more explicitly into account the role of Germany as the EMS center. Column 4 of Table 2.5 reports the estimated coefficients of the same model in column 2, but estimated with a new dependent variable, which counts a contemporaneous revaluation of the DM as a further devaluation of the national currency. The consideration of DM revaluations as devaluations for the other currencies is because the size of the realignment of the national currency could have been larger, had the DM not realigned.

The results strongly suggest that the debt composition variables are the main determinants of the ex-post devaluation size. This evidence clearly supports the theoretical predictions of Section 2.3: within the ERM, countries with the largest shares of foreign currency denominated debt were forced to devalue more.

The final step in our analysis is to compute the effect of an increase in foreign currency denominated debt on the *ex-ante*, or unconditional, devaluation expectations. In our framework, we can interpret the fitted values of the binary probit model as the probability of a change in the official parity, given the existence of speculative pressures on the currencies within the ERM. This probability is estimated as follows:

$$f(x) = \Pr(y = 1) = f(\textit{monetary, debt variables}) \tag{2.18}$$

Correspondingly, through the OLS regression we estimated the size of the devaluation conditional on the occurrence of a realignment:

$$g(y \mid x) = g(monetary,\ debt\ variables) \tag{2.19}$$

It follows that the unconditional expected devaluation, $h(y)$, is simply the product of (2.18) times (2.19). The sign of the total derivative with respect to the change in foreign currency denominated debt is informative about the relative impact of the two opposite effects we found, namely a negative effect on the probability of a crisis and a positive effect on the ex-post devaluation. The total derivative of the ex-ante devaluation expectations is negative and equal to (-0.02), suggesting a positive role for debt denominated in foreign currency. Therefore, the decision to increase its share seems to have reduced the ex-ante expectations of devaluation within the ERM.

2.7 Conclusions

This chapter has shown that if the central bank is not independent, or has not enough of a reputation for being tough with inflation, the issuance of debt denominated in foreign currency or with a short maturity may enhance the credibility of the anti-inflationary policy. In this case, a fixed exchange regime makes the zero-inflation commitment more visible and enhances the credibility of monetary policy by increasing the cost of inflation. Under such regime, foreign currency debt reinforces the commitment to the fixed parity and helps to maintain low inflation expectations, possibly preventing the emergence of a currency crisis.

Despite these effects, debt managers prefer to limit the use of foreign currency debt and at times even the market appears to react negatively to the issuance of such debt. This may happen because a devaluation can never be ruled out and foreign currency debt would exacerbate the effects of a crisis if it ever occurred.

In this chapter, we formalised this well-known argument by using a very simple model those conclusions are supported by evidence from the EMS. Probit estimates show that the decision to issue foreign currency debt significantly reduced the likelihood of an official realignment within the ERM, after controlling for changes in foreign exchange reserves and other macroeconomic fundamentals. However, conditional on a crisis taking place, those countries with higher shares of foreign currency debt experienced more severe devaluations.

Appendix A

Tab. 2.6: Data Sources and Definitions

Variable Name	Source and Definition	Frequency
Net foreign assets growth	International Monetary Fund (IMF) - International Financial Statistics (IFS). Difference between Foreign Assets and Liabilities of the Monetary Authorities. IFS lines (11-16c). Growth rates.	Annual.
Domestic credit growth	IMF - International Financial Statistics (IFS line 32). It includes Claims on central government and on the private sector. Growth rate.	Annual.
Short-term interest rate differential	OECD. 3-months interbank rates. Difference between the domestic series and the corresponding German rate.	Annual.
Exchange rate series	IMF. End-of-period nominal official exchange rate (IFS line ae). Growth rates of the series converted into units of national currency (n.c.) per DM	Monthly.
Debt to GDP ratio	Public debt data are from National Sources as published in Missale (1999). Usually they refer to Central Government debt but the rule is amended in a few cases when data on debt composition were available only for the General Government. GDP data are from the OECD. Ratios.	Annual.
Foreign currency debt	Foreign currency debt is defined as the sum of bonds and loans denominated in foreign currency and debt bearing coupons indexed to the ECU.	Annual.
Long-term fixed rate debt	Sum of fixed-rate bonds and loans denominated in domestic currency with an initial term to maturity longer than one year. Extendible bonds and bonds with an option for early redemption (such as those issued in Belgium and Italy) have been considered as long-term debt if the period preceding the earliest possible maturity is longer than one year.	Annual.

3. BANKING CRISES IN DEVELOPING AND EMERGING MARKETS: THE ROLE OF DEBT AND EXCHANGE RATE FRAGILITY

3.1 Introduction

In this chapter, we extend our analysis of the causes of financial sector fragility to consider instances of systemic banking failures.

The severe episodes of currency and banking crises experienced by emerging markets over the past decade have stimulated quite a large number of theoretical and empirical work to explain and predict financial crises.[1]

Although the empirical literature has mainly focused on currency crises, a parallel stream of studies about the origins of banking crises has also flourished, following the pioneering work by Demirgüç-Kunt and Detragiache (1998a) and Kaminsky and Reinhart (1999) on leading indicators of banking crises.

The empirical analysis presented in this chapter fits into this second strand of literature. We investigate the causes of banking crises in a large panel dataset including developing and emerging markets from the early 1970s to 1997. We would focus on three main issues.

[1] See Nouriel Roubini's Global Macroeconomic and Financial Policy Site at http://www.stern.nyu.edu/globalmacro/ for an up-to-date list of research papers and other contributions about the causes of financial crises.

First, in line with the previous chapters of this thesis, we would devote particular attention to the role of external debt indicators —public and private— as potential determinants of banking crises. By doing so, we would fill a gap in the financial crises literature because relatively few empirical studies have focused on the fiscal aspects of financial crises.[2] This is despite the fact that the Mexican crisis in 1994 and the more recent crises in Argentina (2001) and Turkey (2002) have shown that a financial crash can be precipitated by fiscal problems and aggravated by excessive short-term external debt and domestic liabilities denominated in foreign currency.

Second, we would examine the causal link between currency and banking crises and test whether currency crises —defined as instances of sharp devaluations of the domestic currency— lead banking crises once we control for the simultaneous effect of other variables.

Third, we would look at the dynamics of banking crises to take into account the intertemporal links between past and current episodes of banking crisis. While cross-sectional variation in countries' characteristics can provide important insights on the determinants of the probability of a banking crisis, the time dimension can help us understand the dynamics leading, accompanying and following a crisis event. This consideration motivates our choice to use panel data analysis and model banking crises in a dynamic framework, where we allow for country-specific heterogeneity and temporal serial correlation in the unobservables.

Formally, we estimate the probability of a banking crisis by applying the method of maximum smoothly simulated likelihood (MSSL) to a dynamic probit model with unobserved heterogeneity and autocorrelated errors.[3] The main advantage

[2] One exception is the recent paper by Hemmig, Kell, and Schimmelpfennig (2003) that focuses on the relationship between fiscal vulnerability and financial crises.

[3] Simulation-based estimation methods are reviewed in the methodological chapter that concludes this thesis.

of this approach is that it would allow us to test directly for the existence of *state dependence*, i.e. past episodes of banking crisis affecting the probability of future banking crises. This estimation approach is new in the empirical literature on the causes of banking crises and represents one of the key original contributions of this thesis.

The rest of this chapter is organised as follows. Section 3.2 reviews the empirical literature on the causes of banking crises, while Section 3.3 highlights the main points of departure of our study from the existing literature. Section 3.4 describes the dataset, by providing the definition of banking and currency crises and defining the set of explanatory variables used in the estimation. Section 3.5 explains the empirical methodology. The main results are presented in Section 3.6. Finally, Section 3.7 concludes.

3.2 Review of the Empirical Literature

We can classify the existing empirical studies on banking crises into two main groups, according to the empirical methodology used. Earlier studies have adopted a leading indicators approach, that consists in identifying variables that display an anomalous behaviour at the onset of a banking crisis and thus can be periodically monitored to anticipate future events. The papers by Goldstein (1998), Kaminsky (1998), Rojas-Suárez (1998), Kaminsky and Reinhart (1999), and Goldstein, Kaminsky, and Reinhart (2000) fall into this first category of studies.

A different approach is the one adopted by Demirgüç-Kunt and Detragiache (1998a), Eichengreen and Rose (1998), Hardy and Pazarbaşioğlu (1999), and Eichengreen and Arteta (2000), among others, who use limited dependent variable models to estimate the probability of occurrence of banking crises. Our study follows this second empirical strategy but with important distinctions. In what follows we would critically review these two strands of literature and highlight the main differences with our approach.

3.2.1 Leading Indicators Analysis

In their seminal paper, Kaminsky and Reinhart (1999) use leading indicator analysis to identify a set of early warning indicators of banking sector problems. Their original sample includes 20 industrial and developing countries from 1970 to mid-1995.[4] They identify a total of 26 banking crises and 76 currency crises and also define episodes of '*twin crises*', as banking crises followed by a balance-of-payments crisis within a period of 4 years. They study the distribution of crises over time and compare unconditional probabilities of crises to the probability of observing a banking (currency) crisis conditional on the previous occurrence of a currency (banking) crisis.

The evidence presented by Kaminsky and Reinhart (1999) does not reveal a clear link between banking and balance-of-payments crises during the 1970s, whereas most often banking sector problems precede currency crises in the following decade. The conditional probability of observing a currency crisis after the occurrence of a banking crisis is indeed higher in their sample than the simple unconditional probability of currency crises. However, the authors also find that the peak of a banking crisis generally follows the collapse of the currency, pointing to the existence of a two-way causality between banking and currency crises.

The next step in their analysis is to make use of a non-parametric approach to verify countries' vulnerabilities to specific macroeconomic indicators. This technique entails, first, selecting a set of variables that may potentially lead banking crises and, second, deciding upon a rule that classifies the behaviour of a specific indicator as sending either a signal of an impending crisis or of a tranquil period. The underlying hypothesis is that the economy shows a different behaviour before the occurrence of a crisis and this is reflected by some leading indicators.

[4] Enlarged to 25 small open economies in Goldstein, Kaminsky, and Reinhart (2000).

The main findings of the signal approach used by Kaminsky and Reinhart (1999) confirm that currency and banking crises share some common patterns. The period preceding a banking crisis is indeed characterised by slow output growth, high interest rates and an overvalued exchange rate that undermines the export capacity of a country. The M2 multiplier and the growth of domestic credit over GDP are among the best leading indicators.

One of the advantages of this methodology lies in its simplicity, and the fact that it does not impose *a priori* any structure on the data. Indeed, there are no structural forms to be estimated here but only behavioural patterns of indicators to be plotted around the time of a crisis. An obvious drawback of this method is its univariate nature that can neither discriminate between more or less reliable indicators nor consider their joint contribution to the occurrence of a crisis.

Kaminsky (1998) partially addresses this problem by combining leading indicators into a single index. This composite index is constructed by summing up the signals of individual indicators and weighting them according to their reliability, measured by the noise-to-signal ratio.[5]

This approach is useful to predict the likelihood that a country will experience a crisis, but it does not overcome another limitation of the leading indicators analysis, i.e. its scarce informative content over what causes and drives financial crises. Little can be said about how each single indicator affects the probability of observing a crisis in the immediate future. This issue motivated a second strand of empirical literature that focuses on the determinants of financial crises rather than simply aiming at detecting the incumbent ones.

[5] This is defined as the ratio of the proportion of bad signals to the share of good signals.

3.2.2 Multivariate Analysis

An increasing number of papers has made use of logit or probit analysis to estimate the probability of banking crises. This approach has the major advantage of evaluating simultaneously the contribution of the various macroeconomic indicators examined above.

Demirgüç-Kunt and Detragiache (1998a) analyse the determinants of banking crises by estimating a logit model using annual data over the period 1980–94. Their sample includes both, developing and developed economies, up to a maximum of 65 countries.[6]

The authors identify episodes of 'systemic' banking crises by imposing restrictive conditions on the ratio of non-performing assets over total assets of the banking system and by measuring the cost of rescue operations in terms of GDP loss.[7] In this way they restrict the sample of banking crises to 31 episodes out of 546 observations.

They find that the probability of a banking crisis increases in a weak macroeconomic environment, characterised by slow GDP growth, high inflation and high real interest rates. There is weak evidence that terms-of-trade shocks or credit booms can significantly influence the likelihood of a banking crisis.[8] Fiscal deficits and the rate of depreciation of the currency are not significant either. Debt variables are not included in their specification.

In a series of companion papers (Demirgüç-Kunt and Detragiache (1998b) and

[6] However, they do not include transition economies or some of the most troubled Latin American countries, like Argentina, Brazil and Bolivia.

[7] When these two measures were not available, they looked at episodes of bank runs or large scale nationalisation.

[8] They include the share of credit to the private sector and the lagged rate of growth of domestic credit.

(2000)), the same authors find that financial liberalisation increases the probability of a banking crisis, especially where the institutional environment is weak. Furthermore, countries with explicit deposit insurance tend to be more vulnerable to capital reversals, real interest rates increases, and exchange rate depreciations.

Rossi (1999) extends these results by controlling for other institutional characteristics that may increase financial fragility. By focusing on a smaller sample of 15 countries, he finds that the probability of a banking crisis in developing countries is associated with low GDP growth and fast bank expansion in a weakly regulated system where supervision is low, capital outflows are restricted, and deposits safety nets are in place.

It is worth noting that all the previous studies use mostly contemporaneous regressors to explain the occurrence of banking crises.[9] Their results are thus likely to suffer from endogeneity problems because the direction of causality between crises and regressors is not always unambiguous. Indeed, it may well be that a change in one of the explanatory variables is the result of a crisis and not one of its precipitating causes.

Hardy and Pazarbaşioğlu (1999) address this issue by using a more general specification that includes lagged regressors up to two periods. Their annual dataset covers the period 1976–97 and includes a total of 50 OECD and developing countries. Following the classification in Lindgren, García, and Saal (1996), they identify a total of 43 episodes of banking sector distress. Similarly to Demirgüç-Kunt and Detragiache (1998a), they estimate a multinomial logit model by maximum likelihood, but adopt a different specification of the dependent variable.[10]

[9] In fact, domestic credit growth is the only variable that enters the regressions of Demirgüç-Kunt and Detragiache (1998a) with a two years lag.

[10] In order to distinguish between a crisis and its antecedents, they define a dummy that can take on three values: 2 when a banking crises surfaces, 1 in the preceding period, and 0 otherwise.

Their findings suggest that banking crises tend to be associated with a large contemporaneous fall in GDP; a pattern of boom and bust cycles in inflation and an expansion of credit to the private sector; raising interest rates; and depreciating real exchange rates.[11] Some of these effects are magnified when regional dummies are included.

A critique that can be addressed to this approach is that the authors forecast the most recent crises in emerging markets by using the coefficients of the model estimated over a mix of developing and industrialised countries. There are reasons to believe that the same macroeconomic and financial indicators have a different impact on the probability of observing a banking crisis, depending on the degree of development and regulation of financial markets.

On these grounds Eichengreen and Rose (1998) have collected an annual dataset of 105 developing and emerging market economies from 1975 to 1992. The authors estimate a static probit model by pooling all the observations together and using contemporaneous domestic and external macroeconomic indicators as explanatory variables. Their results show a strong effect of adverse external conditions on the probability of observing a banking crisis, in particular high interest rates and low output growth in the United States.

Contrary to the previous studies, Eichengreen and Rose include debt indicators in the set of explanatory variables. They find that the share of short-term external debt is one of the few significant predictors of a crisis, but it turns up with an unexpected negative sign that contradicts the theoretical conclusions of Sachs, Tornell, and Velasco (1996). Unfortunately, none of the financial structure variables is significant when added to the baseline specification, nor is the exchange rate regime dummy.[12]

[11] Note that a real appreciation is observed in the pre-crisis period.

[12] Mendis (1998) finds instead that in small open economies with flexible exchange rate

In a subsequent paper, Eichengreen and Arteta (2000) estimate probit regressions of banking crises probabilities using a sample of 75 developing countries from 1975 up to 1997. They find that domestic credit booms and large bank liabilities relative to reserves are strongly associated with banking crises. They attribute the perverse negative sign on the budget deficit variable to the likely correlation with the external debt over GNP and the current account variables. For this reason, they eliminate the fiscal variables from the baseline specification.

When looking at the effect of global variables, especially international interest rates, the authors find a weaker effect than Eichengreen and Rose (1998). Given the longer time interval covered, they interpret this finding as evidence of a change in the nature of banking crises of the late nineties. Institutional variables, like financial liberalisation, the type of exchange rate regime and the existence of deposit insurance, play a smaller role.

In summary, according to Eichengreen and Rose, external forces seem to have driven financial sector problems in developing countries up to the early nineties.[13] Their findings contrast with those of other studies that are more in favor of adverse domestic macroeconomic conditions and lending booms, showing that there is little consensus over the actual determinants of banking crises.

3.3 This Study

The work presented in this chapter extends the existing empirical literature on the origins of banking crises in several directions.

regimes, external shocks like the ones described by Eichengreen and Rose (1998) are less likely to trigger banking problems.

[13] We shall return to this point in Section 3.6.4.

First, it adopts a new panel dataset of quarterly observations on 92 developing and emerging markets economies.[14] The range of explanatory variables varies from financial, debt and macroeconomic indicators to global variables. We also include bank-specific indicators and dummies to control for the exchange rate regime and the existence of capital account restrictions. The result is a comprehensive dataset that, compared to other studies, would allow us to control for a larger set of potential determinants of banking crises.

Second, as mentioned before, the panel dimension of our data allows us to analyse the full dynamics in the quarters preceding, accompanying and following an episode of banking crisis, without deleting any relevant observation around the time of a crisis. Most of the previous empirical studies on banking crises make instead use of a crisis window, by deleting observations in the proximity(aftermath) of an episode of banking crisis. In this way, they have altered the time dimension of the dataset and introduced a time span between consecutive observations.

Third, and most important, we adopt a new methodology that controls for:

- state dependence, i.e. past instances of banking crisis influencing the likelihood of observing another banking crisis in the future;
- unobserved heterogeneity, i.e. time-invariant country-specific characteristics that may influence the propensity of a country to experience a banking crisis;
- unobserved serial correlation to account for persistent determinants of banking crises.

[14] The complete list of countries is provided in Appendix A.

3.4 The Data

Our panel dataset includes quarterly observations on 92 developing and emerging markets over almost three decades, from 1970 to 1997.[15] Some of the countries appear in the sample for a restricted time span due to the poor quality of the data or lack of observations. The result is an unbalanced panel dataset with a maximum of 4350 observations.

We focus only on developing countries and emerging markets because there are reasons to believe that the determinants of financial fragility can be significantly different from those at work in more advanced and developed countries.[16]

First, macroeconomic imbalances in developing and emerging countries have been larger, on average, than in industrial countries, thus increasing the vulnerability of their financial systems to external shocks.

Second, financial markets in developing countries are more volatile, and thus banks operate in a riskier environment. This is partly the result of a lack of confidence about the stability of the macroeconomic conditions and is reflected in the investors' reluctance to lock savings in long-term assets. Consequently, the average maturity of the liabilities of financial institutions in developing countries is generally low and this exposes banks to a higher default risk if investors refuse to roll-over short-term obligations and/or access to the international credit markets is limited.

Third, banks in developing countries may play a bigger role as financial inter-

[15] We have included some of the transition countries in their late years, when banking problems were due to current lending practices and not to the stock of non-performing loans inherited from the ex-communist regimes.

[16] For an application of this argument to Latin American countries, see Rojas-Suárez and Weisbrod (1996).

mediaries, given the limited access to other forms of financing like domestic equity.

Fourth, the legal framework in which banks operate is often underdeveloped, regulation is poor and accounting practices are inadequate, making it difficult to monitor banks and evaluate the quality of their assets.

As a result of all these factors, banking crises in developing countries may have a different origin than those in more advanced industrial countries. This is what motivates our choice to focus exclusively on this group of countries.

3.4.1 The Dependent Variable

Dating episodes of banking crises is a problematic issue, not only because they are difficult to identify on the basis of a statistical index, but also because of the lack of relevant information. We could, in principle, select episodes of bank runs by looking at the rate of decrease of currency and time deposits in the banking system, but this is only one of the possible causes of banking crises.

The maturity and currency mismatch between assets and liabilities is another intrinsic source of financial systems' vulnerability. The transmission mechanism is explained by Mishkin (1996). In his view, banks in developing countries are intrinsically vulnerable to a currency devaluation because they lend short-term and in domestic currency, but borrow long-term and in foreign currency.

Given this currency and maturity mismatch, a sharp devaluation of the exchange rate may have disruptive effects on the banks' balance sheets because it would increase the nominal value of the liabilities denominated in foreign currency. This is typically accompanied by a deterioration of the banks' portfolio, due to an increase in the number of distressed borrowers. As the Asian crisis of 1997 has shown, poor lending practices may lead to the deterioration in the quality of bank assets and to an increase in the level of non-performing loans.

The origin of a banking crisis can thus be rooted on the asset side of the banks' balance sheets, not only on the liability side. Unfortunately, these factors are difficult to monitor because data on the exposure of financial intermediaries, non-performing loans, or firms failures are not readily available for most of the developing and emerging countries in our sample. Given these data limitations, we had to rely on historical events to date banking crises, such as bank runs, the closure of financial institutions, or government intervention to support troubled banks.

In the literature, the two main sources of information about past episodes of banking crises are Caprio and Klingebiel (1996) and Lindgren, García, and Saal (1996). Caprio and Klingebiel review episodes of banks' insolvencies occurred from the late 1970s to 1995 in 69 developing and OECD countries, of which 51 are also included in our sample.[17] They define a total of 87 *systemic* cases of banks' insolvencies, i.e.: 'where much of the capital was exhausted'. To identify these episodes, they rely on the assessment of experts or refer to published sources. Unfortunately, they report more detailed information about the causes of the crises only for a smaller sample of 26 countries.

Lindgren, García, and Saal extend the previous analysis to the sample of 181 IMF member countries, 135 of which are developing countries, over the period 1980–96. They distinguish between *crises* (a total of 41 episodes in 36 countries) and *significant problems* (108 cases in total). The first are defined as: 'cases of bank runs or other substantial portfolio shifts, collapses of financial firms or massive government intervention'. Significant problems are identified as 'episodes of financial distress and deep bank unsoundness, short of a crisis'.

[17] Caprio and Klingebiel have later revised and up-dated their earlier list to include crises up to 1998. Their new classification can be found in Caprio and Klingebiel (1999).

Most of the subsequent empirical works on the determinants of banking crises refer back to these two key studies in order to compile a list of crisis episodes, occasionally imposing some restrictions on the definition.

Demirgüç-Kunt and Detragiache (1998a), for example, require for an event to be classified as a crisis that the ratio of non-performing assets over total assets of the banking system was higher than 10 per cent, or that the fiscal cost of the crisis exceeded 2 per cent of domestic GDP. They also count as crises instances of bank runs and cases where emergencies measures were taken, like deposit freezes or the nationalisation of troubled banks.

We adopt the list of banking crises episodes provided by Lindgren, García, and Saal (1996), because it is the most detailed and comprehensive in terms of countries' coverage[18] and provides detailed information on the nature of the crises.

Nonetheless, we had to rely on additional sources (IMF and Economist Intelligence Unit country reports) to integrate this list along the time and country dimension in order to cover the entire sample —from 1970 to 1997— and identify the exact quarters in which those episodes took place. Indeed most of the existing studies, including Caprio and Klingebiel (1996) and Lindgren, García, and Saal (1996), provide information only on an annual basis.[19]

In this study, banking crises will be identified by the occurrence of one of the following events:

[18] They describe events in all but one of the countries that are in our sample. Samoa is the only country that is excluded from their sample.

[19] With the exception of Goldstein, Kaminsky, and Reinhart (2000), who use monthly data on a smaller sample of 25 industrial and developing countries, there is no other study to our knowledge that analyses periods of banking sector distress at a higher frequency and over a larger sample of emerging countries than this one.

- A bank run with consistent deposits' withdrawals.
- The license withdrawal, closure, liquidation or take over of one or more financial institutions.
- The adoption of emergencies measures like a freeze on deposits or prolonged bank holidays.
- Governments' intervention to reform the banking sector, recapitalise or partially take-over troubled banks.

As in Demirgüç-Kunt and Detragiache (1998a), we limit our attention to episodes where total non-performing assets of troubled banks were at least 10 per cent of the total assets of the banking system, or the estimated fiscal cost of the crisis amounted to more than 2 per cent of domestic GDP.

Following these criteria, we identify a total of 205 quarters of systemic banking crises in 43 countries.

In order to check the sensitivity of our results to the definition of banking crisis adopted, we also use a more restrictive definition that excludes episodes of banks' bailout through government intervention. This second definition is therefore based only on the first three selection criteria described above. The total number of banking crises identified in this case is smaller and equal to 102.[20] Throughout the paper, we shall refer to these two definitions as bank crises *with* or *without* bailouts, depending on whether cases of government intervention to rescue troubled banks are taken into account.[21]

[20] The complete list of episodes, together with a short description of the causes of the crises is presented in Appendix B.

[21] To ease the interpretation of the results, quarters with simultaneous government intervention and either a bank run, a bank closure or the adoption of emergencies measures, have been deleted from the sample.

Tab. 3.1: Distribution of Banking Crises over Time

Time Period	*with bailouts*		*without bailouts*		Total
	number	percentage	number	percentage	
1970s	1	0.27%	1	0.27%	376
1980s	68	3.85%	29	1.64%	1764
1990s	136	6.15%	72	3.26%	2210
Total	205	4.71%	102	2.34%	4350

Tab. 3.2: Distribution of Banking Crises across Regions

Region	*with bailouts*		*without bailouts*		Total
	number	percentage	number	percentage	
Africa	68	4.58%	35	2.36%	1486
Asia	54	6.37%	25	2.95%	847
Eastern Europe	34	8.92%	17	4.46%	381
Latin America	44	3.47%	24	1.89%	1268
Middle East	5	1.36%	1	0.27%	368
Total	205	4.71%	102	2.34%	4350

Notes: Banking crises *with* bailouts are defined as cases of either one or more of the following: 1) a bank run; 2) a license withdrawal or closure of one or more financial institutions; 3) the adoption of emergency measures like a freeze of deposits; and 4) government intervention to rescue troubled banks. Banking crises *without* bailouts exclude cases of government intervention, i.e. are defined according to the first three criteria only.

Tables 3.1 and 3.2 provide summary statistics on the distribution of crises by time and region, as a first characterisation of the episodes of banking crises in our sample. Table 3.1 shows that, no matter how they are defined, episodes of banking crises in developing countries have more than doubled during the last decade, possibly due to the increased financial liberalisation enjoyed by these countries.[22]

When we look at the distribution of crises by regions, shown in Table 3.2, Africa has the highest absolute number of banking crises, followed by Asia and Latin America. The ranking changes if we take into account the total number of observations in each sub-sample. Incidentally, the high percentage of banking crises falling into the sub-sample of Eastern Europe is due to the fact that, besides Bulgaria and Russia, it also includes Turkey.

3.4.2 Explanatory Variables

We collected a large set of macroeconomic, financial and debt indicators that, according to the economic theory, are potential determinants of banking crises.[23] The main data sources were the IMF *International Financial Statistics (IFS)* for the macroeconomic and financial variables and the *Global Development and Finance* database of the World Bank for the debt variables and GDP series. Each series was accurately checked for missing or abnormal values and seasonally adjusted. Some of the variables had to be interpolated from annual data in order to have a complete database of quarterly observations for all the countries included

[22] The low number of banking crises in the '70s can be partially explained by the low representation in our sample. Indeed, only for few countries we could collect reliable information from the beginning of the decade, while in most cases the sample starts in the late 1970s. However, the low proportion in terms of the whole sample seems to indicate that banking crises became a *systemic* problem only in the 1980s and 1990s.

[23] The data used in this chapter were jointly collected with María Mercedes Tudela (Bank of England) and are further analysed in Chapter 4 of this thesis, which is a joint work with her.

in our sample.[24] We can classify the explanatory variables of our econometric model into the following sub-groups:

Macroeconomic Variables. This first set of variables includes real domestic GDP growth, real deposit interest rates, total exports and imports growth over GDP and a measure of real exchange rate undervaluation. The latter was obtained by subtracting each RER series from its corresponding Hodrick-Prescott trend.[25] Positive (negative) values of this measure indicate that the RER is undervalued (overvalued) with respect to its historical trend and thus less (more) likely to be re-aligned.

This subset of explanatory variables is meant to characterise the general domestic conditions of the economy and measure the repayment capacity of each country. In fact, a domestic recession is likely to be associated with an increase in financial sector fragility. The transmission mechanism works in the following way. If growth is declining, there would be pressures on the government to pursue more expansionary monetary and fiscal policies to boost economic activity. This might fuel a cycle of lending booms, accompanied by increasing assets and real-estate prices. Monetary policy may have to be tightened, to avoid inflationary pressures, and the bubble will eventually burn. As a consequence, individual borrowers will find themselves unable to pay back their loans and banks will have increasing amounts of non performing assets.

According to this view, we should expect a negative sign in front of the coefficient of GDP growth. A slowdown in exports over GDP or an increase in imports over GDP would instead imply a decline in net trade revenues. The higher export earnings or the lower imports expenditures, the lower the probability of a liquidity

[24] Appendix D contains a complete list of variables' definitions, together with their source and original frequency.

[25] The RER series are author's computations based on nominal exchange rates and relative CPI indexes. Both series were obtained from the IFS statistics by the IMF.

crisis. Similarly, an overvalued exchange rate would harm tradeable' producers, giving rise to a period of distressed borrowing, with adverse consequences on the quality of the banking sector's assets. This implies an expected negative sign for the real exchange rate undervaluation measure.

Monetary and Financial Variables. We also consider credit variables to control for the existence of credit booms and connected lending. In particular, we look at the rate of growth of total domestic credit and its sub-components, i.e. total credit to the private sector and net claims on the central government, all measured in percentages of GDP. The first variable is a typical leading indicator of financial crises. The higher total domestic credit, the higher the probability of a banking crisis. There is also evidence that banking crises are preceded by episodes of lending booms, accompanied by an acceleration in credit to the private sector that has adverse effects on the quality of new loans and thus on the solvency of financial intermediaries. Net claims on the government should instead capture the Krugman's effect, i.e. credit expansion due to the monetisation of fiscal deficits. Both variables, credit to the private sector and to the government, would therefore tend to increase the probability of banking crises.

Debt Variables. We used a number of indicators to test the influence of debt financing instruments on the probability of observing a banking crisis. We first looked at total external debt and total debt service, both as a ratio of exports or GDP, to measure the degree of indebtedness of developing countries. Secondly, we took into account the maturity and structure of the stock of external debt, by considering short-term debt as a ratio of total external debt or foreign reserves, and the share of long-term external debt that is private non-guaranteed or publicly-guaranteed.

These variables would allow us to test the significance of the relation between the structure of external debt and the stability of financial systems described by

Sachs, Tornell, and Velasco (1996). Their view is that countries with large stocks of short-term external debt denominated in foreign currency are especially prone to experience a currency crisis. The occurrence or anticipation of such a crisis can lead depositors to run banks in order to get their domestic currency deposits out of the domestic financial system. This, in turn, may force the government to increase interest rates in an attempt to stop the currency outflow, with adverse consequences on the quality of banks' assets. In fact the decision to increase interest rates may well avoid the currency crash but at the expenses of a deterioration in the banks' loan portfolio.

Finally, we constructed two debt indicators of external vulnerability: short-term debt over reserves and external debt service over exports. The first is a measure of reserves adequacy, because it compares the amount of debt that has to be frequently rolled-over to the total amount of liquid assets of the central bank. The second is a liquidity indicator, because it measures the country's ability to generate enough export revenues in hard currency to cover its debt repayment obligations.

Bank-specific Indicators. We included among the explanatory variables some banking indicators to characterise the financial systems of the countries in our sample. These include: central bank credit to the banking sector as a percentage of GDP and the growth rate of banks' deposits over GDP and banks' foreign liabilities over GDP.

We can interpret the first of these variables as an indicator of the degree of central bank intervention through credit injections into the banking system. The higher central bank credit to commercial banks, the lower the probability of a liquidity crisis. A sudden decrease in banks' deposits over GDP would instead signal the existence of bank runs and deposits withdrawals. Finally, the amount of foreign liabilities over GDP would measure the degree of reliance of the bank-

ing system on off-shore capital to fund its activities and would thus signal the vulnerability of the system to a sudden reversal of capital inflows.

Global Variables. This fifth group of variables should capture the role of external conditions and exogenous shocks in determining banking crises. We focus on the change in the US real interest rate and US inflation as external determinants of financial crises. The first of these two variables may relate banking crises to a sudden capital inflows/outflows, like those experienced by developing countries during the past decades. One common view is that capitals were 'pushed out' of industrial countries by a drop in international interest rates.[26] As a result, emerging markets witnessed an impressive surge in short-term capital inflows, which were highly volatile and subject to the possibility of sudden reversals. Once confronted with capital outflows, these governments had to choose between defending their currency — by increasing domestic interest rates — and preserving the stability of their banking systems, those loan portfolio would deteriorate as a consequence of an increase in domestic interest rates.

Another channel of transmission from world interest rates to banking crises operates through the debt markets. An increase in the level of international interest rates[27] would represent a negative income shock for developing and emerging markets because it would reduce the debt repayment capacity of governments and/or domestic banks' borrowers, and thus increase the probability of observing solvency problems.

Finally, Moreno and Trehan (2000) argue that a deflationary shock in the United States can have a direct effect on economies that are exporters to this market be-

[26] See Fernández-Árias (1996) for a description of the policy debate over capital inflows to Latin American countries.

[27] In this work, a change in the US interest rates would proxy for a change in international conditions. This assumption is motivated by the fact that most of the external debt stock of the countries in our sample is denominated in US dollars.

cause it would lower their export revenues and, consequently, domestic economic activity. The resulting unemployment would make it more difficult for banks' borrowers to pay back their loans. Therefore, disinflation in a major economy, like the United States, could be associated with an increase in the probability of observing a banking crisis.

To proxy for terms-of-trade shocks, we include in our dataset the inflation rates of several commodities. These are computed as follows. First, we constructed a number of indicator variables to identify the main exporters of fuel, metal, raw materials, and food and beverages.[28] We then multiplied these dummies by the corresponding commodity inflation series. The resulting variable would allow us to test, for example, the effect of an increase in fuel prices only in those countries that are main exporters of fuel. Intuitively, a decrease in these prices would increase the probability of a crisis because it would reduce export revenues. We would expect this term-of-trade effect to be particularly important in those developing countries that are characterised by a low degree of export diversification.

Currency Crises Dummy. Following the mainstream empirical literature on currency crises, we devised a statistical index to identify quarters in which the exchange rate was under speculative pressure. For each country, we calculated the quarterly percentage change of the nominal bilateral exchange rate with the US dollar and used two criteria to qualify an episode as a currency crisis. The first criterion selects only exchange rate *depreciations* that exceed a 10 per cent cut-off level. The second focuses on the *rate of depreciation*, by requiring this same 10 per cent depreciation to be also a 25 per cent increase in the rate of depreciation with respect to the previous quarter.[29] The last condition was added in order to avoid counting as currency crises instances of systematic devaluations like those

[28] These are defined as countries that depend on trade of these primary commodities for their export earnings according to the IMF classification. See Appendix A.

[29] A similar procedure is followed by Frankel and Rose (1996), but with different cut-offs for the two criteria due to the lower frequency of their data.

associated with a crawling peg regime or to a period of hyperinflation, like in Latin America during the late 1980s, when the first criterion was met quarter after quarter.

An alternative approach is followed by Eichengreen, Rose, and Wyplosz (1995), who construct an *Exchange Market Pressure* index (EMP), by combining changes in exchange rates, interest rates and central bank reserves. By looking at abnormal behaviours of interest rates and international reserves they not only capture currency crises, but also unsuccessful speculative attacks —i.e. speculative attacks that are not followed by a devaluation of the currency— under the assumption that the monetary authorities would use these two instruments to deter an attack on the currency. Unfortunately, few emerging markets have market-determined short-term interest rates series for long periods of time. Moreover, reserves movements may sometimes be less effective against a speculative attack than the tightening of reserves requirements, emergency rescue packages from international institutions or the imposition of controls on capital outflows. For the above reasons, we decided to adopt a cut-off approach to identify episodes of currency crises rather than an *EMP* measure.

The currency crises dummy is used in the estimations lagged by at least one quarter, to control for the effect of past episodes of currency crises on the probability of observing a banking crisis one period ahead and to test the hypothesis that currency crises lead banking crises.

To check the sensitivity of the results to the lag structure, we also constructed an alternative dummy that takes the value of one if a currency crisis was recorded in any of the four quarters preceding a banking crisis episode. We would call this dummy a currency crises *indicator*, to distinguish it from the currency crises dummy lagged one quarter.[30]

[30] Appendix C contains a list of the currency crisis episodes in our sample.

Control Variables. Our dataset comprises a number of dummy variables to control for institutional characteristics. The first of them is an exchange rate dummy that takes the value of one if the exchange rate regime is classified as 'independently floating' or 'managed floating' by the IMF Exchange Arrangements and Exchange Restrictions Reports. Our dummy takes the value of zero when the exchange rate is 'pegged' and in cases of 'limited flexibility' against a single or multiple currencies. Using the same IMF source, we constructed an additional dummy to control for the existence of capital controls.

The expected sign of the exchange rate dummy is *a-priori* undetermined. On one hand, some degree of exchange rate flexibility is needed to prevent an adverse external shock from having disruptive effects on the domestic financial systems. This is because if an external shock hits the economy and bank borrowers find themselves unable to pay back their loans, a nominal depreciation could prevent banks' insolvency, by lowering the real value of their assets to levels that can actually be paid, while also reducing their liabilities. Under a fixed exchange rate regime depositors are instead guaranteed and the taxpayers would have to bear the costs of banks' restructuring. According to this interpretation, we should expect a negative sign on the estimated coefficient of our exchange rate dummy which takes the value of one if a flexible exchange rate regime is in place.

On the other hand, a pegged exchange rate acts as a commitment device that 'ties policymakers' hands'[31] and makes a devaluation costly in terms of credibility loss. According to this view, floating exchange rates would lead to more erratic monetary policies and thus increase the probability of financial crises.

The same indeterminacy applies to the expected sign of the dummy that takes the value of one if capital account restrictions are in place. There are reasons to believe that capital controls would protect the banking system from the disrup-

[31] This terminology is borrowed from Giavazzi and Pagano (1988).

tive effects of highly volatile capital flows and thus decrease the probability of a financial crisis. At the same time, controls are more likely in countries those financial markets are less developed and thus more intrinsically prone to crises. Furthermore, the mere existence of these restrictions can induce banks to try to circumvent them, by opening off-shore accounts and thus increase the exposure to exchange rate risk. The last considerations suggest a positive correlation between capital account restrictions and banking crises.

Following a flourishing stream of literature that finds a positive relation between financial liberalisation and financial fragility[32], we decided to control for the effect of financial liberalisation on the probability of experiencing a banking crisis. We thus constructed an indicator variable that takes on the value of one if domestic interest rates are free from controls.

3.5 The Empirical Methodology

We use panel data and simulation-based estimation techniques to estimate the probability of banking crises in emerging markets. In particular, we apply the method of maximum smoothly simulated likelihood (MSSL) to a dynamic limited dependent variable model with unobserved heterogeneity and autocorrelated errors. This technique would allow for:

- time dependence among episodes of banking crisis;
- interdependence between banking and currency crises; and
- heterogeneity and serial correlation among unobserved determinants of banking crises.[33]

[32] See, among others, Demirgüç-Kunt and Detragiache (1998b), Demirgüç-Kunt and Detragiache (2000), and Glick and Hutchison (2001).

[33] This assumption differentiates our approach from most of the existing studies that use static logit or probit models with i.i.d. errors to describe currency or banking crises.

In our view, these factors are important because if a country experienced a crisis in the past, the probability of observing another crisis may depend on that previous crisis occurrence. Therefore, the likelihood of financial crises should preferably be estimated with panel data and an appropriate econometric specification that would allow for the existence of inter-temporal linkages between consecutive crises.

Time or *state dependence* among episodes of banking crises can have two origins.[34] On one hand, countries that have already experienced a banking crisis may behave differently from countries that have not witnessed a crisis. This is because the preconditions for the occurrence of another banking crisis may have changed as a result of that previous crisis occurrence. Past experience has in this case a genuine behavioural effect, in the sense that an otherwise identical country that did not experience the event would behave differently in the future from a country that experienced the event. This is what is known as *true state dependence* and can be controlled for in the estimation by the inclusion of a lagged dependent variable among the regressors.

On the other hand, countries may differ in their *propensity* to experience a crisis. By relaxing the hypothesis of identically and independently distributed (i.i.d.) errors, we would explicitly take into account this eventuality. First, a time-invariant country-specific error term would control for the existence of *unobserved heterogeneity.* This may reflect political and institutional factors that are characteristic of a country but are difficult to control for by using a set of standard macroeconomic indicators. Second, we allow for autocorrelation in the error structure, by means of an $AR(1)$ process. This second component takes into account the fact that countries' differences may be correlated over time, due for example to the existence of persistent shocks. The error term of our dynamic probit model

[34] We follow here Heckman (1981) and Börsch-Supan, Hajivassiliou, Kotlikoff, and Morris (1992).

of banking crises should contain both elements to secure reliable estimates. An improper treatment of the structure of the errors could otherwise give rise to a conditional relationship between future and past experience that is termed *spurious state dependence*, thereby past episodes of banking crises may turn out to be significant solely because they are a proxy for persistent and autocorrelated unobservables.

As explained in the methodological chapter that concludes this thesis, the main problem associated with the estimation by classical maximum likelihood of this dynamic probit model with non i.i.d. errors is the high dimensional integration of the associated likelihood function.[35] The method of maximum smoothly simulated likelihood used in conjunction with the GHK simulator would allow us to overcome these computational problems and obtain estimates that are asymptotically efficient.[36]

3.6 Estimation Results

This section reports the results of the estimations by MSSL of the dynamic probit model described above and applied to episodes of banking crises. The model is estimated on a quarterly basis over the whole sample of 92 developing and emerging countries listed in Appendix A.

The dependent variable is a dummy that takes on the value of one in correspondence of episodes of systemic banking distress, as defined in Section 3.4.1. The results reported here are derived by using the broader definition of banking crises, *with bailouts*, that includes cases of government intervention to rescue troubled banks.[37]

[35] See Section 5.2.1 of Chapter 5 for a formalisation of the banking crises model.

[36] See Section 5.3.4 and Section 5.4.2 of Chapter 5.

[37] See Table 3.8 for a comparison of the baseline results to those obtained by using a more restrictive definition of banking crises *without bailouts*.

All the regressors employed in the estimations are lagged at least one period, to avoid endogeneity problems. The inclusion of contemporaneous variables could otherwise lead to an erroneous interpretation of the causality effects, with the outcome of a crisis inaccurately treated as one of its precipitating causes. The final specifications reported here are parsimonious versions of very general models that included the complete lag structure of each explanatory variable up to four quarters.[38]

One of the features that distinguishes this work from previous studies that used static logit/probit analysis is that we use a *dynamic* probit to model banking crises, i.e. we include the lagged dependent variable on the right hand side of the estimated equation. As explained in Section 3.5, this would allow us to test for *state dependence*, i.e. if past occurrences of banking crises have a significant effect on the probability of observing another banking crisis in the future. A dummy for past instances of currency crises would instead check the hypothesis that currency crises lead banking crises one quarter or one year ahead.

With respect to the output of a static probit model with i.i.d. errors, our estimation procedure involves two additional parameters. The first of these two coefficients, σ^2, corresponds to the variance of the country-specific, time-invariant error term. This factor allows for the presence of *unobserved heterogeneity*, such as institutional or political characteristics that are not fully captured by our set of explanatory variables. The second parameter, ρ, allows for the existence of persistent country-specific effects correlated over time.

Since the estimated β coefficients of a probit regression are not immediately interpretable —being the partial derivative of the latent variable with respect to each of the regressors— we also report the estimated elasticities. These are the

[38] The choice of dropping the insignificant terms up to the first lag that is significant does not affect our main results, which do not differ from those of the more general specifications.

partial derivatives of the probability of occurrence of a banking crisis with respect to each of the regressors, normalised at the mean value of each variable over the whole sample.[39] We also indicate the associated z-statistics, which test the null hypothesis of no effect.

3.6.1 The Baseline Specification

Our baseline model includes a set of real macroeconomic and financial variables, as well as some bank-specific indicators that the economic theory has identified as potential determinants of banking crises. We also add a number of global variables to control for the presence of common shocks, as a sudden increase in foreign interest rates or a terms-of-trade shock.

The estimation results of the baseline specification are shown in Table 3.3. The set of domestic macroeconomic variables is highly significant and they all appear with the expected sign. The likelihood of a banking crisis in emerging markets increases the lower domestic GDP growth, the higher real interest rates and imports growth, and the more overvalued the real exchange rate. Interestingly, the probability of a banking crisis reacts with some delay to changes in real GDP and imports growth. Both variables enter the baseline specification lagged by two quarters. The impact of a percentage change in growth is quite remarkable. The estimated elasticity suggests that a one percentage increase in domestic growth would reduce the probability of observing a banking crisis by 9 percentage points. On the contrary, an increase in the ratio of total imports over GDP increases the probability of banking sector problems through a reduction in net trade revenues, that may be a primary source of debt repayment for a significant proportion of banks' borrowers.

[39] Additional insights on how the likelihood of a crisis reacts to changes in each of the regressors can be derived by assuming different criteria of normalisation.

Tab. 3.3: The Baseline Specification

Explanatory Variables	β coeff.	z-stats.	elasticities
Constant	−1.802***	−17.946	−4.172
Real GDP growth, lagged 2Q	−0.046***	−2.803	−0.098
Real interest rate, lagged 1Q	0.001**	1.959	0.011
Growth of imports over GDP, lagged 2Q	0.005**	2.247	0.013
RER undervaluation, lagged 1Q	−0.005*	−1.558	0.004
Growth of credit to the government over GDP, lagged 3Q	−0.000	−0.115	−0.000
Growth of credit to the private sector over GDP, lagged 3Q	0.003**	2.274	0.008
Central bank credit to banks over GDP, lagged 2Q	−0.006	−0.028	−0.008
Growth of banks' deposits over GDP, lagged 3Q	−0.005**	−1.951	−0.016
Growth of banks' foreign liabilities over GDP, lagged 2Q	0.001***	2.491	0.009
Change in US interest rates, lagged 1Q	0.821**	2.154	−0.007
US CPI inflation, lagged 1Q	−0.211***	−2.927	−0.519
Fuel inflation, lagged 4Q	−0.016**	−2.164	−0.023
Banking crises, lagged 1Q	1.932***	14.408	0.213
Currency crises, lagged 1Q	0.091	0.535	0.010
σ^2	0.175***	4.695	
ρ	−0.267***	−4.019	

Notes: Dependent variable: banking crises *with bailouts*. Total number of banking crises: 202. Total number of observations: 4067. Function value at optimum: 600.980.

Given the size of our sample, the t-statistics are virtually Normal. We can therefore use the t-tables to assess the significance of the estimated coefficients. We use the critical values for the 1%, 5% and 10% significance levels, which are: 2.326, 1.645 and 1.282 for one-tailed test, and 2.576, 1.960 and 1.645 for a two-tailed test.

The symbols *, ** and *** denote the 10%, 5% and 1% significance levels, respectively.

The elasticities measure the effect of a unitary change in one of the regressors on the probability of observing a banking crisis, and are evaluated at the mean value of each variable. They should be multiplied by 100 to be converted into percentages.

Similarly, the results in Table 3.3 show that an overvalued exchange rate may harm tradeable' producers, with adverse consequences on the quality of the assets of the banking sector. The estimated coefficient of our measure of RER undervaluation is significant at the 5 per cent level and has a negative sign. Indeed, the more undervalued the RER, the less likely a financial crisis is.[40]

To control for the effect of lending booms and connected lending, we include in our model the two main sub-components of total domestic credit: total credit to the private sector and net credit to the government, both in percentages of domestic GDP. The results in Table 3.3 show that an increase in credit to the private sector increases the probability of a banking crisis, confirming that lending booms threaten the stability of financial systems. This result extends the findings of Demirgüç-Kunt and Detragiache (1998a), Hardy and Pazarbaşioğlu (1999) and Eichengreen and Arteta (2000) to our sample of emerging and developing countries. By contrast, the growth of credit to the public sector is not significant in this specification. This result is not surprising, since we are analysing banking crises here. We would rather expect government deficits financing from the central bank to be an important determinant of currency crises, following the predictions of the 'first generation models' à la Krugman (1979).

Bank-specific indicators constitute the third group of variables included in our baseline specification, after the set of macroeconomic and financial regressors described above. As shown in Table 3.3, a decrease in banks' deposits or an increase in banks' foreign liabilities tend to increase the probability of a bank collapse. As mentioned in Section 3.4.2, a sharp decrease in banks' deposits could signal a loss in confidence in the banking system and anticipate a bank run. The high and positive z-statistics associated with the coefficient on banks' foreign liabilities is

[40] The corresponding elasticity is positive because it is evaluated at the variable's mean, which is negative over the whole sample. This implies that, on average, real exchange rates were overvalued, thus increasing the probability of financial sector problems.

instead signaling the vulnerability of financial institutions to the currency and maturity mismatch between assets and liabilities. Finally, central bank credit to banks tends to reduce the probability of a crisis, although its estimated coefficient is not statistically different from zero in our baseline specification.

The remaining macroeconomic variables in the baseline specification characterise the global environment and are thus common to all the countries in our sample. We first include the change in the level of foreign interest rates, proxied here by interest rates in the United States. As expected, the estimated coefficient is positive and significant at the 1 per cent level, implying that an increase in interest rates elsewhere increases the probability of banking sector problems either directly, through increased external debt repayments, or indirectly through destabilising capital outflows.[41]

Another important global determinant of the probability of banking crises is the inflation rate in the United States. The negative sign associated with its estimated coefficient in the baseline specification confirms the predictions of Moreno and Trehan (2000). They argue that a deflationary shock in the United States can have a negative income effect on exporters to this market because it would lower export revenues and, consequently, endanger their debt repayment capacity. This is another example of how unfavourable external conditions may undermine the stability of financial systems in developing countries.

Our results are robust to the inclusion of commodity prices inflation rates as a proxy of terms-of-trade shocks to exporters of these goods. The reduced specification shown in Table 3.3 includes only fuel inflation that is significant at the 5 per cent level, although with a lag of four quarters.[42] The sign of the estimated

[41] The switch in the sign of the associated elasticity is due to the choice of evaluating the elasticities at the mean value of the data.

[42] Raw materials, metal, food and beverages inflation have been excluded from the baseline specification because they were not significant.

coefficient is negative, as expected. An increase in oil prices decreases the probability of a financial crisis in countries that are exporters of this commodity.

Having controlled for the effect of macroeconomic, financial and global variables, we can turn our attention to the estimated coefficients and elasticities of the lagged banking and currency crisis dummies. No significant leading effect is found from past currency crises to banking crises one quarter ahead. The results of the baseline model seem to exclude, thus far, the hypothesis that currency crises are significant leading indicators of banking crises.[43]

The lagged dependent variable, which controls for the existence of *state dependence* among episodes of banking crises, is instead significant at the 1 per cent level and has a positive sign, pointing to a high degree of persistence among episodes of banking system distress.

Finally, we find that both parameters associated with the error term structure, σ^2 and ρ, are significant at the 1 per cent level. The first parameter reveals the existence of *unobserved heterogeneity*, and might be capturing differences in the financial institutions or regulations of developing countries. The second parameter, ρ, indicates the presence of unobserved persistent and autocorrelated causes of banking crises. This last result is key because it shows the importance of relaxing the hypothesis of i.i.d. errors and controlling for idiosyncratic differences among countries.

3.6.2 Controlling for Exchange and Financial Liberalisation

Table 3.4 tests the robustness of our results to the introduction of dummies to control for the type of exchange rate regime and the presence of restrictions on the capital account or domestic interest rates.

[43] The causal link between currency and banking crises is further analysed in Table 3.6.

Column 1 reports the results of the baseline specification inclusive of a dummy that takes the value of one for countries with a flexible exchange rate arrangement, and zero otherwise. As pointed out by Eichengreen and Rose (1998) and Levy-Yeyati and Sturzenegger (2002), the fact that the estimated coefficient of the exchange rate dummy is not significantly different from zero might be due to differences between the *de jure* classification, provided by the IMF, and *de facto* exchange rate regimes. The exchange rate categories identified by the IMF do not always correspond to the *de facto* exchange rate policy followed by the national banks, as in the case of implicit pegs which are classified as flexible exchange rate arrangements. As a consequence, our exchange rate dummy may be a poor proxy to control for the effective exchange rate regime.

The same reasoning applies to the dummy that controls for capital account restrictions. This variable has a negative sign but it is not significant, as shown in column 2 of Table 3.4.

The specification reported in the third column of Table 3.4 includes a different dummy that controls for the effect of financial liberalisation. This indicator variable takes the value of one if domestic interest rates are liberalised and is used in the estimations lagged by one period.

The results provide evidence in support of the view that financial liberalisation increases financial fragility, as argued by Demirgüç-Kunt and Detragiache (1998b) and Glick and Hutchison (2001). The estimated coefficient is indeed positive and significant at the 1 per cent level.

Tab. 3.4: Introducing Further Controls

Explanatory Variables	(1)	(2)	(3)
Constant	−1.842***	−1.788***	−1.887***
	(−17.965)	(−17.943)	(−18.072)
Real GDP growth	−0.046***	−0.046***	−0.045***
	(−2.810)	(−2.804)	(−2.768)
Real interest rate	0.000**	0.000**	0.000**
	(1.958)	(2.147)	(2.027)
Growth of imports over GDP	0.005**	0.005**	0.005**
	(2.268)	(2.244)	(2.250)
RER undervaluation	−0.005*	−0.005*	−0.005*
	(−1.570)	(−1.553)	(−1.554)
Growth of credit to the government over GDP	−0.000	−0.000	−0.000
	(−0.125)	(−0.113)	(−0.122)
Growth of credit to the private sector over GDP	0.003**	0.003**	0.003***
	(2.301)	(2.273)	(2.357)
Central bank credit to banks over GDP	−0.006	−0.006	−0.006
	(−0.027)	(−0.028)	(−0.026)
Growth of banks deposits over GDP	−0.005**	−0.005**	−0.005**
	(−1.988)	(−1.951)	(−1.972)
Growth of banks foreign liabilities over GDP	0.000***	0.000***	0.000***
	(2.461)	(2.495)	(2.556)
Change in US interest rates	0.816**	0.820**	0.804**
	(2.136)	(2.150)	(2.114)
US CPI inflation	−0.212***	−0.170***	−0.195***
	(−2.819)	(−2.934)	(−2.685)
Fuel inflation	−0.017**	−0.017**	−0.016**
	(−2.167)	(−2.167)	(−2.121)
Exchange rate dummy	0.089		
	(1.027)		
Capital account controls dummy		−0.013	
		(−0.110)	
Financial liberalisation dummy			0.249***
			(2.879)
Past banking crises	1.929***	1.931***	1.933***
	(14.280)	(14.366)	(14.434)
Past currency crises	0.074	0.090	0.067
	(0.431)	(0.527)	(0.392)
σ^2	0.177***	0.175***	0.152***
	(4.649)	(4.683)	(4.017)
ρ	−0.272***	−0.266***	−0.270***
	(−4.284)	(−4.003)	(−4.110)
Function value at optimum	600.474	600.974	596.908

Notes: The exchange rate dummy equals one for floats. Similarly, the capital account dummy takes the value of one if capital account restrictions are in place. The financial liberalisation dummy takes the value of one if domestic interest rates are liberalised.
See also notes to Table 3.3.

Tab. 3.5: Including Debt Variables

Explanatory Variables	(1)	(2)	(3)
Constant	−1.865***	−1.873***	−1.898***
	(−18.291)	(−17.592)	(−18.953)
Real GDP growth	−0.043***	−0.044***	−0.044***
	(−2.669)	(−2.664)	(−2.667)
Real interest rate	0.000**	0.000**	0.000***
	(1.998)	(2.027)	(2.058)
Growth of imports over GDP	0.004**	0.005**	0.004**
	(1.764)	(2.291)	(1.836)
RER undervaluation	−0.005**	−0.005*	−0.006**
	(−1.730)	(−1.445)	(−1.766)
Growth of credit to the government over GDP	−0.000	−0.000	−0.000
	(−0.277)	(−0.140)	(−0.227)
Growth of credit to the private sector over GDP	0.003***	0.003**	0.003***
	(2.406)	(2.209)	(2.396)
Central bank credit to banks over GDP	−0.005	−0.005	−0.004
	(−0.028)	(−0.022)	(−0.019)
Growth of banks deposits over GDP	−0.005**	−0.005**	−0.005**
	(−2.038)	(−1.972)	(−2.007)
Growth of banks foreign liabilities over GDP	0.000***	0.000***	0.001***
	(2.546)	(2.538)	(2.433)
Change in US interest rates	0.767***	0.759**	0.808**
	(2.001)	(1.991)	(2.084)
US CPI inflation	−0.181***	−0.188***	−0.177***
	(−2.465)	(−2.554)	(−2.372)
Fuel inflation	−0.016**	−0.016**	−0.016**
	(−2.133)	(−2.126)	(−2.048)
Financial liberalisation dummy	0.241***	0.235***	0.251**
	(2.751)	(2.645)	(2.579)
Total external debt over GDP	0.156*		0.103
	(1.405)		0.883
Short-term debt over total ext. debt		−0.314	
		(−0.477)	
Private non-guaranteed debt over l.t. ext. debt		0.768	
		(1.167)	
Short-term debt over reserves			0.002**
			(1.717)
Debt service over exports			0.537*
			(1.340)
Past banking crises	1.915***	1.922***	1.893***
	(14.177)	(14.256)	(13.854)
Past currency crises	0.078	0.043	0.061
	(0.453)	(0.248)	(0.350)
σ^2	0.157***	0.151***	0.158***
	(4.056)	(3.870)	(4.051)
ρ	−0.271***	−0.267***	−0.268***
	(−4.090)	(−4.017)	(−3.975)
Function value at optimum	595.849	595.078	593.293

3.6.3 The Impact of Debt Variables

The next step of our analysis was to introduce in the baseline specification a number of external debt variables with the aim of assessing the role played by the maturity and composition of external debt instruments in averting or triggering a banking crisis. As mentioned in Section 3.2, increasing attention has been paid to the causal link between debt management and financial crises, but the theoretical results have not found strong support in the empirical literature. The results shown in Table 3.5 are an attempt to further investigate this topic.

We tried different debt measures, either in levels or in growth rates, and found only two indicators of external vulnerability that are consistently significant and increase the likelihood of a banking crisis. These are shown in column 3 of Table 3.5 and are the ratio of short-term external debt over foreign reserves and debt service payments over total exports.

These two indicators of debt vulnerability dominate both the total level of external debt as a percentage of GDP and its growth rate. Total external debt over GDP is weakly significant when it is the only debt variable included in the model specification (see column 1 of Table 3.5), but it looses importance when the ratio of short-term external debt over foreign reserves and debt service payments over total exports are added to the equation.

We also look at the maturity and composition of external debt, by including the share of short-term external debt and the share of long term debt that is private non-guaranteed. The estimated coefficients are not significant though, as shown in column 2 of Table 3.5.

We find instead that the higher the stock of short-term external debt that is not covered by international reserves, the higher the probability of a banking

crisis. This result confirms the view of Sachs, Tornell, and Velasco (1996) on the origins of the Mexican crisis in 1994. According to the authors, this crisis was aggravated by the decision of the Mexican authorities to issue large amounts of short-term debt denominated in foreign currency.

The Mexican crisis erupted when the stock of external obligations largely exceeded the amount of foreign currency reserves. Confronted with the decision by foreign investors not to roll over the debt reaching maturity, the Mexican authorities had to raise interest rates to prevent a huge capital outflow. The prohibitive level of interest rates, coupled with a sharp recession, had adverse consequences on the banking system. This may well explain why in our sample, countries with a stock of short-term external debt far in excess of foreign reserves are more prone to banking crises.

What is also important in our specification is the total amount of debt service payments relative to exports earnings. Intuitively, the higher exports, the higher the hard currency revenues and the lower the probability of debt default and financial crises.

3.6.4 Leading Currency Crises

One of the most debated issues in the empirical literature on banking crises is whether currency crises are good leading indicators of banking sector problems. The results of our baseline specification reported in Table 3.3 do not seem to support this hypothesis. The coefficient on the dummy variable that takes the value of one in correspondence of episodes of currency crises occurred one quarter ahead of a banking crisis is positive but not significant.

Tab. 3.6: Controlling for Past Financial Crises

Explanatory Variables	(1)	(2)
Currency crisis indicator	0.164*	
	(1.394)	
Currency crisis indicator (1980s)		0.018
		(0.091)
Currency crisis indicator (1990s)		0.229**
		(1.717)
Banking crisis indicator	0.477***	0.467***
	(3.117)	(3.045)
σ^2	0.199***	0.203***
	(4.203)	(4.192)
ρ	0.433***	0.436***
	(5.160)	(5.192)
Function value at optimum	609.451	608.968

Notes: The *currency crisis indicator* is a dummy taking the value of 1 if there was a currency crisis in at least one of the four quarters preceding the occurrence of a banking crisis, and 0 otherwise. The *banking crisis indicator* is similarly defined.
The *currency crisis indicator (1980s)* is a dummy variable that takes the value of 1 if a currency crisis occurred in any of the four quarters preceding one of the banking crises of the 1980s and zero otherwise. A similar approach was followed to construct the *banking crisis indicator (1990s)*. See also comments to Table 3.3.

A possible explanation for this result is that it may take time before the effects of a currency devaluation are transmitted to the banking system. Moreover, our definition of banking crises tends to capture the peak of a period of banking system distress —marked by either the bankruptcy/closure of one or more troubled banks or by government intervention— and not its beginning. Therefore, a lag structure of the currency crises dummy longer than one quarter may be more suitable to investigate the causal link between currency and banking crises.

To examine further the link between currency and banking crises, we re-estimated the model specification inclusive of debt variables by using a different lag structure in both the lagged banking dependent variable and the dummy controlling for past episodes of currency crises.

The lagged dependent variable in this new specification is an indicator variable that takes the value of one if a banking crisis occurred in any of the four quarters preceding another banking crisis. Similarly, a currency crisis indicator would signal the occurrence of a currency crisis in any of the four quarters preceding a banking crisis.

The estimation results are gathered in column 1 of Table 3.6. As the signs and significance of the coefficients associated with the macroeconomic fundamentals and global variables are unchanged with respect to the baseline specification, Table 3.6 reports only the results that are key to the analysis of the link between currency and banking crises.

Contrary to the baseline specification, the currency crisis dummy becomes significant once we extend the lag structure and consider episodes occurred in the whole year preceding a banking crisis. This seems to suggest that the effects of a devaluation of the currency are transmitted to the banking system only with some delay. As explained by Mishkin (1996), the transmission mechanisms from

currency to banking crises would work through the banks' balance sheet, by increasing the nominal value of the liabilities denominated in foreign currency.

The banking crisis indicator remains strongly significant, indicating the presence of *generalised* state dependence among episodes of banking crises.[44]

Turning to the estimated coefficients of the error term, it is important to note the switch in sign of the parameter ρ associated with the autocorrelated error term.[45]

To test whether the nature of financial crises has changed over time, as suggested by the 'third generation' models of currency crises which stress the increasing interdependence between banking and currency crises, we constructed a currency crisis indicator by decades. The *currency crisis indicator (1980s)* is defined as a dummy variable that takes the value of one if a currency crisis occurred in any of the four quarters preceding a banking crisis of the 1980s. The *currency crisis indicator (1990s)* is similarly constructed. The 1970s are taken as the decade of reference. The inclusion in these new indicator dummies in the estimated model allows us to test whether the leading effect from currency to banking crises has been indeed stronger than ever during the past decade.

The estimation results reported in column 2 of Table 3.6 confirm that in the 1990s the leading effect from currency crises to banking crises was stronger than the one found over the whole sample period. Instead, no significant leading effect is associated with crisis episodes occurred in the 1980s with respect to the 1970s.

[44] We interpret this as a more general form of state dependence than the one found in the baseline model because it tests how the probability of a banking crisis today is affected by the state of the system in any of the four preceding quarters.

[45] A positive sign is more intuitive and eases the interpretation of the results, indicating that this specification fits better the data than the baseline model

In summary, the results in Table 3.6 show that the choice of the lag structure is crucial when assessing the significance of the causal link from currency to banking crises. A leading effect from currency to banking crises is found only after controlling for episodes of devaluation occurred in the whole year preceding a banking crisis. The effect is even stronger when we distinguish between crises occurred during the 1980s and the 1990s with respect to those of the 1970s.

These results may well explain why previous studies that use different crises windows have not found a significant leading effect from currency to banking crises.

3.6.5 Panel versus Pooled Data

After checking the robustness of our results to changes in the model specification, we performed a sensitivity test over the structure of the error term. While most of the existing studies on currency and banking crises make use of probit or logit models with identically and independently distributed errors, the estimates presented in this chapter have been obtained by assuming a composite error term that includes a time-invariant country-specific component and an autocorrelated error term.

Table 3.7 reports the results of our baseline specification, estimated with the currency crisis indicator variables, and compares them to those obtained by estimating a simple random effect model without the autocorrelated error term. This second set of results is reported in column 2 of Table 3.7, and clearly suffers from *spurious state dependence.* The omission of the autocorrelated structure in the error term artificially inflates the z-statistic associated with the banking crisis indicator, which is partially capturing the effect of the omitted error term.

Tab. 3.7: Panel versus Pooled Data

Explanatory Variables	panel data	random effects	pooled data
Constant	−1.886***	−1.998***	−1.938***
	(−20.534)	(−32.697)	(−15.898)
Real GDP growth	−0.041***	−0.045***	−0.043***
	(−2.556)	(−2.798)	(−2.766)
Real interest rate	0.001	0.000**	0.000**
	(1.239)	(1.966)	(1.984)
Growth of imports over GDP	0.006**	0.005**	0.005**
	(2.554)	(2.200)	(2.217)
RER undervaluation	−0.008**	−0.007**	−0.006**
	(−1.937)	(−1.861)	(−1.712)
Growth of net credit to the gov.t over GDP	−0.000	−0.000	−0.000
	(−0.129)	(−0.173)	(−0.167)
Growth of credit to the private sector over GDP	0.003***	0.003***	0.003***
	(2.374)	(2.619)	(2.516)
Central bank credit to banks over GDP	−0.003	−0.002	-0.000
	(−0.068)	(−0.073)	(−0.354)
Growth of banks deposits over GDP	−0.005**	−0.005**	−0.005**
	(−2.009)	(−1.889)	(−1.824)
Growth of banks foreign liabilities over GDP	0.001***	0.001***	0.001***
	(2.514)	(2.526)	(2.552)
Share of short-term debt over reserves	0.003**	0.003**	0.003**
	(1.935)	(1.882)	(1.858)
Debt service over exports	0.738*	0.774**	0.802**
	(1.548)	(1.857)	(1.992)
Domestic financial liberalisation	0.313***	0.305***	0.294***
	(2.733)	(3.016)	(3.284)
Change in the US interest rates	0.851**	1.039***	0.940***
	(2.052)	(2.628)	(2.442)
US CPI inflation	−0.192***	−0.168**	−0.164***
	(−2.373)	(−2.210)	(−2.244)
Fuel inflation	−0.014**	−0.016**	−0.015**
	(−1.867)	(−2.054)	(−2.059)
Banking crisis indicator	0.477***	0.949***	1.019***
	(3.117)	(10.471)	(12.448)
Currency crisis indicator	0.164*	0.138	0.120
	(1.393)	(1.275)	(1.150)
σ^2	0.199***	0.195***	
	(4.203)	(4.879)	
ρ	0.434***		
	(5.160)		
Function value at optimum	609.451	630.475	640.808

Notes: See comments to Tables 3.3 and 3.6.

The importance of modelling a panel data structure and estimating the probability of banking crises with the right techniques becomes clearer when comparing the results of our baseline specification with those of a standard probit model in column 3 of Table 3.7 that assumes an i.i.d. error structure and pools all the observations together, thus ignoring the panel dimension of the data. Two effects are worth noting. First, the presence of *spurious state dependence*, which is stronger then the one found when estimating a simple random effect model.[46] Second, the lower z-statistic associated with the currency crisis indicator. This indicator may be capturing the effect of the omitted σ^2, which controlled for time-invariant, country-specific differences.

In brief, the comparison of the z-statistics in column 1 and column 3 of Table 3.7 suggests that the use of standard static probit models to analyse the determinants of banking crises may generate biased results because of the omission of the panel structure.

3.6.6 Excluding Banks' Bailouts

To check the sensitivity of our results to the definition of banking crises, we re-estimated the baseline specification by using an alternative concept of crisis that excludes episodes of government intervention to bailout banks. Crises are thus identified by applying only the first three criteria listed in Section 3.4.1, i.e. the occurrence of either a bank run or a license withdrawal, bankruptcy, or closure of one or more financial institutions.

The estimation results obtained using the definition of banking crises *with* and *without* bailouts are reported in columns 1 and column 2 of Table 3.8, respectively. The comparison of the two columns shows that there are no major differences in the signs and magnitude of the estimated coefficients associated with the domestic and global explanatory variables.

[46] See column 2 of Table 3.7.

Tab. 3.8: Excluding Banks' Bailouts

Dependent Variable:	*with*	*without*
Constant	−1.886***	−2.065***
	(−20.534)	(−13.246)
Real GDP growth	−0.040***	−0.032**
	(−2.556)	(−1.791)
Real interest rate	0.001	0.001*
	(1.240)	(1.512)
Growth of imports over GDP	0.005***	0.006**
	(2.554)	(2.313)
RER undervaluation	−0.008**	−0.009**
	(−1.937)	(−1.844)
Growth of net credit to the gov.t over GDP	−0.000	−0.000
	(−0.129)	(−0.001)
Growth of credit to the private sector over GDP	0.003***	0.004***
	(2.375)	(3.609)
Central bank credit to banks over GDP	−0.003	−0.036
	(−0.020)	(−0.108)
Growth of banks deposits over GDP	−0.005**	−0.005**
	(−2.009)	(−1.851)
Growth of banks foreign liabilities over GDP	0.001***	0.001***
	(2.514)	(2.458)
Share of short-term debt over reserves	0.003**	0.003**
	(1.935)	(2.182)
Debt service over exports	0.738*	0.322
	(1.548)	(0.491)
Domestic financial liberalisation	0.313***	0.290**
	(2.733)	(1.988)
Change in the US interest rates	0.851**	1.153**
	(2.052)	(2.242)
US CPI inflation	−0.191***	−0.169*
	(−2.373)	(−1.644)
Fuel inflation	−0.014**	−0.016**
	(−1.867)	(−1.799)
Banking crisis indicator	0.478***	−0.112
	(3.117)	(−0.595)
Currency crisis indicator	0.164*	0.313**
	(1.393)	(2.150)
σ^2	0.199***	0.000
	(4.203)	(0.053)
ρ	0.434***	0.602***
	(5.160)	(5.895)
Function value at optimum	609.451	331.587

Notes: Banking crises *without* bailouts are defined as cases of either a bank run, or a license withdrawal, closure of one or more financial institutions, or the adoption of emergency measures like a freeze of deposits. Banking crises *with* bailouts include government's rescue packages. See also comments to Tables 3.3 and 3.6.

The probability of a banking crisis *without bailouts* increases the lower GDP growth, and the higher real interest rates and imports growth.

What is outright different is the effect of past currency and banking crises, as shown by the z-statistics associated with the currency and banking crisis indicators in column 2 of Table 3.8. First, the occurrence of a currency crisis strongly increases the probability of observing a banking crisis *without bailouts* in any of the four quarters ahead. The coefficient associated with the currency crisis indicator is now significant at the 5 per cent confidence level. A possible explanation for this result lies in the nature of the banking crises considered here. As already mentioned, this alternative definition of banking crises does not allow for government rescue operations. If this is the case, a devaluation of the currency might inevitably lead to the collapse of the banking system, as explained by Mishkin (1996).

Second, after having experienced either a bank run or the closure of one or more financial institutions in the past, countries seem less prone to experience another banking crisis in the near future. The estimated coefficient associated with the banking crisis indicator is now negative, although not statistically significant.

Finally, the unobserved heterogeneity in our sample vanishes once we adopt the banking crises definition *without* bailouts, as shown by the z-statistics associated with the parameter σ^2 in column 2 of Table 3.8.

3.7 Conclusions

This chapter has focused on episodes of banking crises in a sample of 92 developing and emerging market economies from the beginning of the 1970s to the end of 1997, when the Asian crisis erupted.

We used quarterly observations for a large number of macroeconomic fundamentals, debt and bank-specific variables to estimate a dynamic probit model of banking crises by maximum smoothly simulated likelihood. The inclusion of the lagged dependent variable among the regressors required the explicit consideration of unobserved heterogeneity and temporal serial correlation in the error structure.

We focused our attention on three main objectives. First, the identification of a set of domestic and global variables that significantly affect the probability of a banking crisis. In particular, we looked at the role played by debt variables in triggering or averting the occurrence of such crises by adding a number of debt indicators to the baseline specification. Second, we tested for the presence of leading effects from currency to banking crises. Third, we introduced dynamic elements into the probit model to account for the existence of intertemporal linkages between consecutive crises. The lagged dependent variable and the autocorrelated error term served this purpose.

Our main results can be summarised as follows:

- Macroeconomic fundamentals are important determinants of episodes of financial system distress in developing and emerging markets. Low domestic GDP growth, higher imports expenditures, high interest rates and an overvalued RER significantly increase the probability of observing a banking crisis. Lending booms have also a negative effect on the stability of financial systems.

- Debt variables are also key determinants of the probability of banking crises. The two indicators that are robust to changes in the model specification are short-term debt over reserves and the financing gap between debt service payments and exports revenues.

- Developing countries are very sensitive to changes in global macroeconomic conditions. An increase in the level of international interest rates or a world-wide deflation considerably increase the probability of a domestic financial crisis. Equally, negative terms-of-trade shocks —proxied by fuel inflation— are harmful to the stability of financial systems in countries that rely on exports of primary commodities.

- Bank-specific indicators can help detect financial problems. A bank run on deposits and an increase in the amount of foreign liabilities undermine the stability of financial systems.

- Countries that have experienced a banking crisis in the past are more prone to experience another crisis, while there is mixed evidence that currency crises lead to banking crises. The coefficient associated with the dummy for past currency crises becomes significant once we extend the time interval between currency and banking crises to one year. This result is important because it confirms the basic finding by Kaminsky and Reinhart (1999) — that currency crises tend to precede the *peak* of a banking crisis — but in a multivariate framework, which takes into account the concomitant effect of other potential determinants of banking crises.[47] Moreover, our analysis over the incidence of crises by decades shows a distinct leading effect of currency crises on banking crises occurred during the 1990s with respect to those occurred earlier in the 1970s. This finding gives support to the view that the nature of financial crises has changed over time.

- After controlling for this large number of potential explanatory variables, we find evidence of unobserved heterogeneity and autocorrelation in the error term structure, that may be capturing country-specific institutional differences that are persistent over time.

[47] Kaminsky and Reinhart (1999) use instead univariate analysis and apply a longer time window between currency and banking crises.

This final result highlights the importance of exploiting the full information content of a panel dataset, by using the appropriate panel estimations techniques and relaxing the hypothesis of i.i.d. errors. As shown in Table 3.7, the omission of the autocorrelated error component introduces *spurious state dependence* in the estimates of the lagged dependent variable. This finding is important because it may explain the different conclusions reached by some of the previous studies that use static probit/logit models to estimate the likelihood of banking crises.

Appendix A

The Sample Composition

The 92 emerging and developing countries included in our sample are:

Argentina, Armenia, Bangladesh, Barbados, Belarus, Belize, Benin, Bolivia, Brazil, Bulgaria, Burkina Faso, Burundi, Cambodia, Cameroon, Cape Verde, Central African Republic, Chad, Chile, China, Colombia, Congo Republic, Costa Rica, Côte d'Ivoire, Croatia, Czech Republic, Dominica, Dominican Republic, Ecuador, Egypt, El Salvador, Equatorial Guinea, Estonia, Fiji, Gabon, Gambia, Ghana, Grenada, Guatemala, Guinea-Bissau, Honduras, Hungary, Indonesia, Jamaica, Jordan, Kenya, Korea Republic, Lao PDR, Latvia, Lebanon, Lithuania, Macedonia, Madagascar, Malawi, Malaysia, Mali, Malta, Mauritania, Mauritius, Mexico, Moldova, Mongolia, Morocco, Myanmar, Nepal, Nicaragua, Niger, Nigeria, Panama, Paraguay, Peru, Philippines, Poland, Russia, Rwanda, Samoa, Senegal, Seychelles, Slovakia, South Africa, Sri Lanka, Tanzania, Thailand, Togo, Trinidad and Tobago, Tunisia, Turkey, Uganda, Ukraine, Uruguay, Vanuatu, Venezuela and Zimbabwe.

The dummy for countries depending on a single primary commodity for export earnings has been constructed following the IMF classification in Table 1 of Finance & Development (September 1999). The countries included in each category are:

Fuel exporters : Colombia, Congo Republic, Ecuador, Egypt, Equatorial Guinea, Gabon, Indonesia, Mexico, Nigeria, Russia, Trinidad and Tobago and Venezuela.

Metal exporters : Chile, Mauritania, Mongolia and Peru.

Food Exporters : Belize, Costa Rica, Ecuador, Honduras and Mauritius.

Raw materials exporters : Benin, Burkina Faso, Cambodia, Central African Republic, Chad, Equatorial Guinea, Gabon, Ghana, Indonesia, Lao PDR,

Latvia, Lebanon, Malawi, Mali, Myanmar, Paraguay, Peru and Zimbabwe.

Beverages exporters : Burundi, Cameroon, Colombia, Côte d'Ivoire, El Salvador, Ghana, Guatemala, Honduras, Kenya, Nicaragua, Rwanda and Uganda.

Appendix B

Tab. 3.9: Banking Crises *with* and *without* bailout

Crisis Date	*with*	*without*	Description
Argentina: 1991:2–1997:4			
1994:4	1	1	The Mexican devaluation led to bank runs which resulted in a 18% decline in deposits between Dec. 1994 and May 1995.
1995:1	1	1	About 45/205 institutions were closed/merged through Sept. 1995.
1995:2	1	1	
1995:3	1	1	
Armenia: 1994:2–1997:4			
1995:3	1	1	Sept. 1995: the banking crisis peaked, after the central bank had closed half of the active banks since Aug. 1994.
1996:1	1	0	A bank rehabilitation programme was launched in early 1996, when most of Armenia's 35 commercial banks were insolvent according to international accounting standards. Three of the largest problem banks were restructured.
Bangladesh: 1975:3–1997:4			
1990:3	1	0	Reform of the banking system. The IDA agreed to provide a credit of US$175m to enable commercial banks to operate more efficiently.
1990:4			
1991:1			Debt recovery, especially by the nationalised commercial banks, was very poor in 1991.

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Tab. 3.9: *continued*

Crisis Date	*with*	*without*	Description
1991:2	1	0	
1991:3	1	0	Overdue repayments to 2 development institutions (Bangladesh Shilpa Bank and Bangladesh Shilpa Rin Sengutha) amounted to US$444m.
1992:2	1	1	End of Apr. 1992: the government and the CB suspended the operations of the Bangladesh Commerce and Investment (BCI) company, and investment group which was acting as a deposit taker. As a result, there was a run against the National Credit LTD.
1997:2	1	0	Apr. 1997: following the stock market crash in Oct. /Nov. 1996, the government announced a liquidity injection of US$366m into the banking system to avoid a major crisis of confidence.
Barbados: 1972:1–1994:1			
Belarus: 1996:1–1997:4			
1996:1	1	1	Sept. 1995: Belarus Bank was merged by Presidential decree with state-owned Sberbank.
Belize: 1986:1–1997:4			
Benin: 1993:2–1997:4			
Bolivia: 1986:2–1997:4			
1987:3	1	1	Oct. 1987: the CB liquidated 2 of 12 commercial banks; 7 more reported large losses. Non-performing loans (NPL) reached 30% of banking assets.
1994:4	1	1	Nov. 1994: 2 banks with 11% of assets were closed. There were also deposit runs on other 3 banks.
1997:1	1	1	Feb. 1997: one bank was run and fully taken over by the government.

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Tab. 3.9: *continued*

Crisis Date	*with*	*without*	Description
Brazil: 1993:3–1997:4			
1994:3	1	1	July 1994: 17 small banks were liquidated, 3 private banks intervened and 5 state banks placed under special administration.
1994:4	1	0	Dec. 1994: the CB intervened in Banespa. Losses exceeded US$25bn.
Bulgaria: 1993:1–1997:4			
1993:4	1	0	Dec. 1993: the recapitalisation law passed in Dec. and l. t. ZUNK bonds issued to replace on the asset side of banks' balance sheet pre-1991 NPL to enterprises.
1994:3	1	0	Aug. 1994: the BNB intervened in one of the two major ailing banks.
1994:4	1	0	Late 1994: under a new bad loans law the authorities designed a program for restructuring the 2 major ailing banks.
1996:1	1	1	Between Jan. and May 1996 there have been intermittent runs on banks, including a drawdown of FX deposits from US$2.2bn to US$1.7bn. Liquidation procedures were initiated against 2 medium sized banks and 4 small banks.
Burkina Faso: 1984:1–1997:4			
1991:1	1	0	Early 1991: the banking system underwent significant restructuring. The National Development Bank was put under a government-controlled administration and received an injection of about CFAF15bn. 3 other banks (BFCI-B, UREBA and the investment bank CAI) were also put under temporary receivership and their NPL transferred to the government.
1993:4	1	1	Nov. 1993: the government liquidated the Development Bank and privatised other financial institutions.

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Tab. 3.9: *continued*

Crisis Date	*with*	*without*	Description
1994:4	1	0	Nov. 1994: another series of operations was carried out to restructure the balance sheets of the banks in difficulties. Additional NPL were transferred from 3 commercial banks to the government in exchange of 15 years maturity bonds. The total cost was estimated at CFAF48bn (equal to 4.7 per cent of GDP in 1994).
Burundi: 1987:1–1997:4			
1995:2	1	1	May 1995: the Meridian bank was closed.
1995:3	1	1	Sept. 1995: Meridian bank was liquidated.
Cambodia: 1996:1–1997:4			
Cameroon: 1975:1–1997:4			
1989:3	1	1	Liquidation of SCB in Jul. 1989; BCD and CAMBANK in Aug. 1989; PARIBAS in Sept. 1989.
1991:2	1	1	Apr. 1991: liquidation of the BIAOC.
1994:3	1	1	BNP closed down and handed over its 34 per cent shareholding in the country's largest network (BICIC) to the government for the price of one symbolic franc.
1995:3	1	0	Sept. 1995: the government appointed a monitor committee which took under forced administration the BIAO-Meridien Banque du Cameroon, after the liquidation of its main shareholder, the Bahamas-based Meridien International Bank Limited.
1996:3	1	1	Sept. 1996: the Commission Bancaire de l'Afrique Centrale announced that Banque Meridien BIAO Cameroon had been placed into liquidation.
1996:4	1	1	Oct. 1996: the Credit Agricole du Cameroon was hit by a confidence crisis and faced large scale witdrawals.

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Tab. 3.9: *continued*

Crisis Date	*with*	*without*	Description
1997:1	1	1	March 1997: closure of BICIC, Cameroon's leading commercial bank.
Cape Verde: 1994:4-1997:4			
Central African Republic: 1981:2-1997:4			
1990:4	1	0	Meridien Bank negotiated to take over most of the African network of the troubled Banque Internationale pour l'Afrique Occidentale (BIAO).
1995:1	1	1	March 1995: the financial crisis of the Meridien-BIAO bank led to a depositors' run on the commercial bank and a write-off a CFAF2.1bn claim on its failing parent bank in Luxemburg.
Chad: 1993:4-1997:4			
Chile: 1980:2-1997:4			
1981:4	1	0	Nov. 1981: following bank runs the government intervened in 4 banks and 4 *financieras* (non-bank financial insititutions with 33 per cent of outstanding loans) that lately failed.
1982:2	1	0	June 1982: almost all banks became insolvent and the CB offered to all domestic banks a l. t. repurchase agreement of bad loan portfolios.
1983:1	1	1	Jan. 1983: the authorities decided to take over 5 private banks and liquidate 3 other. The 5 banks included the 2 largest business groups which had expanded rapidly between 1975-81.

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Tab. 3.9: *continued*

Crisis Date	*with*	*without*	Description
1985:1	1	0	Jan. 1985: recapitalisation programme. Assets of intervened banks were transferred to a publicly owned holding company and the banks subsequently recapitalised. Shares of the recapitalised banks were then sold to the public at favorable prices. The quasi-fiscal losses of the CB amounted to 18 per cent of GDP in 1985.
China: 1987:1-1997:4			
1988:4	1	1	Financial institutions faced large withdrawals following political uncertainty.
1989:1	1	1	The governor of the People's Bank of China ordered the closure of all s. t. finance companies. Insurance firms and rural and urban credit cooperatives were investigated.
1990:4	1	0	The government launched a big drive to clear up triangular debts, releasing Rmb60bn and liquidating 60 per cent of the outstanding defaults.
Colombia: 1972:1-1997:4			
1982:3	1	0	Jul. 1982: the authorities had to assist a number of banks. *Banco Nacional* became the first of 6 major banks and 8 finance companies to be intervened. 4 of them were nationalised.
1997:1	1	0	Early 1997: a bank consolidation programme involved mainly commercial finance companies. The number of deposit-taking institutions declined as a consequence of 9 mergers, 3 interventions and 1 voluntary liquidation.
Congo Republic: 1980:1-1997:4			
1994:3	1	1	July 1994: the *Banque Nationale pour le Developpement du Congo* experienced a CFA Afr.10bn flight after its problems were revealed.

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Tab. 3.9: *continued*

Crisis Date	*with*	*without*	Description
1994:4	1	1	Oct. 1994: the Banque *Commerciale Congolaise* is put into liquidation. Dec. 1994: Regulators approved the liquidation of the *Banque Nationale pour le Developpment du Congo.*
1995:1	1	0	Feb. 1995: the government and the World Bank reached an agreement to reform Congo's troubled banking sector.
Costa Rica: 1980:4-1995:2			
1994:4	1	1	Dec. 1994: the government closed one of the largest state-owned banks.
Côte I'voire: 1980:1-1997:4			
1990:1	1	1	The crisis of the financial sector worsened in the first half of 1990. 4 main banks have been liquidated or closed down.
1990:2	1	1	June 1990: the holding company of the BIAO was liquidated. BNP handed over its shares to the Ivorian government on payment of one symbolic franc. A financial stabilisation plan was drafted by the BCEAO governor.
1991:3	1	1	Sept. 1991: The *Banque Nationale pour le Developpement Agricole* failed in Sept. , having failed to recoup more than US$ 201 mil. in bad debts and to rise capital. The government authorised its liquidation on Sept. 25.
Croatia: 1995:3–1997:4			
1995:4	1	0	Nov. 1995: The 5^{th} largest bank entered rehabilitation.
1996:3	1	1	July 1996: Privredna, the largest Croatian bank, was taken over by the Rehabilitation Agency.
Czech Republic: 1994:2–1997:4			
1994:2	1	1	June 1994: liquidation of Kreditni and Prumyslova Banka.

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Tab. 3.9: *continued*

Crisis Date	*with*	*without*	Description
1995:3	1	0	Aug. 1995: liquidation of *AB Banka* and *Ceska Banka*. The CNB produced a comprehensive programme for consolidating small banks in order to prevent a domino effect in this sector. 15/18 banks were included in the programme with radical solutions adopted for 9 of them.
Dominica: 1990:1–1997:4			
Dominican Republic: 1992:2–1997:4			
1996:2	1	0	April 1996: the Monetary Board intervened in the third largest bank, which represented 7 per cent of the total assets of the banking system.
Ecuador: 1991:2–1997:4			
Egypt: 1972:–1997:4			
1993:4	1	0	Late 1993: the authorities developed a plan for selling the public sectors' holding in joint venture banks and for privatising one of the four large public sector banks.
El Salvador: 1978:1–1994:2			
1990:4	1	0	Nov. 1990: a new legislation was enacted to restructure and privatise the financial system. The *Fondo de Sanamiento* was created to support the process.
Equatorial Guinea: 1990:1–1997:4			
Estonia: 1994:1–1997:4			
1994:3	1	0	Aug. -Sept. 1994: the BOE lent the equivalent of 6 per cent of base money to the troubled Social Bank to meet large deposit withdrawals. The activities of the bank were suspended in mid-August and then re-opened, with a liquidity intervention of EEK231m.

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Tab. 3.9: *continued*

Crisis Date	*with*	*without*	Description
1994:4	1	0	Oct. 1994: the BOE merged the Social Bank with another insolvent bank, the Development Bank.
1995:1	1	0	March 1995: the BOE concluded agreements to sell parts of Social Bank and convert the reminder to a loan recovery agency. All the depositors accounts were transferred to other banks.
Gabon:1987:4–1996:4			
Gambia: 1980:1–1991:4			
1985:1	1	0	1985: restructuring of the most important commercial bank, the Gambian Commercial and Development Bank.
1989:1	1	1	1989: liquidation of the Agricultural Development Bank.
1991:3	1	0	July 1991: offering for sale of the Gambian Commercial and Development Bank.
Ghana: 1980:1–1991:4			
1989:3	1	0	July 1989: adoption of a comprehensive restructuring plan for banks to take over NP assets from the banks' balance sheets.
1990:2	1	0	May 1990: replacement of banks NPL with government bonds. The total cost of the intervention reached 6 per cent of GDP.
1990:4	1	0	Dec. 1990: replacement of NP claims on state-owned enterprises by the financially distressed banks with Bank of Ghana bonds.
1991:1	1	0	March 1991: replacement of banks' NPL with government bonds.
Grenada: 1988:4–1997:4			

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Tab. 3.9: *continued*

Crisis Date	*with*	*without*	Description
Guatemala: 1978:2–1997:4			
Guinea-Bissau: 1991:2–1995:4			
Honduras: 1984:2–1997:4			
Hungary: 1989:1–1997:4			
1991:4	1	0	End 1991: the state granted commercial banks guarantees for doubtful loans worth 10bn forints.
1993:1	1	0	March 1993: a loan consolidation programme was carried out. Banks with a capital adequacy ratio lower than $7\frac{1}{4}$ per cent sold to the government claims on domestic enterprises that had been classified as 'bad'. In exchange they received credit consolidations bonds. The total cost of the operation was 4.2 per cent of 1992 GDP.
1993:4	1	0	End of 1993: the government purchased a significant share of banks claims against a selected group of large-state enterprises and transferred these loans to 2 state asset management companies. 8 banks received a capital injection of FT114bn.
1994:2	1	0	May 1994: the 3 largest banks received a capital injection sufficient to rise their capital asset ratio to 4 per cent.
1994:4	1	0	End 1994: the state proceeded with the third and final stage of the recapitalisation of the 3 largest banks to achieve the 8 per cent capital asset ratio.
1997:1	1	1	March 1997: bank run on Postbank. As a result, in the 5 months of 1997, real non-cash M3 declined by 6 per cent.
Indonesia: 1982:2–1997:4			
1990:3	1	1	Sept. 1990: failure of PT Bank Duta.
1992:4	1	1	Nov. 1992: a large bank (Bank Summa) collapsed and triggered runs on 3 smaller banks.

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Tab. 3.9: *continued*

Crisis Date	*with*	*without*	Description
1997:4	1	1	31 Oct. 1997: 16 commercial banks were closed. Mid Dec. '97: deposit runs on banks accounting for 1/2 of the banking system.
Jamaica: 1982:2–1991:1			
Kenya: 1977:1–1997:4			
1988:1	1	0	Early 1988: start of a major restructuring programme of the financial sector.
1993:1	1	1	By early 1993 about 1/3 of banks (accounting for about 63 per cent of total bank assets) had been identified as distressed.
1993:2	1	0	The stability of the financial sector was restored through a rehabilitation programme launched in April 1993. This involved the closure of 4 commercial banks, the replacement of the management of 2 other banks and the liquidation of 8 non-bank financial institutions.
1993:4	1	0	Oct. 1993–Sept. 1994: a new one-year economic programme included further measures to ensure a sound banking system and restructure the National Bank of Kenya, the largest state bank.
1994:1	1	0	
1994:2	1	0	
1994:3	1	0	
1995:2	1	1	June 1995: the state participation into the National Bank of Kenya was reduced below 50 per cent. The local subsidiary of Merdien BIAO was closed.

continued on the next page

Tab. 3.9: *continued*

Crisis Date	*with*	*without*	Description
Korea Republic: 1977:2–1997:4			
1997:4	1	1	Dec. 1997: 14 banks are suspended, 2 large commercial banks taken over by the government.
Lao PDR: 1995:2–1997:4			
Latvia: 1994:4–1997:4			
1995:1	1	1	15 licences were revoked in the first 7 months of 1995. The subsequent closure of one of the largest bank (accounting for about 30 per cent of deposits) and two other banks triggered a bank crisis in the spring of 1995.
1995:2	1	1	
Lebanon: 1991:1–1997:4			
Lithuania: 1994:2–1997:4			
1995:4	1	1	Dec. 1995: the 4^{th} largest bank was closed, 12 small banks were liquidated. Large deposit withdrawals took place at the end of 1995.
Macedonia: 1995:2–1997:4			
1997:1	1	1	March 1997: failure of the largest saving house, TAT, which was found to have about DM100m in unreported deposits.
Madagascar: 1976:1–1997:4			
1995:4	1	0	End 1995: expatriated administrators were appointed to take over the management of both public banks (the National Bank for Rural Development and the National Bank of Commerce) that accumulated losses of FMG114bn (13 per cent of their credit portfolios).
Malawi: 1995:1–1997:4			

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Tab. 3.9: *continued*

Crisis Date	*with*	*without*	Description
Mali: 1988:4–1994:2			
1988:4	1	0	In 1988–89 steps were taken to restructure the *Banque du Developpement du Mali*, including financial restructuring involving CFAF62.5bn worth of NPL. As a result, the BDM-SA was stablished on June 30, 1989 as a mixed capital company in which the Government holds 20 per cent of the shares.
1989:1	1	0	
1989:2	1	0	
Mauritania: 1986:4–1997:4			
hline 1993:2	1	1	June 1993: the Development Bank was closed.
1993:3	1	0	Late 1993: 3 banks were recapitalised on the basis of external audits. The budgetary impact of the programme was of 7.5 per cent of GDP.
1993:4	1	0	
1994:3	1	1	July 1994: the Loan Recovery Agency took over the loan portfolio of the *Union des Banques de Developpement* and the *Banque Nationale de Mauritaine.*
Mauritius: 1991:2–1997:4			
Mexico: 1980:2–1997:4			
1982:3	1	1	Sept. 1982: the government took over the troubled banking system, nationalising private banks by Presidential Decree.
1994:3	1	0	Sept. 1994: the authorities intervened in 2 banks.
1995:1	1	0	Jan. 9, 1995: the authorities announced a scheme to recapitalise banks with capital ratio below the 8 per cent minimum. At the end of March, 8 banks had obtained assistance from the deposit-guarantee fund (FOBAPROA) under the temporary capitalisation programme.

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Tab. 3.9: *continued*

Crisis Date	*with*	*without*	Description
Moldova: 1997:1–1997:4			
Mongolia: 1994:1–1997:4			
1996:4	1	0	Dec. 1996: the Mongolian financial system underwent major restructuring. 2 large insolvent banks, which together accounted for almost 50 per cent of the banking system assets, were closed. A debt recovery agency was also established.
Myanmar: 1992:2–1997:4			
Nepal: 1978:2–1997:4			
1988:1	1	0	Early 1988: the reported arrears of 3 banks (95 per cent of the financial system) averaged 29 per cent of all assets.
Nicaragua: 1994:1–1997:4			
Niger: 1978:3–1997:4			
1988:2	1	1	In the late 1980's, the Niger's banking system faced a severe solvency crisis. The *Caisse Nationale de Credit Agricole* was liquidated on June 1988.
1990:3	1	1	Sept. 1990: the decision was taken to liquidate the *Banque du Developpement de la Republique du Niger.*
1994:3	1	1	July 1, 1994: closure and complete liquidation of the *Caisse Nationale de Credit Agricole.* The unrecovered portion of its portfolio was transferred to the Treasury.
1994:4	1	0	Second-half of 1994: the Meridien BIAO was required to consolidate its own resource base via a capital increase.
Nigeria: 1994:1–1997:1			

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Tab. 3.9: *continued*

Crisis Date	*with*	*without*	Description
1994:4	1	1	By the end of 1994 the number of technically insolvent commercial and merchant banks had risen to 34 and an additional 8 banks were deemed illiquid. Combined, they accounted for 10 per cent of the deposits liabilities of the banking system.
Panama: 1979:1–1997:4			
1988:1	1	1	A bank holiday started in March 1988 and lasted for 9 weeks. As a result of uncertainty and loss of confidence caused by a political crisis, public banks were particularly affected by a loss of deposits and a rapid deterioration in their loan portfolios. 15 banks ceased operations.
1988:2	1	1	
Paraguay: 1978:4–1995:3			
1995:2	1	0	A banking crisis erupted in May 1995 following a highly publicised accounting discrepancy in the value of local currency held in the CBP's vaults. This event shook public confidence. The 3^{rd} and 4^{th} largest commercial banks (*Banco General* and Bancopar) were unable to meet their obligations and were intervened by the CBP. Following the first intervention, there was a massive withdrawal of deposits from private domestic banks. In June, Bancosur and another finance company were intervened.
1995:3	1	0	In July a small commercial bank, *Banco Mercantil*, 2 finance companies and a saving and loans association were intervened. All together these banks amounted to over 15 per cent of the financial system's deposits. Government intervention had been estimated to amount to 4 per cent of GDP by the end of 1995.
Peru: 1990:4–1995:2			
Philippines: 1978:2–1997:4			

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Tab. 3.9: *continued*

Crisis Date	*with*	*without*	Description
1981:1	1	1	Jan-Dec. 1981: a crisis of confidence began when fraud in the commercial paper market resulted in large-scale defaults by borrowers in this market and in bankruptcies among a number of non-financial intermediaries and their holding companies.
1981:2	1	1	
1981:3	1	1	
1981:4	1	1	
1982:1	1	0	Jan. 1982–Sept. 1983: intensification of government intervention to non-financial and financial institutions. The government increased its emergency lending and equity contributions, arranged the takeover of troubled private banks by public financial institutions.
1982:2	1	0	
1982:3	1	0	
1982:4	1	0	
1983:1	1	0	
1983:2	1	0	
1983:3	1	0	
1983:4	1	1	Oct. 1983: financial panic was provoked by the authorities announcement of a moratorium of their external debt payments to foreign commercial banks, resulting in a series of runs on the banks.
1986:4	1	0	Nov. 1986: a further contraction of banking system credit occurred when some 30 per cent of the banking system's total assets, representing the NPL of 2 government-owned banks (the Development Bank of the Philippines and the Philippines National Bank), were transferred to a government agency.

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Tab. 3.9: *continued*

Crisis Date	*with*	*without*	Description
1992:4	1	0	Dec. 1992: a comprehensive commercial bank debt restructuring programme was launched.
Poland: 1987:2–1997:4			
1991:4	1	0	In late 1991, 1 bank was privatised and 7 out of 9 treasury owned banks (with 90 per cent share of total credit market) were recapitalised.
1993:3	1	0	A law on Financial Restructuring of Enterprises and Banks became effective in March 1993 and established the basis to recapitalise banks by transferring treasury bonds to 7 of them in Sept. 1993. This recapitalisation amounted to ZL11tn.
1993:4	1	0	Dec. 1993: the PKO-SA, which deals with consumer foreign deposits and transactions and the Bank for Food Economy (BGZ) were provided with Treasury issued recapitalisation bonds.
1995:1	1	0	Since its inception in Feb. 1995, the Bank Guarantee Fund assisted 3 commercial banks and 88 cooperative banks in their bankruptcy procedures.
Russia: 1995:2–1997:4			
1995:2	1	1	A total of 110 banks in 1994 and 96 banks in the first 8 months of 1995 were closed.
1995:3	1	1	The interbank crisis in Aug. 1995 demonstrated the liquidity problems of Russian banks.
Rwanda: 1978:1–1997:4			
Samoa: 1980:1–1995:4			
Senegal: 1976:1–1995:4			
1989:2	1	0	June 1989: start of a restructuring plan for the *Union Senegalaise de Banques* (USB), which was completed in the following quarter.

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Tab. 3.9: *continued*

Crisis Date	*with*	*without*	Description
1989:3	1	0	
1989:4	1	0	Oct. 1989: plans to recapitalise 4 state banks were announced.
1990:3	1	1	Sept. 1990: the *Banque Senegalo-Kouweitienne* (BSK) had its operating licence revoked by the regional CB. The bank closed after 1 year of suspension.
1991:3	1	1	July 1991: the Bank of Credit and Commerce International Senegal (CBCCI) was closed.
Seychelles: 1982:2–1996:3			
Slovakia: 1994:2–1997:4			
1997:4	1	1	Dec. 1997: the 3^{th} largest bank, (IRB or Investment and Development Bank) was taken under forced administration by the NBS. Credit was provided to the bank to enable it to pay its depositors.
South Africa: 1996:1–1997:4			
Sri Lanka: 1977:1–1997:4			
1993:1	1	0	March 1993: bonds equivalent to 4.8 per cent of GDP were issued to recapitalise 2 state-owned commercial banks with NPL equal to 35 per cent of their portfolios.
1996:4	1	0	As the guaranteed lending turned NP, the government was forced in 1996 to place bonds in the state banks equivalent to 1.8 per cent of GDP.
1997:1	1	0	March 1997: the first two-year Treasury bond was launched by the CB. These securities were issued primarily to state-owned saving institutions such as the National Saving Bank and the Employees Prevident Fund.
Tanzania: 1978:1–1997:4			

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Tab. 3.9: *continued*

Crisis Date	*with*	*without*	Description
1992:1	1	0	Early 1992: following a comprehensive audit of the National Bank of Commerce —the dominant state bank— and the Cooperative and Rural Development Bank, a large amount of their NPL was transferred to the new Loans and Advances Realisation Trust and replaced by government bonds.
1994:1	1	0	Beginning of 1994: the authorities began the restructuring of the 3 existing state commercial banks, beginning with the NBC, to be followed by the CRDB and the People's Bank of Zanzibar.
1995:2	1	1	Mid 1995: the Tanzania Housing Bank was closed.
1997:3	1	0	July 1997: the government decided to split the National Bank of Commerce into 2 banks, the NBC (1997) and the NMB and to create a holding company to manage the residual assets and liabilities of the former NBC.
Thailand: 1977:2–1997:4			
1979:1	1	0	Early 1979: following the stock market crash, one of the largest finance companies failed and the bail-out of the financial sector began.
1983:4	1	0	Oct. 1983: large losses in a finance company led to runs and government intervention.
1984:1	1	0	Between the end of 1983 and 1985 19 finance companies were closed, accompanied by runs. Throughout the period 1984–87, weakness in the financial sector resulted in regulatory intervention or in the CB take over, soft lending, recapitalisation and other support arrangements involving 5 banks that accounted for about 25 per cent of total assets of the system.
1984:2	1	0	
1984:3	1	0	
1984:4	1	0	

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Tab. 3.9: *continued*

Crisis Date	*with*	*without*	Description
1985:1	1	0	
1985:2	1	0	
1985:3	1	0	
1985:4	1	0	
1986:1	1	0	
1986:2	1	0	
1986:3	1	0	
1986:4	1	0	
1987:1	1	0	
1987:1	1	0	March to June, 1987: 97 finance companies received liquidity support from the CB.
1997:2	1	1	June 1997: the CB suspended the activity of 16 finance companies.
1997:3	1	1	July 1997: the currency devaluation was accompanied by a bank run.
1997:4	1	1	Dec. 1997: closure of 56 previously suspended finance companies.
Togo: 1977:3–1995:3			
1988:1	1	0	Jan. 1988: a first programme for restructuring the *Banque Togolaise de Developpement* was launched. CFAF1bn came from the government.
1990:3	1	1	Sept. 1990: the government liquidated the *Caisse Nationale de Credit Agricole.*

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Tab. 3.9: *continued*

Crisis Date	*with*	*without*	Description
1991:2	1	0	April 1991: a second tranche disbursed by the government to recapitalise BTD.
1992:4	1	1	Nov. 1992: most banks were closed for more than 6 months, until the summer of 1993, during which time the quality of the assets deteriorated substantially and liquidity in the system was reduced by almost one half.
1993:1	1	1	
1993:2	1	1	
Trinidad & Tobago:1985:2–1997:4			
Tunisia: 1988:4–1997:4			
1991:4	1	0	End 1991: comprehensive prudential regulation introduced strict standards for loan classification and provisioning. As a result most of the commercial banks were undercapitalised.
1993:3	1	0	Mid 1993: the CB set detailed terms of reference for external audits and off-site reporting requirements. Intervention in favor of a private commercial bank which had lost a significant proportion of its deposits from public enterprises over a few days.
1996:4	1	0	End of 1996: the CB took over a stock of NPL from the Agricolture Bank (BNA), the largest public sector bank, to 2 public enterprises in charge of marketing subsidised foodstuffs.
Turkey: 1987:3–1997:4			
1991:1	1	1	Jan. 1991: the start of the Persian war led to massive withdrawals and a run on banks prompting the government to guarantee all deposits.
1994:2	1	1	Deposit runs in the spring of 1994 resulted in the closure of 3 medium-sized banks. The government introduced full deposit insurance in May 1994.

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Tab. 3.9: *continued*

Crisis Date	*with*	*without*	Description
Uganda: 1984:1–1997:4			
1993:1	1	1	Early 1993: a small bank failed. Several other banks were in difficulties or insolvent, including state-owned banks accounting for more than 40 per cent of the banking system total assets.
1995:1	1	0	First half of 1995: a credit recovery agency, the Non-Performing Assets Recovery Trust, was established to take over the UCB's NPL as part of the restructuring operations of the UCB.
1995:2	1	0	
Ukraine: 1996:2–1997:4			
Uruguay: 1982:1–1997:4			
1982:1	1	0	Early 1982: the *Banco Hipotecario* received substantial financial assistance from the government.
1982:4	1	0	From late 1982 to early 1984 the CBU purchased commercial banks' NPL with dollar denominated bonds and promissory notes under the Portfolio Purchase Scheme linked to bank intervention.
1983:1	1	0	
1983:2	1	0	
1983:1	1	0	
1983:4	1	0	
1984:1	1	1	Beginning 1984: the Banco de Plata was liquidated with deposit being reimbursed.
1984:2	1	0	Apr. 1984: the National Office of Asset Recovery was created to try to recover the banks' portfolios of NP assets.

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Tab. 3.9: *continued*

Crisis Date	*with*	*without*	Description
1985:2	1	1	May 1985: *Banco de Italia*, one of the 3 largest private banks, was taken over. The CBU ordered the intervention and the *Banco de la República Oriental del Uruguay* (BROU) assumed the majority of the equity.
1985:3	1	1	July 1985: the *Banco Pan de Azúcar* was taken over after it became insolvent.
1987:1	1	0	March 1987: *Banco Comercial* was recapitalised by the BROU. At the end of the operation roughly 90 per cent of its capital was held by BROU. This and the previous interventions led to a de facto nationalisation of the banking sector.
1989:2	1	0	June 1989: the government launched and extensive reform of the financial sector. The main objective have been the rehabilitation of 3 of the failed banks absorbed by the BROU.
Vanuatu: 1996:1–1997:4			
Venezuela: 1973:2–1997:4			
1982:4	1	1	The *Banco de los Trabajadores* had to be taken over by the government in late 1982.
1993:4	1	1	Oct. 1993: rumors spread about the distressed financial situation of *Banco Latino*, the second largest bank in terms of deposits. The bank had to meet major deposit withdrawals through large-scale asset sales and borrowing from the CBV.
1994:1	1	1	Jan. 1994: *Banco Latino* was closed.
1994:2	1	0	Early June 1994: 8 distressed financial institutions, with about 21 per cent of total deposits, had to be intervened. By that date a total of 6 per cent of 1994 GDP had already been injected into those banks.
1994:3	1	1	Jul-Aug. 1994: rumors about the financial situation of 2 large banks, *Banco Consolidado* and *Banco de Venezuela*, led to deposit runs.

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Tab. 3.9: *continued*

Crisis Date	*with*	*without*	Description
1994:4	1	1	Dec. 1994: the government decided to close *Banco del Progreso.*
1995:1	1	1	Feb. 1995: 3 other banks had to be closed and their deposits migrated to the banks nationalised during the crisis.

Zimbabwe: 1981:1–1997:4

Notes: banking crises *without* bailout are defined as cases of either a bank run, or a license withdrawal, closure of one or more financial institutions, or the adoption of emergency measures like a freeze of deposits. Banking crises *with* bailouts include government's rescue packages. References: Balino and Sundararajan (1990); Doe (1995); Ebrill (1994); Economist (various issues); Galbis (1995); García-Herrero (1997); IMF (Various issues); Lindgren, García, and Saal (1996); Moser, Rogers, and van Till (1997); Nascimento (1990); Pérez-Campanero and Leone (1991); Turtelboom (1991); Valdés (1994).

Appendix C

Tab. 3.10: Episodes of Currency Crises

Country	Sample size	Crisis date	*10% cut-off*	*15% cut-off*
Argentina	1991:2–1997:4			
Armenia	1994:2–1997:4	1994:4	1	1
Bangladesh	1975:3–1997:4			
Barbados	1972:1–1994:1			
Belarus	1996:1–1997:4	1996:3	1	1
		1997:1	1	1
Belize	1986:1–1997:4			
Benin	1993:2–1997:4	1994:1	1	1
Bolivia	1986:2–1997:4			
Brazil	1993:3–1997:4			
Bulgaria	1993:1–1997:4	1993:4	1	0
		1994:1	1	1
		1994:4	1	0
		1996:2	1	1
		1996:3	1	1
		1997:1	1	1
		1997:3	1	0
Burkina Faso	1984:1–1997:4	1991:2	1	0
		1994:1	1	1

continued on the next page

Tab. 3.10: *continued*

Country	Sample size	Crisis date	*10% cut-off*	*15% cut-off*
Burundi	1987:1–1997:4	1988:2	1	0
		1991:3	1	0
Cambodia	1996:1–1997:4	1997:4	1	0
Cameroon	1975:–1997:4	1982:3	1	0
		1991:2	1	0
		1994:1	1	1
Cape Verde	1994:4–1997:4			
Central African Rep.	1981:2–1997:4	1982:3	1	0
		1991:2	1	0
		1994:1	1	1
Chad	1993:4–1997:4	1994:1	1	1
Chile	1980:2–1997:4	1982:3	1	1
		1984:4	1	1
China	1987:1–1997:4	1990:1	1	1
		1994:1	1	1
Colombia	1972:1–1997:4	1985:2	1	0
		1997:4	1	0
Congo Rep.	1980:1–1997:4	1982:3	1	0
		1991:2	1	0
		1994:1	1	1

continued on the next page

Tab. 3.10: *continued*

Country	Sample size	Crisis date	*10% cut-off*	*15% cut-off*
Costa Rica	1980:4–1995:2	1981:4	1	1
Côte D'Ivoire	1980:1–1997:4	1982:3	1	0
		1991:2	1	0
		1994:1	1	1
Croatia	1995:3–1997:4			
Czech Rep.	1994:2–1997:4			
Dominica	1990:1–1997:4			
Dominican Rep.	1992:2–1997:4			
Ecuador	1991:2–1994:4	1992:3	1	0
		1992:4	1	0
Egypt	1972:1–1997:4			
El Salvador	1978:1–1994:2			
Equatorial Guinea	1990:1–1997:4	1991:2	1	0
		1994:1	1	1
Estonia	1994:1–1997:4			
Fiji	1981:1–1986:4			
Gabon	1987:4–1996:4	1991:2	1	0
		1994:1	1	1
Gambia	1980:1–1991:4	1981:2	1	0

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Tab. 3.10: *continued*

Country	Sample size	Crisis date	*10% cut-off*	*15% cut-off*
		1984:2	1	1
		1991:2		
Ghana	1984:3–1997:4	1984:4	1	1
		1986:1	1	1
		1988:3	1	1
		1992:4	1	0
		1993:3	1	0
		1994:1	1	1
		1995:4	1	0
Grenada	1978:2–1997:4			
Guatemala	1978:2–1997:4	1986:3	1	1
		1989:4	1	0
		1990:1	1	1
Guinea-Bissau	1991:2–1995:4	1991:4	1	1
		1992:3	1	1
		1993:3	1	0
		1994:4	1	0
		1995:3	1	0
Honduras	1984:2–1997:4	1990:2	1	1
		1990:4	1	1

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Tab. 3.10: *continued*

Country	Sample size	Crisis date	*10% cut-off*	*15% cut-off*
		1993:3	1	0
Hungary	1989:1–1997:4	1989:2	1	0
Indonesia	1982:2–1997:4	1983:2	1	1
		1986:4	1	1
		1997:3	1	0
		1997:4	1	1
Jamaica	1982:2–1991:1	1984:4	1	0
		1989:4	1	1
		1990:4	1	1
Kenya	1977:1–1997:4	1981:4	1	0
		1983:1	1	0
		1991:2	1	0
		1993:2	1	1
		1995:2	1	0
Korea Republic	1977:2–1997:4	1997:4	1	1
Lao PDR	1995:2–1997:4	1995:3	1	0
		1997:3	1	1
		1997:4	1	1
Latvia	1994:4–1997:4			

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Tab. 3.10: *continued*

Country	Sample size	Crisis date	*10% cut-off*	*15% cut-off*
Lebanon	1991:1–1997:4	1992:2	1	1
Lithuania	1994:2–1997:4			
Macedonia	1995:2–1997:4	1997:3	1	1
Madagascar	1976:1–1997:4	1982:2	1	0
		1983:4	1	0
		1984:2	1	0
		1987:3	1	1
		1988:3	1	0
		1994:2	1	1
		1997:1	1	0
Malawi	1995:1–1997:4			
Mali	1988:4–1994:2	1991:2	1	0
		1994:1	1	1
Malaysia	1976:1–1997:4	1997:3	1	0
		1997:4	1	1
Malta	1973:1–1997:4			
Mauritania	1986:4–1997:4			
Mauritius	1991:2–1997:4	1991:2	1	0
Mexico	1980:2–1997:4	1982:1	1	1

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Tab. 3.10: *continued*

Country	Sample size	Crisis date	*10% cut-off*	*15% cut-off*
		1982:3	1	1
		1983:1	1	1
		1985:3	1	1
		1995:1	1	1
		1995:4	1	1
Moldova	1997:1–1997:4			
Mongolia	1994:1–1997:4	1996:4	1	1
Morocco	1977:1–1997:4	1983:1	1	0
		1991:2	1	0
Myanmar	1992:2–1997:4			
Nepal	1978:2–1997:4	1986:1	1	0
		1991:3	1	1
Nicaragua	1994:1–1997:4			
Niger	1978:3–1997:4	1982:3	1	0
		1991:2	1	0
		1994:1	1	1
Nigeria	1994:1–1997:4			
Panama	1979:1–1997:4			

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Tab. 3.10: *continued*

Country	Sample size	Crisis date	*10% cut-off*	*15% cut-off*
Paraguay	1978:4–1995:3	1984:2	1	1
		1985:2	1	1
		1987:1	1	1
		1989:2	1	1
Peru	1990:4–1995:2	1991:2	1	1
		1991:4	1	1
Philippines	1978:2–1997:4	1983:4	1	1
		1984:3	1	1
		1990:4	1	0
		1997:3	1	0
		1997:4	1	1
Poland	1987:2–1997:4	1988:1	1	1
		1989:2	1	1
		1989:4	1	1
		1992:2	1	0
		1993:3	1	0
Russia	1995:2–1997:4			
Rwanda	1978:1–1997:4	1994:1	1	1
		1995:2	1	1

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Tab. 3.10: *continued*

Country	Sample size	Crisis date	*10% cut-off*	*15% cut-off*
Samoa	1980:1–1995:4	1983:2	1	0
		1984:3	1	1
Senegal	1976:1–1995:4	1982:3	1	0
		1991:2	1	0
		1994:1	1	1
Seychelles	1982:2–1996:3			
Slovakia	1994:2–1997:4			
South Africa	1996:1–1997:4	1996:2	1	0
Sri Lanka	1977:1–1997:4	1977:4	1	1
Tanzania	1978:1–1997:4	1982:2	1	0
		1983:3	1	1
		1984:3	1	1
		1986:3	1	1
		1988:1	1	1
		1988:4	1	1
		1989:4	1	0
		1990:1	1	1
		1991:2	1	0
		1992:2	1	1
		1993:3	1	1

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Tab. 3.10: *continued*

Country	Country	Sample size	Crisis date	*10% cut-off*	*15% cut-off*
Thailand	Thailand	1977:2–1997:4	1997:3	1	1
Togo	Togo	1977:3–1995:3	1982:3	1	0
			1991:2	1	0
			1994:1	1	1
Trinidad	Trinidad & Tobago	1985:2–1997:4	1986:1	1	1
Tunisia	Tunisia	1988:4–1997:4	1991:2	1	0
			1993:1	1	0
Turkey	Turkey	1987:3-1997:4	1988:1	1	1
			1991:1	1	1
			1991:2	1	1
			1992:1	1	0
			1992:4	1	0
			1993:3	1	1
			1994:1	1	1
			1994:2	1	1
			1995:4	1	0
			1996:1	1	1
			1996:4	1	1
Uganda	Uganda	1984:1–1997:4	1984:3	1	1
			1984:4	1	1

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Tab. 3.10: *continued*

Country	Sample size	Crisis date	*10% cut-off*	*15% cut-off*
		1985:4	1	1
		1989:1	1	0
		1990:3	1	1
		1991:3	1	1
		1992:2	1	1
Ukraine	1996:2–1997:4			
Uruguay	1982:1–1997:4	1982:4	1	1
		1983:1	1	1
		1983:4	1	0
		1984:1	1	1
		1984:4	1	1
		1984:4	1	1
		1985:1	1	1
		1989:4	1	1
		1990:2	1	1
Vanuatu	1996:1–1997:4			
Venezuela	1973:2–1997:4	1987:1	1	1
		1989:2	1	1
		1992:4	1	0
		1994:2	1	1

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Tab. 3.10: *continued*

Country	Sample size	Crisis date	*10% cut-off*	*15% cut-off*
		1996:1	1	1
Zimbabwe	1981:1–1997:4	1983:1	1	1
		1984:3	1	0
		1991:2	1	0
		1991:3	1	1
		1991:4	1	1
		1993:1	1	1
		1994:1	1	1
		1997:4	1	1

Appendix D

Tab. 3.11: Data Sources and Definitions

Variable Name	Data Sources and Definitions	Frequency
	Macroeconomic Variables	
Real GDP Growth	World Bank, World Development Indicators (WDI). GDP at constant 1990 prices, in national currency (n.c.). Growth rates.	Interpolated from annual data by applying cubic spline techniques.
Inflation	International Monetary Fund - International Financial Statistics (IFS). Growth rate of the Consumer Price Index (CPI). IFS line 64.	Quarterly.
Real deposit interest rate	IMF. Deposit interest rate (IFS line 60l) minus CPI inflation (IFS line 64).	Quarterly. We stretched back some of the series by applying the growth rate of the discount interest rate when deposit rates were not available.
Growth of total exports of goods and services over GDP	IMF. Total exports in US$ (IFS lines *7aad* + *78add*), divided by GDP at current prices in US$ from the WDI series. Growth rates.	Quarterly where available, otherwise interpolated from the correspondent annual series by applying a linear technique.
Growth of total imports of goods and services over GDP	IMF. Total imports in US$ (IFS lines *78abd*+*78aed*), divided by GDP at current prices in US$ from WDI. Growth rates.	Quarterly where available, otherwise interpolated from the correspondent annual series by applying a linear technique.

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Tab. 3.11: *continued*

Variable Name	Data Sources and Definitions	Frequency
Real exchange rate	Authors' calculations. We used the nominal bilateral exchange rate against the US$ (IFS line rf). We converted these series into real exchange rates using the CPI (IFS line 64). To construct the undervaluation/overvaluation measure we first calculated the Hodrick-Prescot trend and then used the deviations from it. A decrease in this indicator indicates an increasing overvaluation of the real exchange rate.	Quarterly.
	Monetary Variables	
Foreign exchange reserves over total imports	IMF. Reserves of the Central Bank (IFS line 1d.d), divided by total imports (IFS lines $78abd + 78aed$). In US$	Quarterly.
Growth of total domestic credit	IMF. Total domestic credit (IFS line 32), divided by GDP at current prices. In n.c. and growth rates.	Quarterly.
Growth of credit to the private sector over GDP	IMF. Claims on the private sector (IFS line 32d), divided by GDP at current prices. In n.c. and growth rates.	Quarterly.
Growth of credit to the government over GDP	IMF. Net claims on the central government (IFS line 32an), divided by GDP at current prices. In n.c. and growth rates.	Quarterly.
	Dummy Variables	
Exchange rate regime	IMF. Exchange Rate Arrangements and Restrictions Reports. Dummy=1 if the exchange rate regime is classified as independently or managed floating, 0 otherwise.	Quarterly. We could identify the exact quarter of a regime change from the information provided by the annual IMF reports.

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Tab. 3.11: *continued*

Variable Name	Data Sources and Definitions	Frequency
Capital account restrictions dummy	Dummy variable = 1 if there are restrictions on the capital account. Dummy = 0 if there are no restrictions on the capital account.	Quarterly.
Financial liberalisation	Dummy variable = 1 if domestic interest rates are liberalised. Dummy = 0 if domestic interest rates are not liberalised or information on the process of financial liberalisation was not found.	Quarterly.
	Global Variables	
Change in the US interest rate	IMF. IFS line 60b.	Quarterly.
US growth	IMF. US nominal GDP (IFS line 99b). Growth rates.	Quarterly.
US inflation	IMF. Based on the US CPI index (IFS line 64).	Quarterly.
Change in the world interest rate	Author's computations. The world interest rate is obtained as a weighted average of the interest rates of France, Germany, Japan, Switzerland, the UK and the US. IFS line 60b. The weights correspond to the shares of total external debt denominated in these currencies.	Quarterly.
Fuel inflation	IMF. Commodity price index (1990 = 100) of fuel (petroleum). IFS line 001.76aad. Growth rates.	Quarterly.
Metals inflation	Commodity price index (1990 = 100) of metals (aluminum, copper, iron, lead, nickel, tin and zinc). IFS line 001.76ayd. Growth rates.	Quarterly.

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Tab. 3.11: *continued*

Variable Name	Data Sources and Definitions	Frequency
Food inflation	Commodity price index (1990 = 100) of food (bananas, cereals, meat, vegetable oils and sugar). IFS line 001.76exd. Growth rates.	Quarterly.
Raw materials inflation	Commodity price index (1990 = 100) of raw materials (cotton, hides, rubber, timber, tobacco and wool). IFS line 001.76bxd. Growth rates.	Quarterly.
Beverages inflation	Commodity price index (1990 = 100) of beverages (coffee, cocoa and tea). IFS line 001.76dwd. Growth rates.	Quarterly.
	Debt Variables	
Total external debt over total exports	WDI. Total external debt in current US$, over total exports of good and services.	Annual series. Linear interpolation.
Total external debt over GDP	WDI. Total external debt in current US$, over GDP in current prices and expressed in US$.	Annual series. Linear interpolation.
Total external debt over reserves	WDI. Total external debt in current US$, over reserves excluding gold (IFS line 1d.d)	Annual series. Linear interpolation.
Total debt service payments over GDP	WDI. Total debt service paid in US$ over GDP in current prices and in US$.	Annual series. Linear interpolation.
Short-term debt over reserves	WDI. Short-term external debt over total reserves minus gold (IFS line 1d.d), in US$	Annual series. Linear interpolation.
Private non-guaranteed debt over long-term debt	WDI. Private external non-guaranteed debt over total external long-term debt, in US$.	Annual series. Linear interpolation.

4. WHAT DO TWINS SHARE? A JOINT PROBIT ESTIMATION OF BANKING AND CURRENCY CRISES

4.1 Introduction

The aim of this chapter is to investigate further the determinants of financial crises and the causal link between currency and banking crises. Indeed, what seems to be distinctive about the most recent episodes of financial system distress across the world is the increasing coincidence of banking and currency crises and the severity of their effects.

According to the economic theory, the transmission mechanism between banking and currency crises can run in either direction. Banking crises can lead to a devaluation of the domestic currency if speculators anticipate the inconsistency between a fixed exchange rate and an expansion in monetary policy caused by the bailout of the banking system.[1]

Conversely, currency crises can exacerbate banking sector problems by inducing a deterioration of the banks' balance sheet. This may be either due to the devaluation of the currency itself, or to the decision to increase domestic interest rates in order to prevent a speculative attack. While a devaluation would increase the nominal value of banks' liabilities denominated in foreign currency, high interest rates would negatively impact the quality of the banks' assets by increasing the number of distressed borrowers and thus the amount of bad loans.

[1] This transmission mechanism can be found in Calvo (1997), Miller (1999), Obstfeld (1994), and Velasco (1987).

Finally, *twin crises*, i.e. the joint occurrence of banking and currency crises, can be due to common causes. McKinnon and Pill (1994) relate overborrowing cycles to the distortions of the economic environment in which banks operate, where implicit deposit insurance guarantees are in place and supervision is not adequate. In such a context, banks may fail to take into account the downside risks of their lending activity, increasing their vulnerability to a speculative attack.

Chang and Velasco (1999) ascribe twin crises to a shortage of liquidity that might occur if the level of international reserves of a country is far below the level of its short-term liabilities. A sudden change in market sentiments, with deposits withdrawals and capital outflows, could then exert pressures on both the currency and the banking system, eventually leading to their joint collapse.

Burnside, Eichenbaum, and Rebelo (2000) suggest a theoretical explanation of twin crises which includes both bad economic policies and self-fulfilling beliefs. They show that if the government offers a full guarantee to domestic banks' foreign creditors, banks would expose themselves to exchange rate risk and declare bankruptcy when a devaluation occurs. The presence of these guarantees thus creates the possibility of self-fulfilling crises. When the market participants believe that a devaluation is imminent and the government will bail-out the banking system, they will exchange domestic currency for foreign currency to the point of triggering a devaluation. The result of these expectations is a currency crisis and a banking crisis. In this model fundamentals, or government guarantees, determine whether a crisis will occur, while self-fulfilling beliefs influence the timing.

Despite the large number of theoretical explanations, very few empirical papers have studied the relationship between banking and currency crises since the pioneering work of Kaminsky and Reinhart (1999). The analysis in this chapter tries to fill this gap in the empirical literature by looking at episodes of banking and currency crises occurred from 1970 to 1997 in the sample of developing and

emerging markets described in Chapter 3.[2]

We focus on two main objectives. First, we investigate the determinants of banking and currency crises and try to detect what characterises each type of crisis above and beyond a set of common factors. As in the previous chapters of this thesis, we are especially interested in the effect of debt variables on the probability of twin crises. Second, we test empirically the different transmission mechanisms identified by the theory and investigate the direction of causality between banking and currency crises.

Technically, we use the method of maximum smoothly simulated likelihood (MSSL) in combination with the Geweke-Hajivassiliou-Keane (GHK) simulator described in Chapter 5, to estimate a system of two dynamic probit equations, one for banking crises and another for currency crises. This approach would allow us to:

- Jointly estimate the probability of banking and currency crises;
- Endogenise banking crises;[3]
- Test the interaction between banking and currency crises by introducing lagged and contemporaneous links within and between the two equations of the system.

The remaining of this chapter is organised as follows. Section 4.2 presents a short overview of the empirical literature on twin crises. Section 4.3 explains the econometric model used to jointly estimate banking and currency crises.[4] Summary statistics are presented in Section 4.4, while the main estimation results are gathered in Section 4.5. Finally, Section 4.6 concludes.

[2] For the description of the sample composition and explanatory variables we refer the reader to Chapter 3, Section 3.4 and Appendices A–D.

[3] The system estimation thus overcomes one limitation of the single-equation approach adopted in Chapter 3, which considers past currency crises as exogenously given.

[4] A more detailed explanation of the model specification and estimation technique can be found in Chapter 5.

4.2 Review of the Literature

The anatomy of *twins* was originally described by Kaminsky and Reinhart (1999) in a seminal paper on the causes of banking and balance-of-payments problems. The authors identify banking and currency crises in a restricted sample of 20 industrial and developing countries from the 1970s to 1995. They define twin crises as 'episodes in which the beginning of a banking crisis is followed by a balance-of-payments crisis within 48 months'. The aim of their paper is to empirically investigate the causal linkages between crises and identify distinctive patterns in the behavior of macroeconomic fundamentals during the period surrounding those crises.[5]

The main results of Kaminsky and Reinhart (1999) point the existence of a two-way causality between banking and currency crises. A vicious cycle seems to exist, thereby banking sector problems lead currency crises and these, in turn, have a negative feedback on banks. Ultimately, they show that *twins* share some common determinants. The period preceding a twin crisis is characterised by slow output growth, high interest rates and an overvalued exchange rate.

The work by Kaminsky and Reinhart (1999) represented a starting point for a series of subsequent papers that analyse twin crises using a multivariate approach.

In their probit analysis of the determinants of banking crises in emerging markets, Eichengreen and Rose (1998) use a dummy variable to control for episodes of exchange rate crash, defined as 'nominal depreciations of at least 25 per cent that are also at least a ten per cent increase in the rate of depreciation over the previous year'. Their results do not show any significant effect of the currency crisis dummy on the probability of observing a banking crisis. To check the hypothesis

[5] The authors restrict their analysis to a window of 24 months prior to the occurrence of a balance-of-payments crisis, while the banking crisis window is symmetric around the beginning of a crisis and lasts 12 months.

that banks may react slowly to currency depreciations they lag the currency crisis dummy. Nonetheless, their final results do not improve.

The paper by Eichengreen and Rose (1998) suffers from the limitation of assuming a unidirectional causation between crises that runs from currency crises to banking crises. Rossi (1999) takes also into account the opposite causal effect, from banking to currency crises, by estimating separately two equations: one for episodes of currency crises and another for banking crises. To control for the effect of past occurrences of banking crises on the probability of observing a currency crisis, he introduces among the regressors of the currency crises equation a lagged banking crisis dummy. Similarly, he uses lagged values of the currency crisis dummy in the banking crisis equation. Due to data limitations, he restricts his analysis to a sample of 15 developing countries from 1990 to 1997. He finds that the lagged dummy variable for currency crises is not significant when added to the probit equation for banking crises, whereas past banking crises help to predict currency crises.

Glick and Hutchison (2001) find analogous results on a larger sample of annual observations for 90 developed and developing countries over the period 1975–97. Contrary to Kaminsky and Reinhart (1999), who consider a time span of four years, they restrict the definition of twin crises to '...instances in which a bank crisis is accompanied by a currency crisis in either the previous, current, or following year.'. Similarly to Rossi (1999), they estimate two static probit equations —one for each type of crisis— and test empirically the causal link between crises by means of a contemporaneous and a lagged crisis dummy variables.

Their results seem to suggest that twin crises are a significant phenomenon only in emerging countries. The authors find evidence of a contemporaneous and lagged effect of banking crises on the probability of observing a currency crisis, but only when they restrict their analysis to a sub-sample of emerging markets. Inter-

estingly, they also find a significant contemporaneous effect of currency crises in the banking crises equation. The same results hold true when the two equations are estimated simultaneously,[6] but only when they restrict the sample to emerging markets. On a larger sample, which includes also industrialised countries, there is no clear evidence of a significant causal relationship between banking and currency crises.

4.3 A System Estimation Approach to Twin Crises

We jointly estimate the probability of banking and currency crises in developing and emerging markets by using a system of two dynamic probit equations of the type described in Chapter 3, with unobserved heterogeneity and autocorrelated errors. The first equation describes banking crises and their determinants. The dependent variable is a dummy that equals one if a banking crisis is observed in country i at period t, zero otherwise. The second equation of the system explains the likelihood of currency crises, which are identified by a second dummy variable that distinguishes a currency crisis regime from a tranquil period.

The set of explanatory variables in the banking crisis equation, includes, among other regressors, lagged values of both the banking and currency crisis dummy variables. The lagged dependent variable would test whether past instances of banking crises have an influence on the probability of observing another banking crisis in the future. As explained in the previous chapter, this conditional relationship is known as *state dependence*, to suggest that if a country experienced a banking crisis in the past, the probability of observing another banking crisis might depend on that previous crisis occurrence.

[6] Following Maddala (1983), they use a two-step approach in the estimation. In the first step, fitted values of the endogenous variables are obtained from the estimation of the reduced forms of the two probit equations. The fitted values are then used in the second step as independent variables in the two structural probit equations. Maddala (1983) shows that the estimates obtained with this procedure are consistent but not efficient.

The lagged values of the currency crises dummy would control for a possible leading effect from currency crises to banking crises. As in Chapter 3, we would test the sensitivity of the results to the choice of the lag structure by using alternatively the currency crisis dummy lagged by one quarter and an *indicator* variable that takes the value of one if a currency crisis occurred in any of the four quarters preceding a banking crisis.

Similarly to the banking crisis equation, the set of explanatory variables in the currency crisis equation includes the lagged dependent variable to test for *state dependence* among episodes of currency crises. Past instances of banking crises would test the hypothesis that banking crises lead currency crises.

Unlike the banking equation, the currency crisis equation includes among the regressors a dummy variable that signals the occurrence of a simultaneous banking crisis. This term identifies twin crises by controlling for the effect of cases of systemic banks' distress on the probability of observing a coincident currency crisis.

The error terms of both equations are similar and combine a country-specific time-invariant error term and an AR(1) autocorrelated element. This structure is meant to capture the fact that countries may differ in their *propensity* to experience a banking or currency crisis.

A different predisposition to crises may be either due to the existence of *unobserved heterogeneity* —i.e. country-specific attributes that are time-invariant and may reflect political, institutional and historical differences— or to some unobserved persistent factors.

It is important to stress that the omission of this error structure might give rise to *spurious state dependence*, i.e. cases in which the lagged dependent variable

associated with past episodes of financial crises would turn to be significant solely because it would proxy for the omitted persistent and autocorrelated unobservables. The consideration of both error term components, i.e. the country-specific effect and the AR(1) term, is thus required to avoid biases in the estimation of the lagged dependent variable coefficients.

Finally, we allow for a contemporaneous correlation between the error terms of the banking and currency crisis equation, to capture common causes to banking and currency crises that we fail to explain with the economic variables included as regressors in our two-equation system.

To summarise, the simultaneous estimation of these two dynamic probit equations as a system would allow us to endogenise the occurrence of banking crises and capture any leading and simultaneous effect between banking and currency crises.

As mentioned in Chapter 3 and further explained in the methodological chapter that follows this one, the intertemporal correlations in our model imply the calculation of probabilities given by high-dimensional integrals that are computationally intractable and require the use of simulation estimation methods. We apply the method of maximum smoothly simulated likelihood in combination with the GHK simulator that are described in Chapter 5.

4.4 Summary Statistics

We can characterise the episodes of twin crises in our sample by first looking at their frequency and temporal distribution and computing some descriptive summary statistics.

Tab. 4.1: Simultaneous Banking and Currency Crises

Definition of currency crises	*10% cut-off*	*15% cut-off*
Total number	22	15
Percentage of currency crises	11.22%	12.10%
Percentage of banking crises	10.73%	7.32%

Notes: Banking crises *with bailout* include episodes of government intervention to rescue troubled banks and are defined in Section 3.4.1 of Chapter 3.

The *10% cut-off* currency crises are identified as quarterly devaluations of the nominal exchange rate greater or equal to 10 per cent , which are also at least a 25 per cent increase in the rate of devaluation with respect to the previous quarter.

Similarly, a *15% cut-off* currency crisis corresponds to a 15 per cent devaluation, which is also 20 per cent higher than the devaluation in the previous quarter.

The episodes of banking and currency crises in our sample are listed in Chapter 3, Appendices B and C, respectively.

Tab. 4.2: Banking Crises Preceding Currency Crises

	10% cut-off	*15% cut-off*
Within One Quarter		
total number	16	14
percentage of currency crises	8.16%	11.29%
Within Two Quarters		
total number	24	21
percentage of currency crises	12.24%	16.94%
Within Three Quarters		
total number	35	27
percentage of currency crises	17.86%	21.77%
Within Four Quarters		
total number	41	31
percentage of currency crises	20.92%	25.00%

Tab. 4.3: Currency Crises Preceding Banking Crises

	10% cut-off	*15% cut-off*
Within One Quarter		
total number	14	9
percentage of banking crises	6.83%	4.39%
Within Two Quarters		
total number	28	21
percentage of banking crises	13.66%	10.24%
Within Three Quarters		
total number	43	34
percentage of banking crises	20.98%	16.59%
Within Four Quarters		
total number	48	39
percentage of banking crises	23.41%	19.02%

We would focus here on the definition of banking crises *with bailout* —which includes cases of government intervention to rescue troubled banks— and on the cut-off definition of currency crises, as defined in Sections 3.4.1 and 3.4.2 of Chapter 3, respectively.

In particular, we would look at two different cut-off measures of currency crises: a *10% cut-off* and a *15% cut-off*. The first is defined as a 10 per cent depreciation of the national currency that is also a 25 per cent increase in the rate of depreciation with respect to the previous quarter. The second considers as currency crises a devaluation of 15 per cent, which should also be 20 per cent higher than the devaluation in the previous quarter.[7]

The total number and percentages of currency crises that are associated with a simultaneous banking crisis in our sample are reported in Table 4.1. They vary from a minimum of seven per cent to a maximum of twelve per cent, depending on the currency crisis definition.

Table 4.2 depicts the number of banking crises preceding a currency crisis in an interval that varies from one quarter (first row of Table 4.2) to one year (fourth row of Table 4.2). Similarly, Table 4.3 reports the total number and percentages of currency crises preceding banking crises.

Contrary to Kaminsky and Reinhart (1999) who count as twin crises a banking crisis that follows a currency crisis within a period of four years, we restrict the twin crisis window to a maximum of one year. This is to minimise the risk of defining as twin crises episodes of banking and currency crises that are not related by a clear causal relationship.

[7] The banking and currency crises episodes in our sample are listed in Appendix B and C of Chapter 3, respectively.

If we focus on a one year window, the data reported in Table 4.2 and 4.3 show that the total number of currency crises in the four quarters preceding a banking crisis is higher than the correspondent number of banking crises preceding currency crises. Based on this comparison, we may be induced to infer that currency crises are more likely to lead banking crises than *vice-versa*. However, a more careful analysis of the data reveals that the same conclusion cannot be drawn if we restrict the time interval to just one quarter before a crisis. Therefore, any tentative conclusion based on simple descriptive statistics needs further investigation on the grounds of multivariate analysis.

The summary statistics presented in this section cannot unanimously solve our original question of what type of interaction, if any, links the various episodes of currency and banking crises in our sample. The choice of the lag structure seems to be crucial when assessing the causal link between banking and currency crises. However, the mere existence of a temporal relationship between crises does not necessarily imply causation.

To shed some light on the determinants and causal links between banking and currency crises we have to resort to multivariate system analysis, introduce some dynamics and allow for intertemporal links between the two types of crises. The results presented in the next section are a first attempt to follow this route.

4.5 Joint Probit Results

This section presents the empirical results of our multivariate analysis of the determinants of twin crises. We further exploit the panel dataset used in Chapter 3 that includes quarterly observations on 92 countries from 1970 until 1997.[8]

The determinants of banking and currency crises are examined by adopting the two-equation system approach described in the previous section and formalised

[8] The full list of countries is provided in Chapter 3, Appendix A.

in Section 5.5.1 of Chapter 5. The set of explanatory variables has been selected according to the main predictions arising from the theoretical literature on the origins of financial crises.[9] Some of the regressors are common to both equations, while others are either banking or currency-specific and are therefore included in only one of the two equations.

To avoid endogeneity problems, all the explanatory variables are lagged by at least one quarter. The choice of the lag structure has been determined by following a general to specific approach and by dropping all the lags before/after the first which had a significant direct effect.

4.5.1 The Baseline Specification

The results of our baseline model are presented in Table 4.4. The first part of the table gathers the estimation results referring to the banking crisis equation, while those of the currency crisis equation are presented underneath. Finally, a third panel shows the estimated parameters associated with the error term structure.

Three different sets of estimates are available for the currency crisis equation: total effects, direct effects and indirect effects. The *direct effects* are the estimated coefficients of the currency crisis equation. The *indirect effects* measure the impact that the explanatory variables of the banking crisis equation exert on the probability of currency crises through the contemporaneous banking crisis dummy that appears on the right hand side of the currency crisis equation. The *total effects* are the sum of the direct and indirect effects.[10]

[9] See Appendix D of Chapter 3 for the variables' definitions and sources.
[10] The standard errors for the total effects are calculated using the Delta method.

Tab. 4.4: The Baseline Model

Variables	Total Effects	Direct Effects	Indirect Effects
Banking Crises Equation			
Constant	−1.526***		
	(−34.978)		
Real GDP growth (lagged 2Q)	−0.040***		
	(−2.447)		
M2 over CB reserves	0.080**		
	(2.485)		
Growth of claims on private sector	0.003**		
over GDP (lagged 3Q)	(2.272)		
Real deposits interest rate (lagged 2Q)	0.000**		
	(1.800)		
Growth of banking deposits over GDP	−0.005**		
(lagged 3Q)	(−1.716)		
Growth of foreign banking liabilities over GDP	0.000**		
(lagged 2Q)	(2.253)		
Change in US interest rate	1.222***		
	(3.244)		
US CPI inflation	−0.194*		
	(−2.764)		
RER undervaluation	−0.006**		
	(−1.664)		
Debt service paid over exports (lagged 2Q)	0.761**		
	(1.988)		
Short term debt over reserves	0.003***		
	(2.334)		
Private non-guaranteed external debt over	0.178		
long term debt	(0.322)		
Capital account restrictions	0.069		
	(0.520)		
Domestic financial liberalisation	0.100		
	(1.066)		
Currency crisis previous quarter	−0.005		
	(−0.025)		
Banking crises previous quarter	1.993***		
	(16.365)		
Currency Crises Equation			
Constant	−2.099***	−1.760***	−0.339**
	(−7.049)	(−18.315)	(−1.743)

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Tab. 4.4: *continued*

Variables	Total Effects	Direct Effects	Indirect Effects
Real GDP growth (lagged 2Q)	−0.022	−0.013	−0.009
	(−0.465)	(−0.709)	(−0.883)
M2 over CB reserves	0.018		0.018
	(1.009)		(1.009)
FX reserves over imports	−0.458***	−0.458***	
	(−4.464)	(−4.464)	
Growth of claims on private sector	0.001		0.001
over GDP (lagged 3Q)	(0.051)		(0.051)
Growth of net claims on government	0.000**	0.000**	
over GDP (lagged 2Q)	(1.757)	(1.757)	
Real dep. interest rate (lagged 2Q)	0.000		0.000
	(0.007)		(0.007)
Growth of banking deposits	−0.001		−0.001
over GDP (lagged 3 periods)	(−0.046)		(−0.046)
Growth of banking deposits	−0.006***	−0.006***	
over GDP (lagged 4Q)	(−2.440)	(−2.440)	
Growth of foreign banking liabilities	0.000	0.000**	0.000
over GDP (lagged 2Q)	(0.014)	(1.745)	(0.014)
Change in US interest rate	0.272**		0.272**
	(1.743)		(1.743)
US CPI inflation	−0.386***	−0.343***	−0.043*
	(−5.837)	(−4.173)	(−1.561)
World interest rate	0.053***	0.053***	
	(2.771)	(2.771)	
RER undervaluation	−0.019	−0.018***	−0.001
	(−0.433)	(−4.761)	(−0.146)
Debt service paid over exports	0.169**		0.169**
(lagged 2Q)	(1.701)		(1.701)
Growth of external debt over reserves	0.000**	0.000**	
	(1.737)	(1.737)	
Short term debt over reserves	0.004	0.004***	0.001
	(0.128)	(2.264)	(0.101)
Private non-guaranteed external	1.272***	1.232**	0.039*
debt over long term debt	(14.398)	(1.989)	(1.443)
Fuel inflation	−0.010*	−0.010*	
	(−1.331)	(−1.331)	
Metals inflation	−0.074**	−0.074**	
	(−1.978)	(−1.978)	
Capital account restrictions	0.441***	0.425***	0.015

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Tab. 4.4: *continued*

Variables	Total Effects	Direct Effects	Indirect Effects
	(7.349)	(2.635)	(1.111)
Domestic financial liberalisation	0.355***	0.333***	0.022*
	(7.261)	(3.225)	(1.408)
Currency crisis previous quarter	0.131**	0.132	−0.001
	(2.150)	(0.458)	(−0.120)
Banking crises previous quarter	0.721***	0.278*	0.443**
	(2.572)	(1.324)	(1.751)
Contemporaneous banking crises	0.222**	0.222**	
	(1.744)	(1.744)	
	Error Term Structure		
$\sigma^2_{\mu^b}$	0.175***		
	(5.060)		
$\sigma^2_{\mu^c}$	0.336***		
	(4.700)		
ρ^b	−0.357***		
	(−65.890)		
ρ^c	−0.102		
	(−0.719)		
$\rho_{\xi^b_{it},\epsilon^c_{it}}$	0.175***		
	(5.060)		
Function value at optimum	−1306.200		

Notes: This table reports the estimated coefficients with z-statistics in parenthesis.
Number of observations: 4350. Currency crisis definition: *10% cut-off*. Number of banking crisis observations: 205. Number of currency crisis *with* bailouts: 196. All variables are lagged one period, unless otherwise specified. The significance of the parameters can be assessed using the Normal approximation. Given the size of our sample, the t-statistic is virtually Normal. We can therefore use the t-tables to assess significance. We use the critical values for the 1%, 5% and 10% significance levels, which are 2.326, 1.645 and 1.282, respectively, for a 'one-tailed' test, and 2.576, 1.960 1.645 and for a 'two-tailed' test. *, ** and ***, correspond to the 10%, 5% and 1% significance levels, respectively.
The direct effects are the estimated coefficients of the currency crisis equation. The indirect effects measure the effect of the explanatory variables included in the banking equation on the probability of a currency crisis via the contemporaneous banking crisis dummy. The total effects are the sum of the direct and indirect effects.

Tab. 4.5: Total Elasticities (Baseline Model)

Variables	zero RE	zero RE+s.e.	zero RE−s.e.
Banking Crises Equation			
Real GDP growth (lagged 2Q)	−0.041	−0.044	−0.039
M2 over CB reserves	0.289	0.307	0.271
Growth of claims on private sector over GDP (lagged 3Q)	0.004	0.004	0.004
Real deposits interest rate (lagged 2Q)	0.008	0.009	0.008
Growth of banking deposits over GDP (lagged 3Q)	−0.007	−0.007	−0.006
Growth of foreign banking liabilities over GDP (lagged 2Q)	0.005	0.005	0.005
Change in US interest rate	−0.005	−0.005	−0.004
US CPI inflation	−0.227	−0.241	−0.213
RER undervaluation	0.002	0.002	0.002
Debt service paid over exports (lagged 2Q)	0.184	0.195	0.172
Short term debt over reserves	0.012	0.012	0.011
Private non-guaranteed external debt over l.t. debt	0.015	0.016	0.014
Capital account restrictions	0.063	0.067	0.059
Domestic financial liberalisation	0.029	0.031	0.027
Currency crisis previous quarter	−0.000	−0.000	−0.000
Banking crises previous quarter	0.101	0.108	0.095
Currency Crises Equation			
Real GDP growth (lagged 2Q)	−0.022	−0.023	−0.021
M2 over CB reserves	0.062	0.067	0.059
FX reserves over imports	−0.435	−0.463	−0.401
Growth of claims on private sector over GDP (lagged 3Q)	0.001	0.001	0.001
Growth of net claims on government over GDP (lagged 2Q)	0.001	0.001	0.001
Real dep. interest rate (lagged 2Q)	0.002	0.002	0.002
Growth of banking deposits over GDP (lagged 3Q)	−0.001	−0.002	−0.001
Growth of banking deposits over GDP (lagged 4Q)	−0.001	−0.002	−0.001
Growth of foreign banking liabilities over GDP (lagged 2Q)	0.004	0.004	0.003
Change in US interest rate	−0.001	−0.001	−0.001
US CPI inflation	−0.441	−0.470	−0.413
World interest rate	0.395	0.420	0.370
RER undervaluation	0.007	0.007	0.006
Debt service paid over exports (lagged 2Q)	0.040	0.042	0.037
Growth of external debt over reserves	0.003	0.003	0.002
Short term debt over reserves	0.017	0.018	0.016

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Tab. 4.5: *continued*

Variables	zero RE	zero RE+s.e.	zero RE−s.e.
Private non-guaranteed external debt over long term debt	0.106	0.112	0.099
Fuel inflation	−0.003	−0.004	0.003
Metals inflation	−0.002	−0.002	0.002
Capital account restrictions	0.394	0.420	0.370
Domestic financial liberalisation	0.100	0.107	0.094
Currency crisis previous quarter	0.006	0.006	0.007
Banking crises previous quarter	0.036	0.038	0.033

Notes: The elasticities measure the effect of a unitary change in one of the regressors on the probability of observing a crisis and are evaluated at the mean value of each variable. The elasticity numbers should be multiplied by 100 to convert them in percentages.

The estimated coefficients reported in Table 4.4 are defined as the partial derivatives of the latent variable with respect to each of the regressors. In order to assess the significance of these estimates we also show in parenthesis the associated z-statistics. We present in a separate table (Table 4.5), the estimated elasticities that derive from the baseline model.[11] These are defined as the partial derivatives of the probability of observing a financial crisis —either a banking or currency crisis— with respect to each of the regressors. Given their definition, elasticities can be interpreted more easily than the estimated probit coefficients.

The results in the first panel of Table 4.4, which refers to the banking crisis equation, show that a slow down of domestic GDP growth significantly increases the likelihood of a banking crisis. This result is consistent with the findings of the previous chapter and may be explained by the increased difficulties encountered by banks' borrowers in servicing their debts in a phase of economic recession. Nonetheless, variations in output growth fail to explain the occurrence of currency crises, as can be seen in the second panel of Table 4.4.[12] A similar result was found by Kaminsky and Reinhart (1999) but in an univariate setting. According to the authors, one of the key differences between banking and currency crises is the role played by the real sector, which appears to be crucial in explaining banking crises but not currency crises.

An important difference between banking and currency crises lies in the role of the ratios of M2 over reserve money and in that of foreign exchange reserves over imports. The first of these two ratios is an indicator of the liquidity of financial systems and a measure of the money multiplier effect. An increase in the ratio of M2 to reserve money would imply an increase in liquid deposits and

[11] The elasticities in column 1 are evaluated at the mean values of the dependent variables and are derived from the *total effects* coefficients of the benchmark model presented in Table 4.4 with a random effect equal to zero. However, to check the sensitivity of the result to this last assumption, we also computed the elasticities within a confidence interval of ± one standard error. These two sets of elasticities are reported in columns 2 and 3 of Table 4.5, respectively.

[12] This last finding is robust to changes in the lag structure and model specification.

currency in circulation. These are money instruments that can be easily cashed in by depositors in case of a bank panic, undermining the stability of the banking system. Our results indicate that the higher the value of this ratio, the higher the probability of observing a banking crisis; whereas it does not contribute to the explanation of currency crises.[13]

The second ratio, foreign exchange reserves over imports, is an indicator of foreign reserve adequacy. It measures the government's ability to finance current account deficits and is, therefore, a better indicator of exchange rate sustainability. The higher this indicator, the higher the repayment capacity of a country, and thus the lower the likelihood of a currency crisis, as confirmed by the negative and significant sign associated with this indicator in the currency crisis equation.[14]

Another distinction between banking and currency crises arises from the effect of two sub-components of domestic credit. The probability of banking crises is influenced by domestic claims on the private sector, while currency crises are explained by the growth of claims on the government.

These results are widely consistent with the predictions of the financial crises' literature. A sharp increase in the ratio of claims on the private sector to GDP is a proxy for lending booms. In a context of fast growth of private domestic credit and in the absence of appropriate banking supervision, banks' ability to discriminate marginal projects declines, leading to an increase in the share of non-performing loans in their portfolios.[15]

[13] If we include M2 over reserve money straight among the regressors of the currency crisis equation, its direct and total effects are not significant.

[14] This ratio is not significant when included in the the banking equation instead of M2 over reserve money.

[15] This argument has been emphasised after the Asian financial crisis.

On the other hand, changes in net claims on the central government over GDP would capture the Krugman's effect: excessive credit expansion due to the monetisation of the government's budget deficit as a factor determining currency crises.[16]

Following Rossi (1999), we consider the real interest rate on banks' deposits among the explanatory variables of banking crises. According to this author, banking problems are more likely to surface when real interest rates are high. This is because banks may be unable to extract the higher return paid on their liabilities from borrowers, and, even if they can, the quality of their loan portfolio may deteriorate because high real interest rates not only make it harder for good borrowers to stay current on repayments, but also worsen the average quality of borrowers (adverse selection).

Our results indicate that an increase in the real interest rate on banks' deposits significantly increases the probability of banking crises.[17] This variable has not a total significant effect on currency crises. Moreover, it has not a direct significant effect when included among the regressors in the currency crises equation.

We include the growth of banks' deposits over GDP and the growth of banks' foreign liabilities over GDP in the baseline specification as indicators of banks' soundness. Banks' deposits would act as a proxy for deposit withdrawals and thus as an indicator of on-going bank runs.

Our results indicate that a sharp decrease in the growth of banks' deposits over GDP significantly increases the probability of a banking crisis. Banking foreign liabilities are an indicator of the banking system's dependence on foreign

[16] We tried to include claims on the private sector as an additional explanatory variable in the currency crisis equation, but the associated coefficient was not significant. The same is true for claims on the central government when included in the banking crisis equation. The change in total domestic credit over GDP was not significant in either of the two equations.

[17] Alternatively, the inclusion of the lending over deposit interest rates ratio does not yield significant results.

resources and captures the system's vulnerability to a sudden capital inflow reversal. Specifically, it measures the degree to which the banking system relies on off-shore capital to fund its activities. We find that the higher the value of this variable, the higher the probability of observing a banking crisis.

The same two banking variables appear as regressors in the currency crisis equation[18] to test if the dummy for past episodes of banking crises remains significant in the currency crisis equation even after controlling for banking-specific variables.[19]

We also add to both equations a measure of real exchange rate (RER) undervaluation. As explained in Chapter 3, this series was computed by subtracting each country RER series from the corresponding Hodrick-Prescott trend.[20] Positive values indicate that the exchange rate is undervalued with respect to its trend, while negative values are symptoms of exchange rate overvaluation.

The link between the real exchange rate and currency and banking crises lies in the competitiveness effect derived from a misaligned RER. An overvalued RER would harm tradeables' producers by decreasing their foreign exchange earnings. On one hand, this may have a direct impact on the quality of the loan portfolio of banks, increasing the probability of a banking crisis. On the other hand, it might create the expectation of a future weakening of the currency and lead to a preemptive speculative attack.[21] The argument runs in the opposite way in case of an undervalued RER. The negative coefficient in both banking and currency

[18] In the currency crisis equation, we included banking deposits lagged four periods (instead of three) since we looked for a significant direct effect of this variable on the probability of a currency crisis.

[19] We shall come back to this point when commenting on the estimated coefficient of the banking crisis dummy in the currency crisis equation.

[20] The RER series are authors' computations, based on nominal exchange rates and relative CPI indexes. Both series were obtained from the IMF-IFS statistics.

[21] Notwithstanding, the total effect of RER on the probability of a currency crisis is not significant.

equations is consistent with our expectations as it implies that an undervalued RER reduces the probability of a financial crisis.[22]

Debt variables have been included in both banking and currency crisis equations. Contrary to the currency crises equation, where the growth of total external debt over reserves is the key variable, what is significant in the banking crisis equation is the ratio of debt service payments over exports.[23] This is consistent with the fact that a temporary liquidity shortage can lead to an insolvency crisis if a country cannot generate enough export revenues to pay back its debt.

Another important conclusion that can be drawn from our results is that the maturity and composition of debt instruments matter when assessing banking and currency crises' probabilities. The ratio of short-term debt over reserves has a significant direct effect in both equations.[24] The share of long-term debt that is private and non-guaranteed is not significant in the banking crisis equation, but it has a strong effect on the likelihood of currency crises.

Another block of regressors included in both equations is that of global variables. These are meant to capture external conditions and are thus common to all the countries, but vary over time. Following Eichengreen and Rose (1998), we constructed a composite measure of world interest rates. This variable is obtained by weighting the interest rate series of France, Germany, Japan, Switzerland, the United Kingdom and the United States according to the share of external debt denominated in these respective currencies.

The results show that an increase in the level of world interest rates significantly

[22] The positive sign of the associated elasticities, reported in Table 4.5, is driven by the mean value of this variable, which is high and negative. This indicates that on average in our sample RER were overvalued, increasing the probability of banking and currency crises.

[23] This variable is not significant when included directly into the currency crisis equation. The only relevant effect is the indirect effect.

[24] Interestingly, the total effect in the currency crisis equation is positive but not significant.

increases the probability of a currency crisis. This is because it would raise the cost of servicing variable-rate debt, with adverse consequences on the countries' ability to meet their external obligations. Eventually, it may also cause an outflow of capital that would exert pressures on the currency and increase the probability of a devaluation, as confirmed by the results of our estimation.[25] The world interest rate has a counterintuitive negative sign when included into the banking crisis equation. What is relevant, though, for the explanation of banking crises is the change in the US interest rate. This variable has a positive and significant effect on the probability of banking crises.

Following Moreno and Trehan (2000), we include in both equations the US inflation rate as an additional global explanatory variable. Our results indicate that this variable has the expected negative sign and is significant in both equations.[26]

Two additional global variables appear in the currency crisis equation: the inflation rates of fuel and metal prices. The first variable is obtained by multiplying fuel CPI inflation by a dummy variable that takes the value of one for countries that are exporters of oil, and zero otherwise. We applied the same method to identify those countries that are particularly vulnerable to changes in metal prices. Both variables are significant in the baseline specification, with a negative sign. This result is not surprising. The higher the value of oil or metals, the higher exports revenues, and the lower the probability of a currency crisis for those countries that are exporters of these commodities.

We also add to the baseline model two dummy variables to control for the existence of capital account restrictions and the effects of domestic financial liberalisation.

[25] The same argument can be found in Moreno and Trehan (2000).

[26] Moreno and Trehan (2000) argue that a deflationary shock in the US could have a negative effect on economies that are exporters to the US market because it would lower their export revenues and, consequently, domestic economic activity.

The dummy for capital controls takes the value of one in periods characterised by the imposition of restrictions on the capital account. This variable is significant in the currency crisis equation only. Its positive sign indicates that the existence of capital restrictions tends to increase the probability of a currency crisis. This result is consistent with Rossi (1999), who argues that limitations on capital movements can be circumvented by setting up off-shore accounts or other types of operations that can eventually increase the vulnerability of domestic financial systems.[27]

The second dummy for domestic financial liberalisation takes the value of one in periods in which domestic interest rates were freed. This variable significantly increases the likelihood of currency crises. This result seems to confirm that financial liberalisation increases the fragility of financial systems.

Having controlled for this large set of explanatory variables, we can now turn our attention to the second objective of our analysis, that is the study of the interaction between banking and currency crisis episodes.

In line with the results of Chapter 3, we can infer about the existence of a strong *state dependence* among episodes of banking crises from the positive and significant coefficient associated with the lagged dependent variable in the banking equation. This means that having experienced a banking crisis in the past increases the probability of observing another banking crisis one quarter ahead.

When turning to the currency crisis equation, it is important to note that the lagged dependent variable has a positive and significant total effect on the probability of a currency crisis one quarter ahead. However, the direct and indirect effects have opposite signs and are not significant.

[27] There is also empirical evidence suggesting that capital account controls are largely applied by countries with unregulated and poorly supervised financial systems, which are thus more vulnerable to speculative attacks.

This last result highlights the importance of jointly controlling for both direct and indirect effects when assessing the significance of each variable in the currency crisis equation. By simply looking at the direct effect of the lagged dependent variable we would tend to conclude that past episodes of currency crises do not influence the probability of another crisis, while the analysis of the total effects reveal the presence of state dependence among episodes of currency crisis.

In order to test the causal link between banking and currency crises, we include a currency crisis dummy lagged by one period in the banking crisis equation and, similarly, a lagged banking crisis dummy in the currency crisis equation.

Table 4.4 shows that the coefficient associated with past banking crises is positive and significant in the currency crisis equation, even after controlling for banking-specific variables. Instead, lagged currency crises do not have a significant impact on the probability of banking crises.[28] This result seems to suggest that banking crises lead currency crises.

The coefficient associated with the simultaneous banking crisis dummy in the currency crisis equation is positive and significant. This means that the occurrence of a banking crisis helps to explain the probability of a currency crisis in the same quarter, i.e. banking and currency crises are strongly intertwined, as suggested by the literature on twin crises.[29]

Further insights about the direction of causality between banking and currency crises can be derived from the analysis of the estimated parameters associated with the error structure.

[28] The results from the system estimation thus confirm those of the single-equation estimation of banking crises presented in Chapter 3

[29] This problem is further analysed in the subsections below.

First, the estimates of the parameter associated with the country-specific time-invariant effects, $\sigma^2_{\mu^b}$ and $\sigma^2_{\mu^c}$, reveal the existence of unobserved heterogeneity in both equations; while there are only signs of autocorrelation in the error term of the banking crisis equation.[30]

Second, the contemporaneous correlation between the banking and currency crises equations, $\rho_{\xi^b_{it},\xi^c_{it}}$, is highly significant and positive. This result indicates the existence of common causes to banking and currency crises that are omitted from our baseline specification, i.e. we find further evidence that twin crises are driven by common unobserved factors.

4.5.2 Financial Crisis Indicators

To test the robustness of the results of the baseline specification, and before deriving any definite conclusion on the direction of causality between banking and currency crises, we re-estimated the benchmark model with a modified lag structure of the banking and currency crisis dummy variables.

Instead of looking at episodes of crisis occurred within one quarter, we would test the significance of a new indicator signalling a crisis in any of the four quarters preceding another crisis. We call these new variables banking(currency) crisis *indicators* and use them as substitutes for both the lagged dependent variable (controlling for state dependence) and the lagged crisis dummies (testing the direction of causality between crises).

Since the coefficients and significance of the economic fundamentals do not change substantially with respect to the baseline model, we report only the results that are relevant to the analysis of the causal link between crises (see Table 4.6).

[30] However, the negative sign associated with ρ^b cannot be easily interpreted.

The estimated coefficients of the currency crisis equation reported in column 1 of Table 4.6 are the ones corresponding to the total effects.[31]

The results in column 1 of Table 4.6 show that, once we control for a sufficient number of lags in the dependent variable, the leading effect from banking to currency crises found in the baseline model disappears, so does the simultaneous effect of banking crises on currency crises. Moreover, the contemporaneous correlation across the error terms of both equations is no longer significant.

What we find instead is the presence of *generalised state dependence* in both equations.[32]

Finally, the autocorrelated component in the error term of the banking equation has now a positive and significant effect, which eases the interpretation of this result.

4.5.3 The Error Term Structure

In order to test the relevance of the autocorrelated error term in each of the probit equations of the system, as well as the contemporaneous cross-correlation between the error terms of the two equations, we re-estimated the model without these error terms but with the crisis indicators. The results are reported in column 2 of Table 4.6.

The omission of the positive and significant autocorrelated error term component in the banking equation, ρ^b, artificially inflates the coefficient (and z-statistics) of the lagged dependent variable that accounts for state dependence.

[31] The direct effects would lead to the same conclusions.

[32] We interpret this as a more general type of state dependence than the one described in Section 4.3, because we consider the whole year preceding a crisis rather than just one quarter.

Tab. 4.6: Controlling for Past Financial Crises and the Error Structure

Variables	(1)	(2)	(3)
Banking Crises Equation			
Currency crisis indicator	0.134	0.146	
	(0.985)	(1.249)	
Banking crisis indicator	0.435**	0.865***	0.423**
	(2.039)	(9.032)	(2.080)
Currency crisis indicator (1980s)			−0.152
			(0.607)
Currency crisis indicator (1990s)			0.240*
			(1.639)
Currency Crises Equation			
Currency crisis indicator	0.202***	0.155***	0.213**
	(3.444)	(3.474)	(1.701)
Banking crisis indicator	0.045	−0.060	
	(0.394)	(−0.676)	
Banking crisis indicator (1980s)			−0.231
			(−0.758)
Banking crisis indicator (1990s)			0.145
			(0.991)
Contemporaneous banking crisis	−0.069	−0.141**	−0.082
	(−0.354)	(−1.724)	(−0.414)
Error Term Structure			
$\sigma^2_{\mu^b}$	0.213***	0.227***	0.222***
	(2.835)	(4.915)	(3.022)
$\sigma^2_{\mu^c}$	0.307***	0.326***	0.305***
	(4.354)	(4.926)	(4.350)
ρ^b	0.439***		0.439***
	(3.097)		(3.284)
ρ^c	−0.028		−0.030
	(−0.340)		(−0.367)
$\rho_{\xi^b_{it},\xi^c_{it}}$	0.060		0.050
	(0.349)		(0.277)
Function value at optimum	−1323.461	−1341.370	−1321.334

Notes: The *Currency crisis indicator* is a dummy taking the value of 1 if there was a currency crisis in at least 1 of the 4 quarters preceding the occurrence of a banking crisis, and 0 otherwise. The *Banking crisis indicator* is similarly defined. The *Currency crisis indicator (1980s)* is a dummy variable that takes the value of 1 if a currency crisis occurred in any of the four quarters preceding one of the banking crises of the 1980s. Similarly for the *Banking crisis indicator (1990s)*.

In the currency crisis equation, the autocorrelated error term component was not significant, so the effect of omitting it from the estimation is not as important as for the banking equation. The z-statistic is higher but the coefficient is slightly smaller. This last effect is due to the original negative sign of ρ^c in the model of column 1.

The effect of eliminating the cross-correlation term across equations is reflected in the coefficient of the contemporaneous banking crisis dummy. This coefficient is now higher (in absolute terms) and significant at the 5 per cent level, distorting the effect of a contemporaneous banking crisis on the probability of a currency crisis.

Overall, these results point to the importance of estimating these models with a flexible error structure, in order to avoid biased results.

4.5.4 Indicators of Financial Crises by Decade

To investigate further the causal links between banking and currency crises, we differentiate the financial crisis indicators according to the decade in which the crises took place. For example, the *currency crisis indicator (1980s)* is a dummy variable that takes the value of one if a currency crisis occurred in any of the four quarters preceding one of the banking crises that took place in the 1980s. Similarly, we also constructed two banking crisis indicators by decade that we included in the currency equation. The 1970s are taken as the decade of reference. The results are reported in column 3 of Table 4.6.

As in the single equation estimation of Chapter 3, our results reveal the existence of a significant (albeit only at the 10 per cent level) leading effect of currency crises on banking crises in the 1990s.

No significant effect is found of banking crises leading currency crises in any decade.

In summary, these results seem to suggest that banking crises are not good leading indicators of currency crises once we control for past occurrences of currency crises. On the contrary, past currency crises help to explain banking crises, but only when we focus on episodes occurred during the 1990s relative to those of the 1970s.

4.5.5 Alternative Definitions of Currency Crises

Table 4.7 presents the results of the baseline model estimated using the crises indicators and alternative definitions of currency crises. Following Eichengreen, Rose, and Wyplosz (1996), we adopt a second currency crises definition based on an *Exchange Market Pressure* (EMP) index. This index is computed as a weighted average of quarterly changes in the nominal bilateral exchange rate — with respect to the dollar— and quarterly changes in reserves.[33] Periods in which the country index is above its mean by more that 1.5 standard deviations are defined as crises.[34] [35]

This definition of currency crises differs from the cut-off definition used so far in the estimations because it would also capture unsuccessful speculative attacks, that may not translate into an actual devaluation of the currency because of the central bank intervention on the foreign exchange market. The new set of estimates obtained using this alternative definition of currency crises are gathered in the first column, (*EMP1.5%*), of Table 4.7.

[33] The weights are chosen so as to equalise the conditional volatility of the two components.

[34] Note that these thresholds are country-specific because the standard deviations are computed within-country and not over the whole sample.

[35] Countries with hyperinflation are treated differently from the rest of the sample.

Tab. 4.7: Alternative Definitions of Currency Crises

Variables	*EMP*1.5%	*15% cut-off*
Banking Crises Equation		
Constant	−1.389***	−1.503***
	(−29.633)	(−26.482)
Real GDP growth (lagged 2Q)	−0.047***	−0.034***
	(−2.854)	(−2.323)
M2 over CB reserves	0.129***	0.104***
	(3.252)	(2.738)
Real deposit interest rate (lagged 2Q)	0.000**	0.000**
	(1.654)	(1.732)
Growth of claims on private sector over GDP	0.003**	0.003**
(lagged 3Q)	(2.306)	(2.225)
Growth of banking deposits over GDP	−0.005**	−0.005**
(lagged 3Q)	(−1.681)	(−1.765)
Growth of foreign banking liabilities over GDP	0.000**	0.004***
(lagged 3Q)	(2.543)	(2.440)
Change in US interest rate	1.054***	1.041***
	(2.463)	(2.489)
US CPI inflation	−0.240***	−0.204***
	(−2.973)	(−2.668)
RER undervaluation	−0.008**	−0.010***
	(−2.114)	(−2.377)
Debt service paid over exports (lagged 2Q)	0.553	0.910**
	(1.206)	(1.862)
Short term debt over reserves	0.003**	0.003**
	(1.901)	(2.016)
Private non-guaranteed external debt over long term debt	0.133	0.217
	(0.178)	(0.311)
Banking crisis indicator	0.457***	0.350**
	(3.062)	(1.843)
Currency crisis indicator	0.199**	1.286**
	(1.648)	(1.863)
Currency Crises Equation		
Constant	−1.721***	−1.543***
	(−5.777)	(−3.522)
Real GDP growth (lagged 2Q)	−0.077**	−0.012
	(−1.874)	(−0.252)
M2 over CB reserves	0.028	−0.013
	(1.140)	(−0.607)
FX reserves over imports	−0.350***	−0.428***
	(−4.021)	(−3.489)
Growth of claims on private sector over GDP	−0.000	0.000***
(lagged 2Q)	(0.052)	(−0.049)

continued on the next page

Tab. 4.7: *continued*

Variables	*EMP*1.5%	*15% cut-off*
Growth of net claims on the government over GDP	0.000	0.000***
(lagged 2Q)	(0.780)	(2.723)
Real deposit interest rate (lagged 2Q)	0.000	−0.000
	(0.006)	(−0.007)
Growth of banking deposits over GDP	−0.001	0.001
(lagged 3Q)	(−0.045)	(0.047)
Growth of banking deposits over GDP	−0.001	0.008***
(lagged 4Q)	(−0.038)	(2.738)
Growth of foreign banking liabilities over GDP	0.000	0.000
(lagged 2Q)	(0.014)	(0.005)
Change in US interest rate	0.226*	−0.135
	(1.621)	(−0.717)
US CPI inflation	−0.195***	−0.232***
	(−3.084)	(−2.592)
World interest rate	0.023*	−0.008
	(1.287)	(−0.324)
RER undervaluation	−0.019***	−0.020
	(−6.153)	(−0.376)
Debt service paid over exports	0.118*	−0.118
(lagged 2Q)	(1.596)	(−0.715)
Growth of external debt over reserves	−0.000	0.000**
	(−0.602)	(2.172)
Short term debt over reserves	0.007	0.005
	(0.147)	(0.109)
Private non-guaranteed debt over long term debt	0.614***	1.240***
	(6.953)	(11.918)
Fuel inflation	−0.007	0.003
	(−0.974)	(0.628)
Metals inflation	−0.046*	−0.099***
	(−1.557)	(−2.523)
Capital account restrictions	−0.196*	0.044
	(−1.415)	0.267
Domestic financial liberalisation	0.209**	0.100
	(1.819)	0.819
Currency crisis indicator	0.453***	0.724***
	(9.629)	(9.622)
Banking crisis indicator	0.202***	−0.018
	(2.556)	(−0.185)
Contemporaneous banking crises	0.214*	−0.130
	(1.630)	(−0.892)

continued on the next page

Tab. 4.7: *continued*

Variables	*EMP*1.5%	*15% cut-off*
Error Term Structure		
$\sigma^2_{\mu^b}$	0.203***	0.221***
	(3.247)	(3.648)
$\sigma^2_{\mu^c}$	0.000	0.197***
	(0.095)	(3.222)
ρ^b	0.330***	0.497***
	(3.923)	(4.848)
ρ^c	0.230***	−0.052
	(3.748)	(−0.580)
$\rho_{\xi^b_{it},\xi^c_{it}}$	0.239***	−0.034
	(2.096)	(−0.304)
Function value at optimum	−1372.452	−1094.820

Notes: *EMP*1.5% means 1.5 standard deviations over the mean of the EMP index. The number of currency crises corresponding to this definition is 210.
The *15% cut-off* measure defines crises as a 15 per cent depreciation and a 20 per cent increase in the rate of depreciation. The number of currency crises corresponding to this definition is 124.
See also comments to Table 4.4 and Table 4.6.

The results in the second column, (*15% cut-off*), refer instead to a more restrictive cut-off definition of currency crises that applies a cut-off of 15 per cent on the nominal depreciation of the exchange rate, higher than the one used so far.[36]

As can be seen from Table 4.7, the adoption of the *EMP1.5%* definition of currency crises produces different results. The real output growth variable has now a negative and significant sign. Another important difference lies in the debt indicators, because only private non-guaranteed debt helps to predict this type of currency crises.

According to these results, banking crises tend to lead currency crises, but the *vice-versa* is also true: the currency crisis indicator is significant in the banking equation. These findings highlight how difficult it is to identify a clear-cut causal relationship between banking and currency crises. A somewhat more robust result is that of *generalised state dependence* among both banking and currency crises.[37] The contemporaneous influences between banking and currency crises, captured by the endogenous banking dummy in the currency equation and the simultaneous correlation in the unobservables, are also significant.

Interestingly, the parameter associated with unobserved heterogeneity in the currency crisis equation, $\sigma^2_{\mu^c}$, is no longer significant when we use the *EMP1.5%* definition instead of *10% cut-off*. This result suggests that this term was maybe capturing the willingness and ability of central banks to defend the exchange rate parity. These country-specific characteristics are already taken into account in the definition of currency crises based on the EMP index, which incorporates changes in total reserves of the central bank, and are therefore no longer significant in the estimation.

[36] This 15 per cent depreciation should also represent a 20 per cent increase in the rate of depreciation with respect to the previous quarter.

[37] We are using here the same indicator of crises used in the previous section, that takes the value of one if a banking (currency) crisis is observed in any of the four quarters preceding another banking (currency) crisis.

When turning to the results obtained by using the *15% cut-off* definition, it is worth noting that the currency crisis indicator included in the banking equation is significant at the 5 per cent level. This seems to suggest that more severe currency crises (as those indicated by a level of depreciation higher than 15 per cent) have a positive and significant impact on the probability of observing a banking crisis in the future. Instead, the banking crisis indicator in the currency crisis equation is not significant.

4.6 Conclusions

The econometric analysis presented is this chapter has highlighted some empirical regularities in banking and currency crises occurred in a sample of 92 developing and emerging market economies from the mid 1970s to the end of the 1990s.

Our results show that financial crises (banking or currency crises) are driven by a common set of economic fundamentals, as well as some banking and currency specific indicators.

Debt variables are common causes of banking and currency crises. The ability of a country to honour its debt payments, either measured by the debt service ratio or the amount of short-term debt over reserves, significantly affects the likelihood of banking crises. Speculative pressures on the domestic currency are, instead, more likely the higher is the growth of the total external debt of a country.

Banking crises seem to cause currency crises one quarter ahead, but this link vanishes when we extend the crisis window to one year.

More robust results on the causal relationship between the two types of crises are derived when we differentiate crises by decades. Our analysis shows a statistically significant differential effect of currency crises occurred in the 1990s on the probability of banking crises, independently of the specification chosen.

Alternatively, we find a significant leading effect of currency crises on banking crises when we consider devaluations that are over a 15 per cent threshold.

If we change the definition of currency crises to include unsuccessful speculative attacks, the causal link works in both directions: banking crises lead currency crises and *vice-versa.*

To conclude, the results presented in this chapter suggest that, along with the increasing liberalisation and globalisation of financial markets, banking and currency crises have become closely intertwined and driven by common fundamentals. Currency crises seem to lead banking crises, at least during the nineties, but a causal link between the two cannot be determined unambiguously over the whole sample period. Both types of crises share some common factors, but which crisis surfaces first is ultimately a matter of circumstances.

5. SIMULATION-BASED ESTIMATION OF LIMITED DEPENDENT VARIABLE MODELS USING PANEL DATA: MOTIVATION, METHODS AND APPLICATIONS.

5.1 Introduction

In the previous two chapters of this thesis we made use of simulation techniques to overcome the computational problems associated with the maximum likelihood estimation (MLE) on panel data of dynamic probit models with flexible serial correlation in the unobservables.

The main aim of this chapter is to explain why we had to resort to simulation-based estimation techniques and outline the key properties and advantages of the maximum smoothly simulated likelihood (MSSL) method that we used to estimate the probability of banking and twin crises. Using the banking and twin crises econometric models described in Chapter 3 and Chapter 4, we would also show how the GHK-MSSL approach can be applied to the estimation of a system of two dynamic probit equations with flexible serial and contemporaneous correlation in the unobservables. This is an original result in the field of applied econometrics.

The key problem associated with the estimation of a broad class of limited dependent variable (LDV) models using classical MLE methods is the need to evaluate multidimensional probability integrals in likelihood functions or conditional moments conditions. The high dimensional order of integration makes these expressions computationally intractable.

These computational problems may arise in the context of simple discrete choice models when, for example, individuals have to evaluate the choice between more than two alternatives (multinomial probit models) or in binary models that allow for flexible serial correlation in the unobservables, like the single-equation probit model of banking crises estimated in Chapter 3.

In the past, researchers have limited their attention to special classes of LDV models that were computationally tractable, by imposing for example some very restrictive conditions on the correlation structure of the unobservables. If one assumes that the errors are independently and identically distributed (i.i.d.), the probabilities would have logit functional forms that can be easily computed. However, this model would suffer from the assumption of the 'independence of the irrelevant alternatives', which does not appear to be applicable in our case.[1]

The simulation technique developed by Geweke (1989), Hajivassiliou and McFadden (1990) and Keane (1990), better known as the GHK simulator, makes it possible to estimate by MSSL (developed by Börsch-Supan and Hajivassiliou (1993)) a broader class of LDV models with flexible covariance structure, which encompasses the banking and twin crises models described in Chapter 3 and Chapter 4 of this thesis.

The remaining of this chapter is organised as follows. In Section 5.2 we present the classical formulation of a limited dependent variable model. Using the example of the banking crises model of Chapter 3, we derive in Section 5.2.1 the associated maximum likelihood function and highlight the multivariate integration problems associated to classical estimation methods. In Section 5.3 we briefly review the main simulation-based estimation methods, while in Section 5.4 we explain how simulation routines work by focusing on the GHK simulator. In Section 5.5, we demonstrate the application of the GHK simulator to the estimation of the bank-

[1] See McFadden (1973).

ing and twin crises models that are used in Chapter 3 and Chapter 4 of this thesis and formalised in this chapter. Finally, Section 5.6 concludes.

5.2 The Canonical LDV Model

In this Section, we follow the formulation in Hajivassiliou (1993), Börsch-Supan and Hajivassiliou (1993) and Hajivassiliou and Ruud (1994) to describe the class of limited dependent variable models.

The canonical limited dependent variable model can be described as a combination of a linear latent variable model and a nonlinear relationship, τ, between the latent variable, y^*, and an observable variable, y.

Consider a random sample of N economic agents(countries). Assume each individual(country) i is observed over T_i periods. The pooling of observations on a cross-section of individuals over several time periods, with $i = \{1, \cdots, N\}$ and $t = \{1, \cdots, T_i\}$, defines a panel dataset. Let observe the data array (y_i, X_i), where y_i is a $(T_i \times 1)$ vector of limited dependent variables referring to individual i, and X_i is a $(T_i \times K)$ array of exogenous variables. We assume y_i is an indirect observation on a latent vector y_i^* according to a many-to-one mapping $y_i = \tau(y_i^*)$, with y_i^* given by a linear model

$$y_i^* = X_i\beta + \epsilon_i \qquad \text{where} \qquad i = \{1, \ldots, N\} \tag{5.1}$$

where β is a K-dimensional vector of parameters, and ϵ_i a $(T_i \times 1)$ vector of disturbances with covariance matrix Ω_i.

Define:

$$D(y_i) = \{y_i^* | y_i = \tau(y_i^*)\} \tag{5.2}$$

Then, the likelihood associated with the observation (y_i, X_i) on the generic indi-

vidual i is defined as:

$$l_i(\theta; y_i) = \int_{y^* \in D(y_i)} g(y_i^* - X_i\beta, \Omega_i) dy_i^* \tag{5.3}$$

where $i = \{1, \ldots, N\}$. The function g indicates the joint multivariate density function of the disturbances ϵ_i of the latent variable model, and $D(y_i)$ is the set of latent variables y_i^* obeying to the nonlinear relation $\tau(\cdot)$ for a given observed dependent variable y_i.

In general, the integral in (5.3) will have a closed form solution only if g, the joint multivariate density function, and $D(y_i)$, the area of integration, are particularly benign. Multinomial logit models, for example, fall into this category of discrete choice models that can be easily estimated by MLE.

In most other cases, like a simple binary probit model with a flexible correlation structure, the estimation of the parameters in (5.3) would require the evaluation of multi-dimensional integrals for each observation and each iteration of the maximisation process. This makes the use of classical estimation methods computationally intractable.

The banking crises model presented in Chapter 3 falls under this broad category of LDV models that require alternative estimation methods. In what follows, we describe the model specification and associated likelihood function.

5.2.1 A Binary Dynamic Probit Model of Banking Crises

Consider a panel dataset, where a sample of N countries is followed over time, with country i being observed for T consecutive periods.[2]

[2] We assume here a balanced panel dataset, where each individual is observed for the same number of periods, T.

Let y_{it}^{b} be a binary limited dependent variable, which takes the value of one if a banking crisis takes place in country i at time t, and zero otherwise. Let y_{it}^{b} be an indirect observation of a latent vector y_{it}^{b*}, specified as a linear function of a $(K \times 1)$ vector of explanatory variables, x_{it}, and a vector of parameters β, according to a many-to-one mapping $\tau(y_{it}^{b*})$:

$$y_{it}^{b} = \begin{cases} 1 & \text{if} \quad y_{it}^{b*} \equiv x_{it}'\beta + \varepsilon_{it} > 0 \\ 0 & \text{otherwise} \end{cases}$$

where $i = \{1, \cdots, N\}$ is the number of countries in our sample of emerging and developing countries, and $t = \{1, \cdots, T\}$ is the number of time periods.

The set of explanatory variables encompasses macroeconomic fundamentals as well as global variables. The dynamic feature of this probit model derives from the inclusion of the lagged dependent variable on the right hand side of the probit equation.[3]

Let the distribution of the latent vector of the generic country i be the multivariate normal, with $y_{it}^{b*} \sim N(x_{it}'\beta, 1)$. Then, the probability that a binomial random variable Y_{it} equals one, conditional on a set of explanatory variables x_{it}, is given by $\Phi(x_i'\beta)$, where $\Phi(\cdot)$ denotes the standard normal cumulative distribution function (c.d.f.).

In view of the assumption of independence of $(y_{it}^{b*} \mid x_{it})$ across time and across countries, the estimation by maximum likelihood (MLE) of this binomial probit model does not pose any major problem and is performed by most of the available econometric software packages.

[3] As explained in Chapter 3, this would allow us to test for the presence of *state dependence*, i.e. past banking crises affecting the probability of observing another crisis in the future.

However, it suffices to modify the error structure, to allow for country specific effects and correlation across time among the observations referring to the same country i, to produce a likelihood function that contains multidimensional integrals —of the order of the number of time observations for each country— that cannot be easily approximated.

This correlation feature is quite common in the context of panel data. One way of modelling this correlation is by means of a random-effect model combined with an autoregressive error structure. This is the error term structure adopted in Chapter 3 when estimating banking crises, ad can be formalised as follows:

$$\varepsilon_{it} = \alpha_i + \eta_{it},\ \eta_{it} = \rho_i \eta_{it-1} + \upsilon_{it} \tag{5.4}$$

where υ_{it} are i.i.d. and $|\rho| < 1$.

The first error term, α_i represents country-specific, time-invariant unobservable determinants of banking crises, while the autocorrelated component, η_{it}, allows for persistence in the unobservables.

In addition, we suspect that this error term may be correlated with the explanatory variables on the RHS of the probit equation that describes banking crises. This correlation would impair the statistical properties of the estimated coefficients if not properly corrected for. To solve this problem, we explicitly model the linear dependence between the RHS variables and the error term and let $\alpha_i = \gamma' x_{i\cdot} + \xi_i$ where $x_{i\cdot}$ is the mean value of x_{it} over time, and ξ_i is a residual term that accounts for unobserved country-specific effects.

This error term structure implies a variance-covariance matrix of the form $\Omega(y^*) = I_N \otimes \Omega_i$, where $i = \{1, \cdots, N\}$ and each block, Ω_i, is defined as:

$$\Omega_i = \sigma_\eta^2 \cdot \begin{pmatrix} 1 & \rho & \rho^2 & \cdots & \rho^{T-1} \\ \rho & 1 & \rho & \cdots & \rho^{T-2} \\ \rho^2 & \rho & \cdots & \cdots & \vdots \\ \vdots & \vdots & \cdots & 1 & \rho \\ \rho^{T-1} & \rho^{T-2} & \cdots & \rho & 1 \end{pmatrix} + \sigma_\alpha^2 \cdot J_T \tag{5.5}$$

where J_T is a $(T \times T)$ matrix of ones and $0 \leq \sigma_\alpha \leq 1$.[4]

The probability of the sequence of events in country i, $y_i^b \equiv (y_{i1}^b, \ldots y_{iT}^b)$, can be written as the T_i-dimensional integral over the vector y_i^{b*}:

$$Pr\{y_i^b; \theta, x_i\} = \int_{a_i(y_i^b)}^{b_i(y_i^b)} \phi(y_i^{b*} - x_i'\beta, \Omega_i) dy_i^{b*} \tag{5.6}$$

where θ is the set of parameters to be estimated, i.e. $\theta \equiv (\beta, \sigma_\alpha^2, \rho)$, and the limiting values a and b are defined as follows:

$$a_{it} = \begin{cases} 0 & \text{if} \quad y_{it}^b = 1 \\ -\infty & \text{if} \quad y_{it}^b = 0 \end{cases}$$

$$b_{it} = \begin{cases} +\infty & \text{if} \quad y_{it}^b = 1 \\ 0 & \text{if} \quad y_{it}^b = 0 \end{cases}$$

Assuming independence of the unobservables across countries, we can write the likelihood function associated with this problem as the product of the events' probabilities:

[4] In this specification, the variance parameters σ_α^2 and σ_η^2 cannot be identified separately, therefore the following normalisation $\sigma_\alpha^2 + \sigma_\eta^2 = 1$ is frequently used.

$$\mathcal{L}(\beta,\Omega)=\prod_{i=1}^{N} Pr(\{y_i^b\}|\{X_i\};\beta,\Omega) \tag{5.7}$$

where the index i denotes an observation in a sample of N countries and we stacked all the time observations referring to each individual in the $(T_i \times 1)$ vector y_i, with each of the probabilities in (5.7) given by the $T-i$-dimensional integral (5.6).

In general, traditional numerical methods cannot compute such integrals with sufficient speed and precision to make the estimation by MLE feasible because the number of operations increases exponentially with the sample size, N.

An additional complication arises from the treatment of the set of initial conditions that, for simplicity, we assume here as exogenous.[5]

An alternative approach to the classical estimation of general LDV models is to exploit simulation results in parametric estimation to approximate the high dimensional integrals in the likelihood function (5.7).

Compared to the traditional methods of numerical integration, simulation allows the specification of quite general error structures over large panel datasets.[6] To estimate the likelihood of banking crises defined in (5.7), we applied the method of maximum smoothly simulated likelihood together with the GHK simulator described in the following sections.

[5] We are aware of the limitation of this assumption but, given the time length of our sample that includes on average more than 8 observations (two years of quarterly data) for each country, this hypothesis does not significantly affect our results.

[6] This is because the number of operations, for a given number of draws, increases only linearly with the dimension of the sample, N.

5.3 Simulation-Based Estimation Methods for LDV Models

The use of simulation-based estimation allows the approximation of the multi-dimentional choice probabilities in the likelihood function (5.7) or in scores and moment conditions that are otherwise computationally untractable with classical estimation methods. The various approaches to simulation-based simulation described below can be classified under the generalised method of simulated moments. This is the simulated counterpart of the generalised method of moments.

Following Hajivassiliou and Ruud (1994), we summarise below the main properties of the key simulation-based estimation methods, highlighting the comparative advantages of the Maximum Smoothly Simulated Likelihood (MSSL) approach that is used in Chapter 3 and Chapter 4 of this thesis.

5.3.1 Maximum Simulated Likelihood

The maximum simulated likelihood (MSL) estimator was developed by Lerman and Manski (1981) who used Monte Carlo simulation methods to approximate the choice probabilities of a multinomial discrete choice probit model. The MSL approach consists of substituting the joint multivariate density function in the log likelihood function with an unbiased simulator. The maximum simulated likelihood estimator is then defined as the argument that maximises the simulated log-likelihood function for a given simulation sequence.[7]

The simulation method proposed by Lerman and Manski (1981) is the crude frequency or crude Monte Carlo simulator (CMC), which consists of approximating the true discrete choice probabilities with an empirical frequency, computed by making repeated Monte Carlo random draws from the true distribution and then considering only those realisations that fall into the domain of the latent vector. Despite the advantage of being quick to calculate, this simulation method

[7] See Hajivassiliou and Ruud (1994) for a formal definition of this estimator.

presents a number of drawbacks.

- First, it is not a smooth function in the parameters, thus hindering estimation by MLE.
- Second, the frequency simulator can take the value zero with positive probability. It could be the case that over R replications, the number of observed matches is zero.
- Third, a very large number of draws is required to obtain accurate estimates of small probabilities. This feature implies that the frequency simulator yields consistent estimates by MSL only when both sample size and number of draws go to infinity.[8]

To overcome these difficulties, Börsch-Supan and Hajivassiliou (1993) developed the MSSL method adopted in this thesis.

5.3.2 The Method of Simulated Moments

McFadden (1989) suggested a way to overcome the simulation problems associated with the method of MSL by Lerman and Manski (1981). He proved that simulation is viable even for a finite number of replications, R, provided that: an unbiased simulator is used for the choice probabilities; the functions to be simulated appear linearly in the conditions defining the estimator;[9] and the same set of random draws is used to simulate the model at different trial parameters values.

The method of simulated moments (MSM) developed by McFadden (1989) and Pakes and Pollard (1989) satisfies the properties listed above because choice probabilities enter linearly in the moment conditions. The idea behind this approach is to simulate choice probabilities with an unbiased estimator and then solve the simulated moment conditions to derive the MSM estimator.

[8] Hajivassiliou and Ruud (1994) prove that under a set of regularity conditions, the MSL estimator is consistent if the number of replications, $R \to \infty$, as $N \to \infty$. They also show that under some restrictive conditions the MLS estimator is asymptotically efficient.

[9] This condition is violated by the MSL estimator.

Hajivassiliou and Ruud (1994) show that the MSM estimator provides consistent estimates with a fixed number of replications, R, provided the law of large numbers works. However, full efficiency can be achieved only by increasing R without bound as the sample size, N, increases.

5.3.3 The Method of Simulated Scores

An alternative approach to the methods above has been suggested by Hajivassiliou and McFadden (1990), who proposed to simulate directly the scores of the likelihood function rather than approximating the choice probabilities in the likelihood function or in the moment conditions. There are two ways of approaching this problem and they both rely on the proposition that every score function can be expressed as the expectation of the score of the latent variable conditional on the observed data:[10]

$$\nabla_\theta \ln f(\theta; y) = \frac{\nabla_\theta f(\theta; y)}{f(\theta; y)} \tag{5.8}$$

$$= E[\nabla_\theta \ln f(\theta; y^*) \mid y] \tag{5.9}$$

where ∇_θ is an operator representing partial differentiation with respect to the elements of θ.

The first approach consists of using simulation to approximate directly the expectation of the score of the latent log-likelihood, (5.9), conditional on a set of observations.

Hajivassiliou and Ruud (1994) show that the *method of simulated scores* (MSS) estimator so derived is consistent and uniformly asymptotically normal (CUAN) provided an unbiased simulator of the score function is used.

[10] See Hajivassiliou and Ruud (1994) for a derivation of this result.

An alternative approach to the simulation of the score function is to simulate separately the linear derivative in the numerator and the likelihood in the denominator of the score expression (5.8). This second method is faster to compute than the first one, but is affected by a simulation bias.

5.3.4 Maximum Smoothly Simulated Likelihood (MSSL)

The method of maximum smoothly simulated likelihood (MSSL) has been developed by Börsch-Supan and Hajivassiliou (1993). The authors have shown that by relying on accurate simulators that are smooth functions of the parameters, one can overcome the problems associated with the fact that the MSL estimator is a non-linear function of the simulator.

In what follows, we borrow from Hajivassiliou and Ruud (1994) the formal definition of the MSSL estimator.

For a given sample of observations $\{y_i\}$, with $(i = 1, \cdots, N)$, let the log-likelihood function for the unknown parameter vector, θ, be:

$$l_N(\theta) \equiv \sum_{i=1}^{N} [\ln f(\theta; y_i)]$$

Let $\tilde{f}(\theta; y, \omega)$ be an unbiased simulator, so that $f(\theta; y) \equiv E_\omega[\tilde{f}(\theta; y, \omega) \mid y]$, and a continuous function of θ and ω, where the latter is a simulated vector of R random variates. Then the *maximum smoothly simulated likelihood* estimator is defined as:

$$\hat{\theta}_{MSSL} \equiv \arg\max_{\theta} \tilde{l}_N(\theta) \qquad \text{where} \qquad \tilde{l}_N(\theta) \equiv \sum_{i=1}^{N} \ln \tilde{f}(\theta; y_i, \omega_i) \tag{5.10}$$

for a given simulation sequence $\{\omega_i\}$. When $\tilde{f}(\cdot)$ is generated according to the GHK method described in Section 5.4.2, it satisfies the unbiasedness and continuity requirements of the MSSL definition.

Hajivassiliou and McFadden (1998) prove that the MSSL estimator is consistent and uniformly asymptotically normal (CUAN), and asymptotically fully efficient, provided the number of simulations R employed per individual observation raises without bound, at least as fast as $\sqrt{N}$, where N is the sample size.

In practice, the MSSL estimator can be implemented by using a standard maximum likelihood optimisation package, modified to allow for the likelihood contributions to be simulated using the GHK procedure. This is in contrast to the MSM and MSS simulation-based estimation methods that require more sophisticated software.

An additional advantage of this simulation-based estimation method is that the computational effort of the MSSL approach increases almost linearly with the dimension of the latent variable vector, making its application particularly attractive to the estimation of discrete choice problems with panel data.

For these reasons, we decided to use this method in conjunction with the GHK simulator, to estimate the probability of banking and twin crises in emerging markets.

5.4 Simulation Techniques

As explained in the previous section, the main idea behind simulation-based estimation is to simulate the latent data generating process and then use such simulations to evaluate the likelihood and log-likelihood functions and their derivatives with respect to the unknown parameters.

Following Hajivassiliou (1993) and Börsch-Supan and Hajivassiliou (1993), the two sub-sections below contain, first, a short description of how a generic simulation routine works and, second, a more detailed explanation of the GHK simulator.

5.4.1 Simulation Routines

A generic simulation algorithm involves an iterative search over a vector of unknown parameters, θ. The starting point of this iterative procedure consists of drawing a set of R uniform random variates, $(\tilde{u}_i^1, \tilde{u}_i^2, \cdots, \tilde{u}_i^R)$, that will be kept until the end of the simulation process. Then, for a given vector of trial parameters, $\theta^{(n)} = (\beta^{(n)}; \sigma^{(n)})'$, the procedure transforms these uniform draws $\tilde{u}_i^r$ into a set of R simulated errors, $\tilde{\epsilon}_i$. This can be done by applying the inverse of the cumulative distribution function of the true ϵ's on the random draws $\tilde{u}_i^r$. These simulated errors, in turn, would generate a set of R simulated latent vectors, $\tilde{y}_i^{*r}(\theta^{(n)})$ that can be used to calculate the empirical counterpart of the likelihood function, (5.10) .

The iterative search algorithm will continue trying different parameter vectors, θ, using the same draw of random vectors $\tilde{u}_i^r$, until the relevant criterion, for example the maximisation of the simulated maximum likelihood, is satisfied.

5.4.2 The GHK or Smooth Recursive Conditioning Simulator

The GHK, or smooth recursive conditioning simulator, developed by Geweke (1989), Hajivassiliou and McFadden (1990) and Keane (1990), is based on drawings from a recursively truncated multivariate normal p.d.f., after a Cholesky transformation.

The procedure used to construct the simulated probabilities relies upon the fact that normal random variables, conditional on other normal random variables, are still normal. In what follows, we borrow from Börsch-Supan and Hajivassiliou (1993) and Hajivassiliou (2002) a description of the GHK algorithm.

Define $M = A\Omega A'$, where A is defined according to (5.2), and let L be the lower triangular Cholesky factor of M, such that $LL' = A\Omega A'$.

Instead of drawing from the original distribution of the latent variable, subject to the restrictions of the observed choices,

$$y^* \sim N(X\beta, \Omega) \qquad \text{s.t.} \quad a \leq A \cdot y^* \leq b$$

we draw a random vector

$$e \sim N(0, I) \quad \text{s.t.} \quad a^* \equiv a - AX\beta \leq Le \leq b^* \equiv b - AX\beta$$

Due to the triangular nature of L, these restrictions are recursive:

$$\begin{aligned} e_1 \sim N(0,I) \quad & \text{s.t.} \quad a_1^* \leq l_{11}e_1 \leq b_1^* \\ & \Leftrightarrow \quad a_1^*/l_{11} \leq e_1 \leq b_1^*/l_{11} \\ e_2 \sim N(0,I) \quad & \text{s.t.} \quad a_2^* \leq l_{21}e_1 + l_{22}e_2 \leq b_2^* \\ & \Leftrightarrow \quad (a_2^* - l_{21}e_1)/l_{22} \leq e_2 \leq (b_2^* - l_{21}e_1)/l_{22} \end{aligned} \tag{5.11}$$

The key contribution by Hajivassiliou and McFadden (1990) was to show that these univariate truncated normal variates, e_i , can be drawn according to the formula $e \equiv G^{-1}(U) = \Phi^{-1}[(\Phi(b) - \Phi(a)) \cdot U + \Phi(a)]$, where U is distributed according to a univariate uniform distribution on $[0, 1]$ and Φ denotes the univariate cumulative normal distribution function.[11]

The likelihood function (5.3), or the probability that $a \leq Ay^* \leq b$, can be simulated by the probability that $a^* \leq Le \leq b^*$. This is the product of the probabilities Q_i's that each e_i falls in the respective intervals given by (5.11):

$$\begin{aligned} l(y^*, X; \beta, \Omega) &= Prob(a_1^*/l_{11} \leq e_1 \leq b_1^*/l_{11}) \\ &\quad \cdot Prob((a_2^* - l_{21}e_1)/l_{22} \leq e_2 \leq (b_2^* - l_{21}e_1)/l_{22} \mid e_1) \cdots \\ &\quad \cdot Prob((a_1^* - l_{11}e_1 - \cdots - l_{Ni-1}e_{i-1})/l_{NN} \leq e_I) \\ &\quad \leq Prob(b_1^* - l_{N1}e_1 - \cdots - l_{Ni-1}e_{i-1})/l_{NN} \mid e_1, \cdots, e_{N-1}) \\ &= Q_1 \cdot Q_2(e_1) \cdot Q_3(e_1e_2) \cdots Q_I(e_1, \cdots, e_{N-1}) \end{aligned}$$

This can be approximated by the simulator

[11] See Proposition 1 in Hajivassiliou and McFadden (1990) for a derivation of this result.

$$\tilde{l}(y^*, X; \beta, \Omega; R) = \frac{1}{R} \sum_{r=1}^{R} \prod_{i=1}^{N} Q_i(e_{1r}, \cdots, e_{i-1,r}) \tag{5.12}$$

with e_{ir} drawn from a truncated $N(0,1)$, and R number of replications.

We summarise below the main properties of the GHK simulation method, which are formally derived by Hajivassiliou and McFadden (1990) and Börsch-Supan and Hajivassiliou (1993).

- As established by Lemma 1 in Hajivassiliou and McFadden (1990), the simulator $\tilde{l}(y^*, X; \beta, \Omega; R)$ defined by (5.12) is an unbiased estimator of $l(y^*, X; g, \beta)$.[12]

- $\tilde{l}(y^*, X; \beta, \Omega; R)$ is a smooth simulator, i.e. it is a continuous and differentiable function of the parameters β and Ω of the model. This feature implies that conventional numerical methods can be used to solve the first-order conditions associated with the simulated likelihood function.

- The simulated probability values of the GHK simulator are bounded away from 0 and 1. This is in contrast to the crude frequency simulator used by Lerman and Manski (1981), which generates a discontinuous objective function that can take the value 0 with positive probability.

- The computational effort in the simulation is mostly concentrated in drawing the e_i and it increases almost linearly with the dimensionality of the integral in (5.3). This makes the GHK simulator particularly attractive for panel data estimation over large samples.

Börsch-Supan and Hajivassiliou (1993) present Monte Carlo results on the distribution of simulated choice probabilities for the crude frequency simulator, the Stern simulator[13] and the GHK simulator. They find that the GHK simulator dominates the other two methods, because it produces probability estimates with

[12] See the cited paper for a formal proof.
[13] See Stern (1992).

much smaller variance than those associated to the frequency simulator or the Stern simulator. Thanks to this feature, the GHK simulator has a negligible approximation bias even for a small number of replications.[14]

This result is important because it justifies the application of the GHK method to the estimation by maximum smoothly simulated likelihood that is described in Section 5.3.4 above. The comparatively smaller variance of the GHK simulator indeed simplifies the computation of the simulated probabilities in the maximum likelihood function with respect to alternative simulation methods, like the crude frequency simulator.

5.5 *An Application of the GHK Approach to the Simulation of Financial Crises' Probabilities*

This section illustrates the application of the GHK approach to the estimation of financial crises' probabilities. We would first provide a formalisation of the twin crises model used in Chapter 4 of this thesis, and then derive the GHK canonical representation associated with the twins model.

5.5.1 Modelling Twin Crises

The model estimated in Chapter 4 can be formalised a follows. Consider a random sample of N countries, observed for T_i periods. Let y_{it}^b define a vector of limited dependent variables, where $i = \{1, \ldots, N\}$ and $t = \{1, \ldots, T_i\}$.

The variable y_{it}^b takes on the value of one if a banking crisis is observed in country i at time t, and zero otherwise. Similarly, y_{it}^c is a limited dependent variable that takes on the value one if country i experiences a currency crisis at time t, and zero otherwise.

[14] This is another advantage with respect to the crude frequency simulator, which requires a large number of replications to approximate small probabilities.

We assume that banking crises, $y_{it}^b = 1$, are an indirect observation of a latent vector y_{it}^{b*} according to a many-to-one mapping $y_{it}^b = \tau(y_{it}^{b*})$, with y_{it}^{b*} given by the linear model

$$y_{it}^{b*} = X_{it}^b \beta^b + \varepsilon_{it}^b, \tag{5.13}$$

where X_{it}^b is an array of predetermined variables, β^b is a vector of parameters to be estimated, and ε_{it}^b is the disturbance vector.

The set of explanatory variables, X_{it}^b, in equation (5.13) includes, among other regressors, lagged values of both y_{it}^b and y_{it}^c. As explained in Chapter 4, the introduction of lagged values of y_{it}^b would test for the existence of *state dependence* among episodes of banking crises. The lagged values of y_{it}^c are included among the regressors of the banking crisis equation to test for a possible leading effect from currency crises to banking crises.

Similarly, we define currency crises, $y_{it}^c = 1$, as indirect observations of the latent vector y_{it}^{c*}, which is defined as follows:

$$y_{it}^{c*} = y_{it}^b \gamma + X_{it}^c \beta^c + \varepsilon_{it}^c \tag{5.14}$$

The term $y_{it}^b \gamma$ would capture the contemporaneous links between banking crises and currency crises. It would test whether the presence of banking sector problems accentuates the propensity of a country to experience a simultaneous currency crisis. The remaining terms in Equation (5.14) are defined in a similar way to those of Equation (5.13). Therefore, X_{it}^c includes lagged values of the currency and banking dummies, y_{it}^c and y_{it}^b .

The error term structure of this system of two dynamic probit equations is specified by the pair $\varepsilon_{it} = [\varepsilon_{it}^b, \varepsilon_{it}^c]$. For the banking crisis equation, we assume

$$\varepsilon_{it}^b = \mu_i^b + \nu_{it}^b, \qquad \nu_{it}^b = \rho^b \nu_{it-1}^b + \xi_{it}^b \tag{5.15}$$

where $\mu_i^b \sim N(0, \sigma_{\mu^b}^2)$, $\xi_{it}^b \sim N(0,1)$, and $\nu_{i0}^b \sim N(0, \sigma_{0^b}^2)$. Stationarity implies that $\sigma_{0^b}^2 = \sigma_{\nu^b}^2 = 1/(1-\rho^b)$, μ_i^b and ν_{it}^b are independent.

Correspondingly, for the currency crisis equation assume

$$\varepsilon_{it}^{c} = \mu_i^c + \nu_{it}^c, \qquad \nu_{it}^c = \rho^c \nu_{it-1}^c + \xi_{it}^c \tag{5.16}$$

where $\mu_i^c \sim N(0, \sigma_{\mu^c}^2)$, $\xi_{it}^c \sim N(0,1)$, and $\nu_{i0}^c \sim N(0, \sigma_{0^c}^2)$. Stationarity implies that $\sigma_{0^c}^2 = \sigma_{\nu^c}^2 = 1/(1-\rho^c)$. μ_i^c and ν_{it}^c are also independent.

The time-invariant, country-specific μ_i terms in the error structure of both equations are meant to capture the fact that countries may differ in their *propensity* to experience a banking or currency crisis. These different predispositions may be either due to *unobserved heterogeneity*, given by μ_i, or to countries' differences that are correlated over time. To control for the last effect, we included an AR(1) component, ν_{it}, in the disturbance.

Finally, we assume that $cov(\mu_i^b, \mu_i^c) = 0$ and $cov(\nu_{it}^b, \nu_{it}^c) = 0$, but allow for a contemporaneous correlation, $\rho_{\xi_{it}^b, \xi_{it}^c} \neq 0$, between the error terms of the two equations, so that $cov(\xi_{it}^b, \xi_{it}^c) = \sigma_{\xi_b \xi_c}$. This simultaneous correlation would capture common unobserved determinants of banking and currency crises.

The choice of a flexible error structure in each of the two equations of the system defining twin crises, together with the contemporaneous correlation that links the banking to the currency equation, result in a non-scalar variance-covariance matrix.

Let's stack the limited dependent variable observations first by time period, alternating banking and currency crises observations, and then by country, with $t = \{1, \cdots, T_i\}$ and $i = \{1, \cdots, N\}$. The variance-covariance matrix would then take the general block-diagonal form:

$$\Omega = I_N \otimes \Omega_i \tag{5.17}$$

The blocks off the main diagonal contain all zeros because of the assumption of independence across countries. However, each block along the main diagonal,

which refers to a particular country i, has a $(2T_i \times 2T_i)$ dimension and is equal to:

$$\Omega_i = \begin{pmatrix} \sigma^2_{\mu^b} + \sigma^2_{\nu^b} & \sigma_{\xi_b\xi_c} & \sigma^2_{\mu^b} + \rho_b\sigma^2_{\nu^b} & \rho_c\sigma_{\xi_b\xi_c} & \cdots & \sigma^2_{\mu^b} + \rho_b^{T_i-1}\sigma^2_{\nu^b} & \rho_c^{T_i-1}\sigma_{\xi_b\xi_c} \\ \sigma_{\xi_b\xi_c} & \sigma^2_{\mu^c} + \sigma^2_{\nu^c} & \rho_b\sigma_{\xi_b\xi_c} & \sigma^2_{\mu^c} + \rho_c\sigma^2_{\nu^c} & \cdots & \rho_b^{T_i-1}\sigma_{\xi_b\xi_c} & \sigma^2_{\mu^c} + \rho_c^{T_i-1}\sigma^2_{\nu^c} \\ \vdots & \vdots & \sigma^2_{\mu^b} + \sigma^2_{\nu^b} & \sigma_{\xi_b\xi_c} & \cdots & \vdots & \vdots \\ \vdots & \vdots & \sigma_{\xi_b\xi_c} & \sigma^2_{\mu^c} + \sigma^2_{\nu^c} & \cdots & \vdots & \vdots \\ \vdots & \vdots & \vdots & \vdots & \cdots & \vdots & \vdots \\ \cdots & \cdots & \cdots & \cdots & \cdots & \sigma^2_{\mu^b} + \sigma^2_{\nu^b} & \sigma_{\xi_b\xi_c} \\ \cdots & \cdots & \cdots & \cdots & \cdots & \sigma_{\xi_b\xi_c} & \sigma^2_{\mu^c} + \sigma^2_{\nu^c} \end{pmatrix} \tag{5.18}$$

The contemporaneous links in our model, which originate this Ω structure, imply the calculation of probabilities in the likelihood function that are given by high-dimensional integrals which require the use of simulation techniques.

We use the maximum smoothly simulated likelihood in conjunction with the GHK simulator. We explain below the application of this simulation method to our estimation problem.

5.5.2 Simulation by MSSL/GHK

In this section, we formally derive the application of the MSSL/GHK approach to the estimation of the twin crises model described above. The presentation follows Hajivassiliou (2002).

Consider the two latent variables, y^{c*}_{it} and y^{b*}_{it}, and the two binary limited dependent variables y^c_{it} and y^b_{it} as defined in Section 5.5.1. For the sake of illustration we would strip out the banking crisis indicator from the matrix of explanatory variables X^c_{it} of the currency crises equation, and the currency crisis indicator from the explanatory variables of the banking crisis equation, X^b_{it}. We would call the resulting matrices Z^c_{it} and Z^b_{it}, respectively. We can then write:

$$y_{it}^{c} = \begin{cases} 1 & \text{if } \; y_{it}^{c*} \equiv y_{it}^{b}\gamma + Z_{it}^{c}\beta_z^{c} + \mathbf{1}(\sum_{s=1}^{4} y_{i,t-s}^{b} > 0)\delta^{c} + \varepsilon_{it}^{c} > 0 \\ 0 & \text{otherwise} \end{cases}$$

$$y_{it}^{b} = \begin{cases} 1 & \text{if} \quad y_{it}^{b*} \equiv Z_{it}^{b}\beta_z^{b} + \mathbf{1}(\sum_{s=1}^{4} y_{i,t-s}^{c} > 0)\delta^{b} + \varepsilon_{it}^{b} > 0 \\ 0 & \text{otherwise} \end{cases}$$

where $\mathbf{1}(\sum_{s=1}^{4} y_{i,t-s}^{c} > 0)$ is an indicator variable that takes the value of one if a currency crisis occurred in at least one of the four quarters preceding a banking crisis, zero otherwise. Similarly, $\mathbf{1}(\sum_{s=1}^{4} y_{i,t-s}^{b} > 0)$ is an indicator function for banking crises.

Consider the probability expression:

$$Prob(y_{i5}^{c}, y_{i5}^{b}, \ldots, y_{iT_i}^{c}, y_{iT_i}^{b} | Z_i^{c}, Z_i^{b}, y_{i1}^{c}, \ldots, y_{i4}^{c}, y_{i1}^{b}, \ldots, y_{i4}^{b}, \theta)$$

where θ summarises all the parameters to be estimated.

For a typical observation y_{it}:

$y_{it}^{c} = 1$	$y_{it}^{c*} > 0$	$\varepsilon_{it}^{c} + y_{it}^{b}\gamma + Z_{it}^{c}\beta_z^{c} + \mathbf{1}(\sum_{s=1}^{4} y_{i,t-s}^{b} > 0)\delta^{c} > 0$
$y_{it}^{c} = 0$	$y_{it}^{c*} < 0$	$\varepsilon_{it}^{c} + y_{it}^{b}\gamma + Z_{it}^{c}\beta_z^{c} + \mathbf{1}(\sum_{s=1}^{4} y_{i,t-s}^{b} > 0)\delta^{c} < 0$
$y_{it}^{b} = 1$	$y_{it}^{b*} > 0$	$\varepsilon_{it}^{b} + Z_{it}^{b}\beta_z^{b} + \mathbf{1}(\sum_{s=1}^{4} y_{i,t-s}^{c} > 0)\delta^{b} > 0$
$y_{it}^{b} = 0$	$y_{it}^{b*} < 0$	$\varepsilon_{it}^{b} + Z_{it}^{b}\beta_z^{b} + \mathbf{1}(\sum_{s=1}^{4} y_{i,t-s}^{c} > 0)\delta^{b} < 0$

Therefore:

$$Prob(y_{it}^{c}, y_{it}^{b}, \ldots | Z_i^{c}, Z_i^{b}, y_{i1}^{c}, \ldots, y_{i4}^{c}, y_{i1}^{b}, \ldots, y_{i4}^{b}, \theta) \;=$$

$$Prob\{(1 - 2y_{it}^{c})[\varepsilon_{it}^{c} + y_{it}^{b}\gamma + Z_{it}^{c}\beta_z^{c} + \mathbf{1}(\sum_{s=1}^{4} y_{i,t-s}^{b} > 0)\delta^{c}] < 0,$$

$$(1 - 2y_{it}^{b})[\varepsilon_{it}^{b} + Z_{it}^{b}\beta_z^{b} + \mathbf{1}(\sum_{s=1}^{4} y_{i,t-s}^{c} > 0)\delta^{b}] < 0, \ldots\}$$

In terms of the canonical GHK formulation, the probability of a pair (y_{it}^c, y_{it}^b) is equivalent to:

$$\begin{pmatrix} a_{it}^c \\ a_{it}^b \end{pmatrix} < \begin{pmatrix} \varepsilon_{it}^c \\ \varepsilon_{it}^b \end{pmatrix} < \begin{pmatrix} b_{it}^c \\ b_{it}^b \end{pmatrix}$$

Applied to our estimation problem, this results in the following configuration:

y_{it}^c	y_{it}^b	a^c	b^c	a^b	b^b
0	0	$-\infty$	$-(y_{it}^b\gamma + Z_{it}^c\beta_z^c + Hy_{it}^b\delta^c)$	$-\infty$	$-(Z_{it}^b\beta_z^b + Hy_{it}^c\delta^b)$
0	1	$-\infty$	$-(y_{it}^b\gamma + Z_{it}^c\beta_z^c + Hy_{it}^b\delta^c)$	$-(Z_{it}^b\beta_z^b + Hy_{it}^c\delta^b)$	∞
1	0	$-(y_{it}^b\gamma + Z_{it}^c\beta_z^c + Hy_{it}^b\delta^c)$	∞	$-\infty$	$-(Z_{it}^b\beta_z^b + Hy_{it}^c\delta^b)$
1	1	$-(y_{it}^b\gamma + Z_{it}^c\beta_z^c + Hy_{it}^b\delta^c)$	∞	$-(Z_{it}^b\beta_z^b + Hy_{it}^c\delta^b)$	∞

where $Hy_{it}^b \equiv \mathbf{1}(\sum_{s=1}^4 y_{i,t-s}^b > 0)$ and $Hy_{it}^c \equiv \mathbf{1}(\sum_{s=1}^4 y_{i,t-s}^c > 0)$

Therefore, the implementation of GHK requires the following steps:

1. Define the (2×1) vectors a_{it}, b_{it}, and ε_{it}. Stacking all the T_i observations for country i, alternating the banking and currency dependent variables, gives the $(2 \cdot T_i \times 1)$ vectors a_i, b_i, and ε_i, where ε_i is characterised by the $(2 \cdot T_i \times 2 \cdot T_i)$ variance-covariance matrix (5.18).

2. Through this representation, the probability of a sequence of banking and currency crises (y^c, y^b) in a given country i is given by events of the form:

$$P(y_1^c, \ldots, y_{T_i}^c, y_1^b, \ldots, y_{T_i}^b) = Prob(a_i < \varepsilon_i < b_i)$$

It follows that this approach fully incorporates:

- The contemporaneous correlations in ε_{it}.

- The one-factor plus $AR(1)$ serial correlations in ε_{it}.
- The dependency of y_{it}^c on y_{it}^b.
- The dependency of y_{it}^c on past occurrences of y_i^b and *vice versa.*

The problem of estimating banking crises, described in Chapter 3 and formalised in Section 5.2.1 above, has an analogous representation.[15]

To implement the GHK approach in the estimations by maximum smoothly simulated likelihood we modified the procedures written by Vassilis Hajivassiliou to fit our problem. These procedures return the simulated likelihood probability, $\tilde{P}$, as a function of the following arguments:
m = dimension of the multivariate normal vector Z;
$mu = E[Z]$;

[15] Let the binary limited dependent variable y_{it}^b be an indirect observation of the latent variable y_{it}^{b*}:

$$y_{it}^b = \begin{cases} 1 & \text{if } y_{it}^{b*} \equiv x_{it}'\beta + \epsilon_{it} > 0 \\ 0 & \text{otherwise} \end{cases}$$

where the set of explanatory variables includes lagged values of y_{it}^b.

For a typical observation of country i at time t:

y_{it}^b	y_{it}^{b*}
1	$\epsilon_{it} + x_{it}'\beta > 0$
0	$\epsilon_{it} + x_{it}'\beta < 0$

In terms of the canonical GHK formulation, this can be represented through the linear inequality:

$$\alpha^b < \epsilon^b < \gamma^b$$

where α^b and γ^b are given by:

y_{it}^b	α^b	γ^b
1	$-x_{it}'\beta$	∞
0	$-\infty$	$-x_{it}'\beta$

The probability of a sequence of observables $\{y_{it}\}$, where $t = (1, \cdots, T)$ is given by events of the form:

$$P(y_{i1}, \ldots, y_{iT}) = Prob(\alpha_i < \epsilon_i < \gamma_i)$$

$w = V[Z]$;

$wi = w^{-1}$

c =Cholesky factor of w;

vectors a and b, defining the restriction region $a < Z < b$;

R = number of replications;

u =a $m \times R$ matrix of i.i.d. uniform $[0, 1]$ variates.

These procedures are available at:

`http://econ.lse.ac.uk/~vassilis/pub/simulation`.

5.6 Conclusions

In this methodological chapter we showed how simulation-based estimation methods can help overcome the computational problems associated with the classical estimation by maximum likelihood of a broad class of limited dependent variable models that includes the banking and twin crises model estimated in the second part of this thesis.

Our models are characterised by a series of dynamic features that, combined with the assumption of a flexible temporal and contemporaneous correlation in the unobservables, cause classical estimation methods to become computationally intractable.

After a brief review of the principal simulation-based estimation methods, we showed a direct application of the GHK-MSSL method to both the single probit model of banking crises estimated in Chapter 3 and the system of two dynamic probit equation describing *twin crises* in developing and emerging markets used in Chapter 4.

CONCLUSION

The debate over the nature and determinants of financial fragility intensified after the collapse of the Mexican peso in December 1994. This was the first of a series of currency and banking crises that hit developing and emerging markets in the late nineties. While some theories have stressed macroeconomic imbalances as the main sources of these crises, others have highlighted their self-fulfilling nature.

The research presented in this thesis was motivated by the desire to improve our understanding of the causes and outcomes of financial vulnerability. By using both theoretical and empirical tools of analysis, we focused on debt management policy as a potential deterrent or trigger of financial sector problems. We differentiated between public and external debt, and looked at the influence of these variables on the sustainability of exchange rates and banking systems.

In the first part of the thesis, we developed a simple rules-versus-discretion model that embodies self-fulfilling elements to analyse the interaction between debt management and monetary or exchange rate policies. In particular, we examined how the choice and sustainability of a monetary policy target, be it, the inflation or exchange rate, can be affected by the type and characteristics of debt instruments.

We found this a challenging topic because of the apparent contradiction between the policy prescriptions arising from the theory and reality. Despite the fact that the anti-inflationary properties of indexed or foreign currency denominated debt are well known within the debt management literature, in many OECD countries the share of foreign currency debt declined since the late eighties, accompanied by a lengthening of debt maturities. At the same time, the presence of a large

stock of foreign currency debt has neither prevented the emergence nor improved the outcome of currency and banking crises in many emerging markets over the past decade.

The theoretical results presented in Chapter 1 and Chapter 2 suggest a possible explanation for these facts. We proved that the efficacy of debt characteristics as incentives for anti-inflationary policy depends on the type of monetary and exchange rate regime. If monetary policy can be delegated to an independent central bank, this is a better solution to credibility problems than increasing the costs of inflation by issuing indexed or foreign currency debt. In this case, our model suggests that nominal debt, possibly of a long maturity, should be issued to support output stabilisation. If, on the other hand, the central bank does not have full operational independence —or the policymaker and the private sector do not share the same information— foreign currency debt can reinforce the commitment to an exchange rate peg by reducing inflationary expectations. However, the issuance of foreign currency denominated debt cannot rule out the possibility of a bad outcome, i.e. a devaluation of the currency. Conditional on a currency crisis, countries with higher shares of foreign currency debt would tend to devalue more. This result was confirmed by our econometric analysis of the episodes of official realignment within the Exchange Rate Mechanism of the EMS during the period 1979–1995.

In the second part of the thesis, we followed an empirical approach to examine the causal links between debt, exchange rate fragility and systemic banking failures. We turned our attention to episodes of banking and currency crises in developing and emerging markets from the mid-1970s to the onset of the Asian crisis in 1997.

In Chapter 3 we assessed the probability of banking crises by estimating a dynamic probit model with unoserved heterogeneity and autocorrelated errors using simulation-based estimation techniques for panel data. This approach allowed us

to take into account the intertemporal nature of financial crises and examine the dynamics leading to, accompanying and following a crisis. In this respect, we departed from the traditional literature that excludes observations in the proximity of a crisis and relies on static logit/probit models estimated on pooled observations.

We found that episodes of banking crises in emerging markets are driven by a combination of domestic macroeconomic fundamentals and global variables. Debt vulnerability is one of the key causes of banks' unsoundness. The inclusion of the lagged dependent variable among the explanatory variables revealed the existence of a strong *state dependence* among episodes of banking crises, indicating that countries that experienced banking crises in the past are more prone to experience another banking crisis. Also, banks seem to react with some delay to a currency devaluation. The dummy variable testing for leading effects from currency to banking crises is significant only when lagged by one year. Interestingly, the leading effect is strong and significant when we restrict our attention to episodes of crisis occurred in the 1990s, signalling crises of a different nature.

After controlling for a large number of explanatory variables, we found evidence of unobserved heterogeneity and autocorrelation in the error term. The first reflects country-specific, time-invariant characteristics, like historical or institutional factors that and not fully captured by the set of explanatory variables. The second is an unobserved source of persistence in the data. The consideration of these two terms is necessary to avoid *spurious state dependence* in the estimates of the lagged banking dependent variable. The set of results obtained by omitting the panel structure and pooling together all the observations, thus neglecting the country/time dimension of our data, suffered from this serious problem.

In Chapter 4, we deepened the analysis of the causal link between banking and currency crises by examining the determinants of *twin crises*, i.e. concomitant banking and currency crises. We estimated by maximum smoothly simulated likelihood a system of two dynamic probit equations (analogous to the one used in Chapter 3), one for banking and another for currency crises. We tested the existence of a causal link from banking to currency crises by allowing a leading and contemporaneous effect of the banking dummy variable in the currency crisis equation. With respect to the single-equation estimation carried out in Chapter 3, the system approach thus has the advantage of fully endogenising the occurrence of banking crises in the currency crisis equation.

Each of the two probit equations of the system was characterised by unobserved heterogeneity and autocorrelated errors. Moreover, we assumed simultaneous unobserved correlation between the two equations, to allow for the possibility that twin crises are driven by omitted common factors.

The results presented in Chapter 4 suggested that, along with the increasing liberalisation and globalisation of the financial markets, banking and currency crises have become closely intertwined and driven by common fundamentals.

Currency crises seem to lead banking crises, at least during the nineties, but a causal link between the two types of crisis could not be determined unambiguously over the whole sample period.

Additional insights might be gathered by reverting the causal link and endogenising currency crises in the banking crisis equation. This could be done within our framework by including the lagged and contemporaneous currency crisis indicator in the equation describing banking crises. We leave this task for our future research agenda.

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