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Essays on financial crises in emerging markets

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Abstract

The financial crises in emerging markets in 1997–1999 were preceded by financial liberalisation, rapid surges in capital inflows, increased levels of indebtedness, and then sudden capital outflows. The study contains four essays that extend the different generations of crisis literature and analyse the role of capital movements and borrowing in the recent crises.

Essay 1 extends the first generation models of currency crises. It analyses bond financing of fiscal deficits in domestic and foreign currency, and compares the timing and magnitude of attack with the basic case where deficits are monetised. The essay finds that bond financing may not delay the crisis. But if the country's indebtedness is low, the crisis is delayed by bond financing, especially if the borrowing is carried out with bonds denominated in foreign currency.

Essay 2 extends the second generation model of currency crises by adding capital flows. If these depend negatively on crisis probability, there will be multiple equilibria. The range of country fundamentals for which self-fulfilling crises are possible is wider when capital flows are included, and thus more countries may end up in crisis. An application of the model shows that in 1996 in many emerging economies the fundamentals were inside the range of multiple equilibria and hence self-fulfilling crises were possible.

Essay 3 studies financial contagion and develops a model of the international financial system. It uses a basic model of financial intermediation, but adds several local banks and an international bank. These banks are able to use outside borrowing, the amount of which is determined by the value of their collateral. The essay finds that the use of leverage by local and global banks and the fall in collateral prices comprise an important channel and reason for contagion.

Essay 4 analyses the causes of financial crises in 31 emerging market countries in 1980–2001. A probit model is estimated using 23 macroeconomic and financial sector indicators. The essay finds that traditional variables (eg unemployment and inflation) and several indicators of indebtedness (eg private sector liabilities and banks' foreign liabilities) explain currency crises. When the sample was divided into pre- and post-liberalisation periods, the indicators of indebtedness became more important in predicting crisis in the post-liberalisation period.

Key words: currency crises, banking crises, emerging markets, borrowing, collateral, contagion, liberalisation

Tiivistelmä

Vuosien 1997–1999 valuutta- ja pankkikriisejä kehittyvillä markkinoilla edelsi pääomavirtojen nopea kasvu, velkaantumisen lisääntyminen ja yhtäkkinen pääomapako. Tämä tutkimus koostuu neljästä artikkelista, jotka laajentavat nykyistä kirjallisuutta tutkimalla pääomavirtojen ja velkaantumisen merkitystä.

Ensimmäisessä artikkelissa laajennetaan ensimmäisen sukupolven valuuttakriisimalleja tutkimalla koti- ja ulkomaanvaluutan määräistä velkaantumista ja vertaamalla sitä perustilanteeseen, jossa budjettialijäämät katetaan keskuspankkirahoituksella. Lainaaminen ei välttämättä lykkää kriisiä. Jos maan velkaantuminen on vähäistä, lainaaminen kuitenkin lykkää kriisiä, varsinkin jos obligaatiot ovat ulkomaanvaluutan määräisiä.

Toisessa artikkelissa laajennetaan toisen sukupolven valuuttakriisimalleja tutkimalla pääomavirtoja. Jos pääomavirrat ovat riippuvaisia kriisin syntymisestä, syntyy monen tasapainon tila. Kun pääomavirrat lisätään malliin, itseään toteuttavat kriisit ovat entistä todennäköisempiä. Mallin sovellus osoittaa, että monien kehittyvien maiden fundamentit olivat vuonna 1996 alueella, jolla itseään toteuttavat kriisit olivat mahdollisia.

Kolmannessa artikkelissa tutkitaan kriisien leviämistä ja kehitetään yksinkertainen malli kuvaamaan kansainvälistä rahoitusjärjestelmää. Tutkimuksessa laajennetaan perusmallia rahoituksen välittymisestä lisäämällä siihen monta paikallista ja yksi globaali pankki. Pankit voivat käyttää ulkopuolista rahoitusta, jonka suuruuden määräävät pankkien vakuusarvot. Artikkelissa osoitetaan, että velkaantuminen ja vakuusarvojen romahtaminen luovat merkittävän väylän ja syyn rahoituskriisien leviämiselle.

Neljännessä artikkelissa tutkitaan valuutta- ja pankkikriisien syitä 31 kehittyvässä maassa vuosina 1980–2001. Selittävinä muuttujina on 23 makrotaloutta ja rahoitussektoria kuvaavaa indikaattoria, joiden vaikutusta kriiseihin tarkastellaan probit-menetelmän avulla. Tulosten perusteella eräät perinteiset muuttujat, kuten työttömyys ja inflaatio, ja useat maan velkaantuneisuutta kuvaavat indikaattorit, kuten yksityisen sektorin velkaantuminen ja pankkien ulkomainen velkaantuminen, selittävät valuuttakriisejä hyvin. Rahoitusmarkkinoiden vapauttamisen jälkeen velkaindikaattorien selitysaste kasvoi entisestään.

Asiasanat: valuuttakriisi, kehittyvät maat, liberalisointi, velkaantuminen, probit-menetelmä, kriisien tarttuminen, pääomavirrat

Acknowledgements

This thesis was inspired by the financial crises in Asia, Russia and Latin America in 1997–1999. These crises have been interesting and fun for economists and have inspired numerous academic studies, but they surely were not fun for the citizens of these poor countries. Hopefully, the essays of the thesis and my future work can provide some practical help for the authorities in these emerging economies.

The thesis will be presented at the Turku School of Economics and Business Administration and was written mainly at the Bank of Finland Institute for Economies in Transition (BOFIT). Without BOFIT's pleasant environment and resources, this project would have never been completed. I am greatly indebted to Pekka Sutela, the head of the Institute, who in the summer of 1998 gave me the opportunity to pursue these inquires. The project took longer than it should have, and now Pekka might well regret his recruitment decision.

I have had the privilege of having not just one supervisor but several talented commentators. I owe my special gratitude to Professor Pertti Haaparanta and Research Supervisor Jukka Pirttilä, who have carefully read and commented on the various versions of the essays. Also many other colleagues have commented on my papers and encouraged me. For example, Fernando Broner, Abdur Chowdhury, Douglas Gale, Lauri Kajanoja, Iikka Korhonen, Mika Kuismanen, Paul Masson, and Pedro Rodriguez have provided valuable comments. I would also like to thank Johanna Lukkarila, the co-author of the fourth essay, for fluent and productive cooperation. I am also grateful to Professor Guillermo Calvo, who gave me the opportunity to spend the year 2001 at the University of Maryland, where, among other things, the ideas for the first and third essay were born. In the final stages, the suggestions by the preliminary examiners, Professors Tapio Palokangas and Kari Heimonen, clearly improved the thesis. Naturally all the remaining errors are mine.

I would also like to thank the whole BOFIT staff, the Bank of Finland's great library, Glenn Harma who revised the language, and Päivi Nietosvaara for the make-up work. Finally, I would like to thank my family and friends. My parents, Maija and Eero, have given valuable support during the early years of my life, and today Riina and Camilla are my sources of daily encouragement and support. This work is dedicated to Riina and our children.

Helsinki, July 2004
Tuomas Komulainen

Contents

Introduction

Capital mobility, borrowing, and financial crises

Tuomas Komulainen

1 Motivation

The literature on financial crises has generally progressed most rapidly in the wake of actual crises, and the resulting analyses have changed in line with the economic circumstances and problems of the period in question.[1] The most recent round of crises started in Asia in July 1997, when the Thai authorities allowed the baht to float and depreciate. Shortly thereafter, four other Asian countries (Philippines, Malaysia, Indonesia and Korea) were forced to float their currencies. During 1997–1999 altogether more than ten emerging market countries experienced currency crisis, which inspired a new wave of academic research. The new studies should be closely attuned to the current economic environment and thus better able to explain the recent crises in emerging markets.

> *The answer surely is that capital movements today are the central issues. Crises are now different in that they involve very large amounts of very short-term money. That is one aspect. Second, that the economy is highly leveraged around that money, so that when something happens, the whole house of cards collapses. And thirdly, the world economy is deeply global, through the financial structures and that means that when something happens anywhere, it happens everywhere. So that of course makes international financial crises today something really interesting. (R. Dornbusch 1998)*

The financial liberalisation, and capital flows that followed, clearly changed the environment in which emerging market countries operate.[2] After liberalisation, some countries became magnets for massive capital inflows. During 1984–1989 the yearly net capital inflow to emerging economies was only USD 15 billion, but in 1990–1996 it was already USD 150 billion. In 1996 alone, the net capital inflow was USD 260 billion.[3] This 16-fold increase expanded the

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[1] See eg Kindleberger (1978) and Diaz-Alejandro (1985) on the history of financial crises, and Jeanne (1999) for a recent survey on currency crisis theories and Marion (1999) on banking crisis theories. Usually as a financial crisis is denoted either currency or banking crisis.

[2] On the influence of financial liberalisation and capital mobility see eg Mahar and Williamson (1998), Demirgüc-Kunt and Detriache (1998), Rodrik and Velasco (1999), and Obstfeld (1998).

[3] Net capital flows include net direct investment, net portfolio investment, official and private borrowing, and other long- and short-term net investment flows (IMF 2001).

investment opportunities in these poor countries, but the increased capital mobility also meant increased financial instability. In 1996 total capital inflows to five Asian countries (South Korea, Indonesia, Thailand, Malaysia and Philippines) amounted to USD 74 billion, but in 1997 and 1998 there were instead capital outflows of USD 6 billion and USD 32 billion (IMF 2001). This turnaround was equivalent to 10% of the combined GDP of these countries. Similar sudden stop of capital inflows or large capital account reversals occurred in almost all the countries hit by the recent crises (Calvo and Reinhart 1999).

The borrowing by either firms or governments was the other side of the capital inflows. In the five Asian crisis countries, the ratios of foreign liabilities of banks to GDP increased 10–20 percentage points in 1994–1997. The borrowing was carried out mainly in short-term debt. In these Asian economies short-term liabilities exceeded assets, which rendered them vulnerable to illiquidity and financial crisis.[4] In some other crisis countries governments carried out the borrowing. In Russia, the public debt-to-GDP ratio increased from around 30% of GDP in 1995 to 55% of GDP before August 1998. Similarly in Argentina the debt-to-GDP ratio rose from 29% in 1993 to over 50% in 2001. This borrowing and the cross-border capital flows rendered the financial systems in emerging economies and the financial centres in developed world dependent on each other and vulnerable to contagion. Ultimately, the crises spread within Asia and from Russia to Latin America.

Although this thesis consists of four separate essays, the extension of capital movements is a common thread of the thesis. The first essay analyses how government borrowing extends the first generation theory on currency crisis. The second essay introduces capital flows into a currency crisis model with multiple equilibria. The third essay extends a basic model on financial intermediation into a model of the international financial system and studies how crises can spread via financial linkages. The final essay improves the empirical literature by using several indicators on the banking sector, indebtedness, and liberalisation. The aim and hope of the thesis is that with the extensions and results we are better equipped to analyse, understand and prevent financial crises in emerging markets.

[4] For theoretical models on banking crisis and international illquidity, see eg Chang and Velasco (2000, 2001).

2 Literature overview

2.1 First generation models

Currency crisis theories go back to the Salant and Henderson (1978) model of speculative attack on the gold market, which Krugman (1979) applied to the foreign exchange market. We present here the basic setup of the model based on Flood and Garber (1984).[5] The equations of the model are as follows:

$$\frac{M}{P} = \alpha_0 - \alpha_1(i) \tag{1}$$

$$P = P^* S \tag{2}$$

$$i = i^* + \frac{\dot{S}}{S} \tag{3}$$

$$M = D + R \tag{4}$$

where M denotes the monetary base, P the price of the domestic good and P^* the price of the foreign good. The domestic and foreign one-period interest rates are denoted with i and i^*. S denotes the exchange rate, as the price of a unit of foreign currency, and $\dot{S}$ the time rate of change of S. The stock of foreign reserves is denoted by R_t and domestic credit by D. Equation (1) gives the demand for real balances, equation (2) depicts purchasing power parity, equation (3) is the uncovered interest rate parity, and equation (4) gives a decomposition of the monetary base.

If the domestic credit grows but money demand is fixed, the international reserves must decrease during the fixed rate period

$$\dot{R} = -\mu \tag{5}$$

Thus, at some point reserves will be exhausted. At the switch time, interest rates will rise and there will be a discrete drop in the demand for money. A step depreciation of the exchange rate would offer

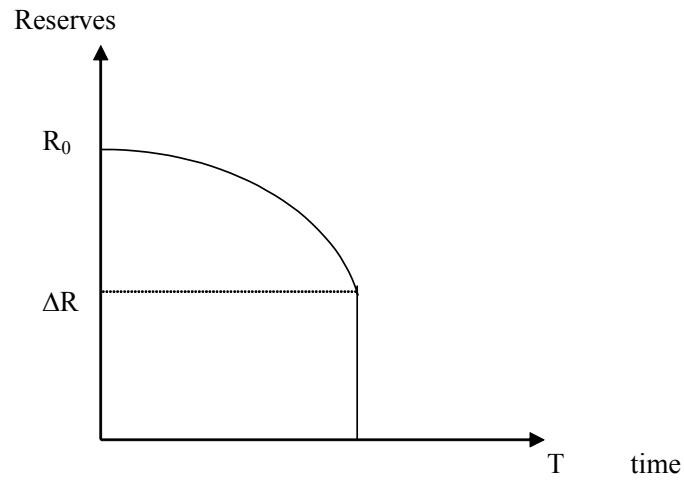
[5] The presentation of the model also follows in part Flood and Marion (2001) and Flood et al (1996).

investors a foreseeable capital gain, and so the speculative attack would occur a bit earlier – again inducing a step depreciation of the currency and inducing investors to attack a bit earlier. Working backward in this fashion, we get the size of the attack. This equals the critical level of reserves at which investors will sense that a speculative attack can succeed

$$\Delta R = \frac{\alpha_1 \mu}{\alpha_0 - \alpha_1 i} \tag{6}$$

Figure 1 shows the dynamics of the model. Two factors induce adjustment of the money market equilibrium: the demand for money drops due to higher interest rates and the money supply falls by the size of the attack.

Figure 1. **Loss of reserves in a Krugman-type crisis**



Setting reserves equal to zero, we can calculate from the equation (1) the shadow exchange rate, $\tilde{S}$, which balances the money market and prevails after the attack

$$\tilde{S} = \frac{\alpha_1 \mu}{(\alpha_0 - \alpha_1 i^*)^2} + \frac{D}{\alpha_0 - \alpha_1 i^*} \tag{7}$$

Denoting $a = \alpha_0 - \alpha_1 i^* > 0$, $P^* = 1$ and adding the size of the attack, the timing of the crisis T can be calculated from equation (5)

$$T = \left(R_0 - \frac{\alpha_1 \mu}{a} \right) \frac{1}{\mu} \tag{8}$$

The timing of crisis depends on the growth of domestic credit, μ, and initial reserves, R_0.[6] The strength of this model is that a sudden speculative attack and loss of reserves occur even though all the behavioural functions are continuous and the fundamentals develop predictably. The first generation models share the basic assumption of weak country fundamentals, which are known to be unsustainable in the context of a fixed exchange rate regime. This then establishes a unique relationship between fundamentals and timing of the crisis.

Several authors have since extended this basic first generation model of currency crisis. Connolly and Taylor (1984) added tradable and nontradable goods to the model. One of their findings was that a currency crisis can be caused by a loss of competitiveness and a current account deficit. Blackburn (1988) highlighted the effect of price flexibility on the timing of collapse. He also introduced imperfect asset substitutability into his models.[7] Since the basic first generation model fails to explain several stylised facts, like higher interest rates prior to crisis, several studies have introduced uncertainty into the model. In Flood and Garber (1984) domestic credit growth depends on a random component, and in Willman (1989) the threshold level of reserves is uncertain.

Although widely used by governments, surprisingly few studies have analysed how bond financing of fiscal deficits affects crises vulnerability. Buiter (1987) extended the model to include one-off government borrowing with foreign currency denominated bonds. The study does not, however, analyse the case where domestic credit is held constant via borrowing. Calvo (1998) discussed the case where the deficits are financed with domestic currency-denominated bonds, but it does not explicitly study the timing of crisis. The first essay of the thesis fixes this shortcoming by examining bond financing of

[6] The exact timing of the speculative attack and currency crisis was solved by Flood and Garber (1984), in both a perfect-foresight model and a stochastic market model without perfect foresight.

[7] Also Willman (1988) assumes that domestic goods and bonds are not perfect substitutes, but he uses a different assumption regarding wage formation. His insight was that it is not just monetary policy but rather the mix of fiscal, monetary and incomes policy that is important for the analysis.

fiscal deficits, in both domestic and foreign currency, and compares the timing and magnitude of the attack with the basic case where the deficits are monetised. These extensions modify the results of the first generation model, and might bring the old theory closer to current reality.

2.2 Second generation models

The limitations of first generation models became evident at latest after the EMS crisis in 1992–1993, which inspired new theories of currency crises. Unlike the earlier models, these second generation models take into account the possibility of self-fulfilling crises (eg Obstfeld 1986, 1994, 1996 or Jeanne 1997). An increase in devaluation expectations generally makes it more costly for the authorities to maintain an exchange rate peg. These costs rise eg as higher interest rates lead to unemployment. The government weighs the costs of defending the exchange rate against the benefits.[8] Investors anticipate the government's calculation and can raise the costs of defence (interest rates, unemployment) even further, and the crisis can become self-fulfilling.

We illustrate these second generation models by presenting a simple two-period model, following Jeanne (1999), where the source of multiple equilibria is the authorities' potential loss due to an increase in unemployment.[9] We assume that the monetary authority can sterilise reserve flows instantaneously and set the quantity of money at any desired level in periods 1 and 2. Moreover, the government always maintains the fixed exchange parity in the first period $(E_1 = \overline{E})$ but may devalue in the second period. We assume that the amount of devaluation, if it takes place, is d. And the

[8] The variety of fundamentals that influence the policymaker's decision can be quite large. These include 'hard' observable fundamentals, eg unemployment or trade balance, but also 'soft' fundamentals, such as the beliefs of foreign exchange market participants. For example, a sudden shift in market sentiment regarding the government's willingness to tolerate unemployment may trigger a currency crisis, which would not happen with a different set of investors' expectations. Reasons for defending a fixed exchange rate are eg: it serves as a guarantor of low inflation or it facilitates international trade and investments (see eg Obstfeld 1994 and Krugman 1998b). These second generation models are also called 'escape-clause' models, since the authorities have the option of abandoning the peg and validating the second equilibrium.

[9] In Obstfeld (1994, 1996) the basic logic of the model is similar than to that of the model presented above, although Obstfeld's versions are infinite in time and stochastic and endogenise the amount of devaluation, d.

monetary authority sets the quantity of money in period 2. Accordingly $M_2 = (1+d)\overline{M}$, which implies $E_2 = (1+d)\overline{E}$.

The government decides whether to devalue by considering the implications of the decision for the domestic unemployment rate in period 2. The unemployment rate is determined by an expectations-augmented Phillips curve

$$U_2 = \rho U_1 - \alpha(\pi - \pi^e) \tag{9}$$

where U_1 and U_2 denote deviations of the unemployment rate from its natural level in periods 1 and 2. The term π is the domestic inflation between periods 1 and 2, and π_e is the expected rate of inflation. The government decides whether to devalue in period 2 by minimising the loss function

$$L = (U_2)^2 + \delta C \tag{10}$$

where δ is a dummy variable indicating the government's decision (1 if it devalues and 0 otherwise) and C is the cost of opting out of the fixed exchange rate arrangement (ie the benefit of the peg).

The equilibrium can be characterised by proceeding backward. We observe first the optimal decision of the policymaker in period 2, given private agents' expectations, and then determine the conditions under which these expectations are rational. Private agents form their expectations with perfect foresight, expecting devaluation with probability zero or one.

Critical to the devaluation decision is whether the costs of maintaining the peg are higher than the costs of devaluation. If the private sector does not expect devaluation ($\pi^e = 0$), then the government loss function is simply $L^D = (\rho U_1 - \alpha d)^2 + C$ if it devalues and $L^N = (\rho U_1)^2$ if it does not. In this case (no devaluation expectations), not to devalue is the optimal decision if

$$\frac{C}{\alpha d} - 2\rho U_1 > -\alpha d \tag{11}$$

If the private sector expects a devaluation ($\pi^e = d$), the domestic government must either defend the currency [loss function: $L^N = (\rho U_1 + \alpha d)^2$] or devalue [loss function: $L^D = (\rho U_1)^2 + C$]. In

this case (private sector expects devaluation), devaluation is optimal decision if

$$\frac{C}{\alpha d} - 2\rho U_1 < \alpha d \tag{12}$$

We denote the LHS of inequalities (11) and (12) by ϕ and can thus distinguish between three cases, depending on the value of ϕ: 1) No devaluation, if $\phi > \alpha d$. There is only one equilibrium, where the private sector does not expect devaluation and the government does not devalue. 2) Devaluation, if $\phi < -\alpha d$. There is only one equilibrium, where the government's devaluation in period 2 is perfectly anticipated by the private sector. 3) Multiple equilibria, if $-\alpha d \leq \phi \leq \alpha d$. Government can either devalue or not, and these are the two possible equilibria.

This produces some important results. First, devaluation expectations are not always uniquely determined. Here, the authorities' costs due to higher unemployment give rise to multiple equilibria: one in which there are no attacks, no change in fundamentals and indefinite maintenance of the peg; and another in which investors expect an attack. The new fundamentals in the second equilibrium are validated after the investors' expected change in the exchange rate actually occurs. The currency crisis is then modelled as a sudden jump from one equilibrium to another. Secondly, inside the 'grey' area (the conditions given in case 3), whether or not devaluation occurs is determined by the markets' self-fulfilling mood. Devaluation or a currency crisis occurs if the private sector expects it. And thirdly, just a slight deterioration of fundamentals is enough to move the fixed exchange rate system from stable to unstable region. For example, a slight increase in the unemployment rate, U_1, may shift the economy to the grey area, where a self-fulfilling crisis is possible.

Besides unemployment there are several other factors which may induce self-fulfilling expectations and multiple equilibria. For example, Masson (1999) determines the fundamentals according to a balance of payments approach.[10] Since the debt payments of the government depend on the devaluation probability, self-fulfilling expectations and multiple equilibria may arise. The second essay of the thesis extends the model in Masson (1999) with capital flows. If capital flows depend on crisis probability, capital flows may create a

[10] The model set-up in Masson (1999) is based on Jeanne (1997).

multiple equilibria situation. Furthermore, in the model herding behaviour by lenders creates a mechanism for sudden stop of capital inflows. With capital flows included, the range in which multiple equilibria arise is wider and many emerging market countries were inside that range before the recent crises.

2.3 Banking crises in an open economy

Since the Asian crisis, most observers have come to agree that the first or the second generation theories do not sufficiently explain the mechanism of the recent crises. Stylised facts and empirical research show that banking and currency crises occur often simultaneously. Consequently, several studies have extended banking crisis models to the open-economy setting, and explain the recent crises in terms of problems in the financial system. The logic of banking and currency crisis can be similar in many respects.[11] Both types of crisis are attacks on price fixing policies; government tries to maintain a fixed price for foreign currency using its reserves, while banks try to maintain a fixed price between deposits and currency. In both types of theories, the run produces a discontinuous drop in the asset holdings of the price-fixing institution.

The open-economy versions of banking crisis models can also be classified as predictable bank run models (cf. first generation theories on currency crisis) or models with self-fulfilling expectations by the depositors (cf. second generation theories on currency crisis). Velasco (1987) and Corsetti et al (1999) include the non-performing loans of the banking sector as government liabilities. These must be financed by domestic credit expansion, which may then lead to balance of payments crises. Similarly, in Dooley (1997) government insures part of banks' foreign-currency deposits, which induces moral hazard behaviour and, possibly, currency crisis. The logic of these models is similar to the first generation models of currency crises and the crises in these models are caused by bad policies of the individual countries.

Stylised facts on the Asian crisis indicate that not only bad country fundamentals but also international illiquidity and financial panic had a role in these recent crises.[12] Some studies have extended the Diamond and Dybvig (1983) model with self-fulfilling features to the open-economy setting. In the Diamond and Dybvig model banks'

[11] This literature review on banking and currency crises is based partly on Marion (1999).
[12] See Corsetti et al (1998), Chang (1999) and Calvo (2002).

assets are invested in illiquid production technology, but the banks provide liquid deposits for consumers. The bank run is then induced by self-fulfilling expectations, where depositors try to exchange deposits for bank reserves. Using an open-economy version of the Diamond and Dybvig model, Chang and Velasco (2000) study the interaction between bank fragility and the exchange rate regime. They compare fragility of the system between currency boards, fixed and flexible rates, and with and without a lender of last resort. If the central bank tries to fix the exchange rate and act as lender of last resort, currency crises may occur. In another version of the model, Chang and Velasco (2001) allow foreign short-term borrowing by banks, which places international illiquidity at the centre of the problem. They find that capital outflows induced by foreign investors may now coincide with a bank run induced by domestic depositors, which increases the probability and magnitude of crisis.[13] These studies point out that the large short-term liabilities relative to liquid reserves was one reason for the recent crises. Furthermore, if foreign investors reduce their investments to emerging markets – for example do not roll over the short-term debt contracts – illiquidity of financial systems and crises may easily follow.

The financial crises in 1997–2000 spread first within Asia and later to Russia and Latin America. This contagion of financial crises has induced only a few theoretical studies which explain contagion by weaknesses in the international financial system.[14] Allen and Gale (2000) extend the Diamond and Dybvig model to several banks and study the possibility of financial contagion. In their model, banks diversify by holding short-term deposits in other banks. The possibility of contagious banking crises depends on the liquidity preference shocks and on the completeness of the interregional claim market. If the banks hold deposits only in some neighbouring banks, the banking system is more fragile and financial contagion more probable than in a more complete market structure.

The third essay of the thesis also builds a theoretical model on contagion but uses the version by Allen and Gale (1998), where the return on the long-term asset is risky, and the bank run is induced by a low return on the long-term asset. The essay builds a simple model of

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[13] In Goldfajn and Valdes (1997) foreign investors deposit into a local financial intermediator, which reinvests the funds in a risky illiquid asset. Low return on the risky asset may induce a bank run, capital outflow and currency crisis.

[14] Calvo and Mendoza (2000) discuss optimal diversification and show that costly information gathering might not be profitable when the number of countries is large. This can cause herding behaviour and contagion.

the international financial system, which includes several local emerging market banks and one international bank.[15] The international bank and the local banks may use leverage. The amount of borrowing is based on banks' collateral. In the model, the use of leverage and the fall in collateral prices comprise the main linkage for contagion.

2.4 Empirical literature

A rush of empirical literature on currency and financial crises emerged after the EMS crisis in 1992 and again after the Asian crisis in 1997. Sachs et al (1996) and Blanco and Garber (1986) concentrate just on specific crisis episodes. Using a larger data set, Kaminsky et al (1998) and Kaminsky and Reinhart (1999) employ a method based on the signal approach, the basic premise being that an economy behaves differently on the eve of a financial crisis than during times of normalcy. These studies identify variables that catch systematically deviant behaviour prior to crisis episodes. A variable is said to issue a signal when it departs from its mean beyond a certain threshold. The threshold level is chosen for each indicator in a way that minimises the risk of false signals and the risk of missing crises, ie it minimises the 'signal-to-noise ratio'. Kaminsky et al (1998) use the signal approach to predict currency crises for a sample of five industrial and 15 developing countries during the years 1970–1995. They find that the variables with the greatest explanatory power include exports, deviation of real exchange rate from trend, ratio of broad money to reserves, output, and equity prices. Perhaps the most thorough attempt to craft an early-warning system based on signal method is found in Goldstein et al (2000).

A different method to the study of common causes of crises is to employ discrete-choice models. These studies use logit or probit functions, and the predicted outcome, ie probability of crisis, is constrained between zero and one. The overall effect of the explanatory variables is evaluated simultaneously. Standard statistical tests are also possible. In one of the earliest studies of this type, Eichengreen et al (1995) use data from 1959 through 1993 for

[15] The international bank represents all banks and investment funds operating in emerging markets globally. Calvo (1999) uses the slogan 'Wall Street as a carrier' with a model where informed investors face margin calls after one crisis. The uninformed investors interpret the margin calls and the following sell-off as a decrease in the expected return on emerging market assets and mimic the actions of informed investors.

industrial countries to characterise the common causes of currency crises and illuminate their contagious nature. Frankel and Rose (1996) use a probit model to estimate the probability of crisis in an annual sample of 105 developing countries covering the period 1971–1992. They note that currency crises tend to occur when the growth of domestic credit and foreign interest rates are high, and FDI and output growth are low.[16]

The fourth essay of the thesis examines the causes of financial crises in 31 emerging market countries during 1980–2001. Although the role of liberalisation has been widely debated, the essay is the first study that divides the sample into pre- and post-liberalisation periods and examines whether financial liberalisation has modified the causes for crises. It estimates a probit model using 23 macroeconomic and financial sector variables, and finds that traditional variables such as unemployment and inflation, as well as several indicators of indebtedness such as private sector liabilities and banks' foreign liabilities, explain currency crises.

In addition to common causes, some recent studies examine the role of self-fulfilling expectations and the contagious nature of financial crises. Jeanne (1997) studies the 1992–1993 crisis of the French franc with a model in which unemployment is the cause of multiple equilibria. He finds some evidence that self-fulfilling expectations had a role in the crisis of the French franc.[17] After the Asian crisis many empirical studies examined whether a crisis or shock in one country increases the cross-market linkages.[18] Some of the studies test the correlations between asset prices. Usually these studies find evidence of large co-movements, but there is less agreement on whether such co-movement really increases during a crisis. Other studies examine whether the likelihood of crisis is higher in a given country when there are crises in other countries. Using a probit model, Eichengreen et al (1995) find that the probability of a domestic currency crisis increases with crises elsewhere. Using the signal method, Kaminsky and Reinhart (1998, 2000) conclude that contagion has been primarily regional and that the contagion increases

[16] For other studies using probit or logit models, see eg Berg and Patillo (1999), Kumar et al (2002) and Milesi-Ferretti and Razin (1998).

[17] Masson (1999) uses a model where the debt payments are the source of multiple equilibria and finds that in some countries the fundamentals were in 1994–1996 in the range in which self-fulfilling crises are possible. The second essay of the thesis finds that when capital flows are included in the model, the fundamentals of most emerging market countries were inside the range of multiple equilibria.

[18] For definitions of contagion and surveys see Dornbusch et al (2000), Pericoli and Sbracia (2003), Claessens and Forbes (2001), and Kaminsky and Reinhart (2000).

when the crisis is associated with a common lender.[19] Although economists still do not know the exact reasons for contagion, most agree that it did exist, and that during the recent crises it spread mainly via the financial linkages.

3 Summary of the essays and contributions

3.1 Borrowing and balance of payments crises

The first essay of the thesis extends the first-generation model of currency crises. Although widely employed by governments, debt financing of fiscal deficits has not yet been adequately studied in the currency crisis literature. In the first generation model on currency crisis by Krugman (1979) the collapse of a fixed exchange rate regime is caused by excessive money creation to finance the fiscal deficits. Although Buiter (1987) and Calvo (1998) study bond financing of fiscal deficits, no study has analysed the role of borrowing and debt denomination in the timing of crisis or magnitude of the attack.

The essay addresses this shortcoming by studying borrowing, in both domestic and foreign currency, and compares the timing and magnitude of the attack with the basic case where the deficits are monetised. The model also includes a risk premium, which depends on the government's indebtedness. The study finds that borrowing may not necessarily postpone the crisis. But if the public debt level is low, the currency crisis can be postponed by borrowing. Furthermore, if the bonds are denominated in foreign currency, the crisis occurs later than with bonds denominated in domestic currency. The essay also examines how the variation of the risk premium, eg due to volatile capital movements, affects the timing of crisis. In this case, a larger magnitude of capital flows may advance or postpone the crisis. With these extensions, the first-generation model of currency crisis

[19] Similarly, Caramazza et al (2004) found that strong financial linkages through a common creditor are the most significant variable to explain financial contagion. Van Rijkeghem and Weder (2000) studies capital flows during the recent crises, and particularly the role of bank lending, and conclude that having common bank lenders was a fairly robust predictor of bank flows and currency crisis. Kaminsky et al (2003) finds that mutual funds enhance the contagion.

can better explain the reasons, magnitude, and timing of some of the recent crises, for example in Russia, Turkey or Argentina.

3.2 Sudden stop of capital inflows and currency crises

One crucial characteristic of the recent crises was a sudden stop of capital inflows, or capital account reversal, which in almost every case amounted to more than 10% of the country's output. The second essay of the thesis uses a currency crisis model by Masson (1999), where the conditions for multiple equilibria and self-fulfilling crises are based on the balance of payments of the given country. The source of multiple equilibria is the higher debt service costs due to depreciation expectations.

The second essay of the thesis extends this second generation model of currency crisis with capital flows. If capital flows depend negatively on the probability of crisis, there will be multiple equilibria. The study employs lenders' herding behaviour as the causal mechanism for the sudden stop of capital inflows that marked the recent crises. This was accomplished via Basu's (1991) loan pushing model, where herding behaviour causes a discontinuous supply of credit to the country. The fragility of the credit market equilibrium renders the country vulnerable to sudden changes in capital flows. The range of country fundamentals for which multiple equilibria and self-fulfilling crises are possible is now wider when capital flows are included in the model. Consequently, with given fundamentals more countries may end up in crisis. Furthermore, even a smaller-than-expected subscription for a bond issue or lower expected returns generally in emerging markets may cause a total cessation of foreign financing and a currency crisis. The study applies the model for several emerging market countries just before the crises in Mexico (1995) and Asia (1997). The main observation is that in almost all of these countries the fundamentals were inside the range of multiple equilibria and hence self-fulfilling crises were possible.

3.3 Contagion via financial linkages

The exact reasons for the contagion of financial crises in 1997–1999 are not well known. The empirical studies and stylised facts suggest that the use of leverage by the banks in emerging markets and having a common lender may be possible reasons behind the contagion. Although contagion is widely debated in policy discussions and verified in several empirical studies, theoretical studies on contagion are still rare. The third essay of the thesis addresses this shortcoming by developing a simple model of the international financial system and studying the fragility of the international financial system and the linkages through which crises are able to spread. The essay uses the model of Allen and Gale (1998) as a basic model of financial intermediation, but adds several local EM banks and an international bank. These banks are able to use outside borrowing, the amount of which is determined by the value of their collateral. Indeed, the essay also links together the literature on credit constraints and financial crises.

The study generates a number of results. First, costly liquidation of the long-term asset is a precondition for contagion. Second, without the use of leverage by either the local EM banks or the global banks, the international financial system is not very fragile, and contagion is unlikely. Third, the fall in asset and collateral prices is a vital linkage for contagion. Fourth, contagion is more severe when local EM banks use leverage than when global banks borrow. Fifth, when both the local EM banks and the global banks use leverage, the international financial system is highly vulnerable to contagion and the crises can spread to several countries. The essay points particularly to the use of leverage and the fall in collateral prices as an important channel and reason for contagion.

3.4 What drives financial crises in emerging markets?

The fourth essay of the thesis analyses the causes of financial crises in 31 emerging market countries during 1980:1–2001:12. It estimates a probit model using 23 macro-economic and financial sector indicators, including dummy variables for banking crises, exchange rate regime, and liberalisation. Although the empirical literature on common causes of financial crises is quite extensive nowadays, the ways in

which liberalisation of capital flows and financial sectors change the economic environment and influence the likelihood of crisis has yet to be adequately addressed. The essay is the first study that divides the sample into pre- and post-liberalisation periods and examines whether financial liberalisation modifies the causes for crises.

The study finds that traditional variables such as unemployment and inflation, as well as several indicators of indebtedness such as private sector liabilities and banks' foreign liabilities, explain currency crises rather well, and it appears that currency crises occur in tandem with banking crises. When the sample was divided into pre- and post-liberalisation periods, the study finds that the indicators of indebtedness became more important in predicting crisis during the post-liberalisation period, while the real variables diminished in significance. The importance of indicators of indebtedness is an interesting and novel result, and might indicate a structural change in the global capital markets. Nowadays, large amounts of financial liabilities may easily lead to a sudden capital outflow and crisis.

As for the timing, a currency crisis tends to occur approximately two years after the liberalisation of domestic financial sectors and four and a half years after the liberalisation of capital flows. However, no support was found for the argument that the deregulation of capital flows in itself was the cause of the recent crises in the emerging markets. The results of the essay emphasise the need for careful monitoring of the various indicators of indebtedness. Given the high degree of international capital mobility, this is especially relevant for the emerging markets in general and particularly for countries intending to liberalise.

3.5 Main contributions and discussion

The main contribution of the thesis as a whole is the extension of the crisis literature with capital movements, which in many crisis countries were in debt instruments. The existing theories on currency crises analyse capital movements quite straightforwardly, and might not be appropriate for application to the recent crises in emerging markets, marked by sudden and massive capital movements. The essays in the thesis repair this shortcoming and modify the various generations of the literature.

Although the essays are independent studies, they do produce some common – and also novel – findings. First, with liberalised capital movements, emerging market countries seem to borrow more

and, maybe, excessively. Second, with liberalised capital flows, self-fulfilling crises appear easier. Third, with inadequate institutions such as poor banking supervision, but already liberalised and closely interdependent capital movements, crisis in one country may easily lead to decreases in collateral prices and crises in other countries. Fourth, nowadays additional indicators on the banking sector and indebtedness are vital for crises prevention.

The results also have some policy implications. Institutions should be set up so that excessive borrowing by the government or private corporations is not encouraged. The level of indebtedness of emerging market countries increased after the liberalisation of capital flows. Large amounts of financial liabilities of the government or domestic banks may today easily lead to a sudden capital outflow and crisis. The use of leverage and the fall in collateral prices creates an important channel and reason for contagion. Clearly new indicators on the banking sector, collateral prices and indebtedness need to be closely monitored by the country authorities and by the international financial institutions.

With volatile capital movements, emerging economies are indeed highly vulnerable to crisis. If the exchange rate peg is not credible, capital outflows will weaken the country fundamentals and may create a multiple equilibria situation. Even relatively healthy economies may end up with self-fulfilling expectations and crises. Recently, emerging market countries have started to accumulate large reserves and to hold their currencies undervalued. These are most likely counter-measures to crisis vulnerability, and might well be here to stay, unless further reforms are carried out regarding excessive borrowing and lending, information accessibility, financial system regulation and supervision etc.

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Essay 1

Borrowing and balance of payment crises

Tuomas Komulainen

Abstract

The study extends the first-generation model of currency crises. We study bond financing of fiscal deficits, in both domestic and foreign currency, and compare the timing and magnitude of the attack with the baseline case where the deficits are monetised. We also introduce a risk premium that depends on the government's indebtedness. We find that borrowing may not necessarily postpone the crisis. But if the public debt level is low, the currency crisis can be postponed by borrowing. When bonds are denominated in foreign currency the crisis occurs later, but the magnitude of the attack is larger than when bonds are denominated in domestic currency. Furthermore, if the risk premium is higher during a turbulent period, the crisis occurs earlier.

1 Introduction

Excessive budget deficits and government indebtedness have been mentioned as reasons for some of the recent currency crises, for example in Russia in 1998 and Argentina in 2001 (eg Sutela 2000, Mussa 2002). Similarly, budget deficits and foreign borrowing were the main causes of debt crises in many developing countries in 1980s. Although the currency crisis literature is quite extensive nowadays, surprisingly few studies have analysed the influence of government borrowing on currency crises.[1]

In the currency crisis model by Krugman (1979) the collapse of a fixed exchange rate regime is caused by excessive money creation to finance fiscal deficits.[2] Buiter (1987) extended the model to include one-off government borrowing with foreign currency-denominated bonds. The study does not, however, analyse the case where foreign borrowing is continuous and domestic credit is held constant. Calvo (1998) discussed the case where the deficits are financed with domestic currency denominated bonds, but it does not explicitly study the timing of crisis. In Flood and Marion (2000) the budget deficits are partly financed with bonds denominated in domestic currency, but again the study does not analyse the role of borrowing in the timing of crisis or in the magnitude of the attack.

Indeed, the role of debt denomination has not yet been explicitly studied using the first generation model of currency crises, even though, in emerging economies, crisis prevention and debt denomination are important concerns for authorities responsible for debt management. Furthermore, no study, to our knowledge, has included a risk premium that depends on the government's indebtedness.[3] Thus, we include in a basic currency crisis model by Flood and Garber (1984) bond financing of deficits and a risk premium which depends on government indebtedness. We will analyse the consequences of bond financing in both domestic and foreign currency.

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[1] Daniel (2001) builds a model related to the literature on fiscal theory of price level and studies the consequences of stochastic shock to government transfers on currency crisis. See Agenor et al (1992) and Willman (1992) for surveys on studies on first generation theory.

[2] See also the simplified version of the model in Flood and Garber (1984). See also Flood et al (1996), which includes a bond market in the currency crisis model and studies the role of sterilisation.

[3] See eg Willman (1988), Flood et al (1996) and Flood and Marion (2000) for different versions of risk premiums used in currency crisis models.

Financial liberalisation in the 1980s was followed by large capital inflows, ie borrowing by either the government or private banks and firms. In crisis times, capital flows reversed and consequently the volatility of capital flows has been mentioned as a possible reason for the recent crises (Calvo and Vegh 1999, Calvo 1996, 2002). Calvo et al (1996) and Calvo and Reinhart (1999) show that the magnitude of capital flows and their reversals has been substantial in the recent crises. During a boom period borrowing in emerging markets is easy and the risk premium is low. But during the turbulent times borrowing is difficult and emerging market countries have to cope with a higher risk premium. Thus, we will also study how changes in the risk premium alter the timing of crisis.[4]

With these extensions the currency crisis model in this study tells the following story: the government of an emerging market (EM) country finances its budget deficit by issuing bonds. Foreign investors' demand for bonds and the risk premium depend on the EM country's indebtedness. Furthermore, the demand for bonds and the risk premium are volatile. When investors expect a speculative attack to be successful, capital inflows cease and an attack materialises. We have an extended Krugman (1979) type crisis model, and we will study and compare the dynamics of reserves, timing of crisis and magnitude of the attack.

2 Model

The basic currency crisis model presented here follows Flood and Garber (1984), Flood et al (1996) and Kajanoja (2001).[5] The equations of the model are as follows:

$$\frac{M_t}{P_t} = \alpha_0 - \alpha_1 i_t \qquad \alpha_0 > 0, \alpha_1 > 0 \tag{1}$$

$$P_t = P_t^* S_t \tag{2}$$

[4] Implicitly we will study the role of capital movements to the timing of crisis. The first generation theories usually assume that uncovered interest parity holds, and so take into account capital movements, but not their volatility. See eg Carr and Darby (1981) and Kanniainen and Tarkka (1984) on the role of monetary shocks in money demand.

[5] The model presented here is a discrete version of the model. Symbol Δ denotes the difference operator.

$$i_t = i^* + \frac{\Delta S_{t+1}}{S_t} + \rho B_t \qquad \rho > 0 \tag{3}$$

$$M_t = D_t + R_t \tag{4}$$

where M_t denotes the monetary base, P_t the price of the domestic good and P_t^* the price of the foreign good. The domestic and foreign one-period interest rates are denoted i_t and i_t^*. S_t denotes the exchange rate (price of a unit of foreign currency), and $\Delta S_{t+1}/S_t$ is the devaluation rate. The stock of foreign reserves is denoted by R_t and domestic credit by D_t.

Equation (1) gives the demand for real balances, equation (2) is the purchasing power parity, and equation (4) gives the decomposition of the monetary base. Equation (3) is the covered interest rate parity with a risk premium, which depends on the government's indebtedness, B_t.[6] Except for the risk premium, ρB_t, the basic setup (equation 1–4) is similar to earlier currency crisis models, like Flood and Garber (1984) or Flood et al (1996).[7]

2.1 Domestic currency debt

Here the government's budget deficit δ is financed with domestic currency bonds, B_t. The budget deficit is assumed to be fixed in every period. The budget deficit and the increase in government borrowing is defined as

$$\Delta B_t = \xi_t + i_t B_{t-1} = \delta \tag{5}$$

The budget deficit includes the primary deficit ξ and the interest payments.[8] The debt stock at the end of a period is:[9]

[6] Although we do not include defaults in the model, investors require a higher return if the country's bonds outstanding are increasing.

[7] Appendix 1 calculates the magnitude of the attack and the time of the crisis without the risk premium and on the assumption that the budget deficit is financed with the growth of domestic credit.

[8] We thus implicitly assume that the government adjusts the primary deficit as the interest payments increase. This is quite strong assumption, but before the crises in Turkey, Russia and Argentina the governments diminished the primary deficits as the interest payments increased. Nevertheless, these crises materialised.

$$B_t = \delta t \tag{6}$$

Domestic credit is constant during the fixed exchange rate period, and equation (1) can be written as

$$D_t + R_t = P^* \overline{S}[\alpha_0 - \alpha_1(i^* + \rho B_t)] \tag{7}$$

For simplicity we denote $P^* = 1$ and the fixed exchange rate $\overline{S} = 1$. We obtain the dynamics of international reserves during the fixed rate period by differentiating equation (7):

$$\Delta R_t = -\alpha_1 \rho \delta \tag{8}$$

Due to the government borrowing, money demand will be lower and the higher risk premium higher. Thus, the reserves decline.

At the time of the crisis reserves are exhausted. We denote the time of the crisis T_D and the size of the attack $\Delta_T R_D$. Consequently, the condition of the attack can be written as

$$R_0 - \alpha_1 \rho \delta T_D - \Delta_T R_D = 0 \tag{9}$$

After the attack, the government finances the budget deficit by domestic credit. The growth of domestic credit after the attack is denoted μ_T[10] and the increase in domestic credit is determined

$$D_{T+1} = D_T + \mu_T \tag{10}$$

Denoting the exchange rate, which will prevail after the attack, $\widetilde{S}_t$, equation (7) can be written in format

$$D_t = \widetilde{S}_t \left[\alpha_0 - \alpha_1 \left(i^* + \frac{\Delta \widetilde{S}_{t+1}}{\widetilde{S}_t} + \rho B_t \right) \right] \tag{11}$$

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[9] We assume that a currency crisis occurs before investors stop financing the deficit and debt payments. In addition, we assume that the bonds are held entirely by foreigners.

[10] The domestic credit growth after the attack ($\mu_T > 0$) equals the budget deficit δ. We will shortly discuss the role of domestic credit after the attack in section 3.

where the debt stock B_t just before the attack is $B_T = \delta T_D$. After the attack the exchange rate depends on the domestic credit growth, and we write the exchange rate after the attack, $\widetilde{S}_t$, into the format

$$\widetilde{S}_t = k_0 + k_1 D_t \tag{12}$$

Since domestic credit increases by μ_T after the crisis, $\Delta\widetilde{S}_{t+1}$ equals $\mu_T k_1$. We denote $a = \alpha_0 - \alpha_1 i^* > 0$, and substituting (12) into equation (11) we can derive the coefficients

$$k_0 = \frac{\alpha_1 \mu_T}{(a - \alpha_1 \rho B_T)^2} \tag{13}$$

$$k_1 = \frac{1}{a - \alpha_1 \rho B_T} \tag{14}$$

At the instant of the crisis money demand will drop by $\alpha_1 \mu_T k_1$ and so money supply will have to drop by the same amount. The size of the attack is thus defined by

$$\Delta_T R_D = \alpha_1 \mu_T k_1 \tag{15}$$

We are now able to write the condition on the attack (equation 9) as

$$R_0 - \alpha_1 \rho \delta T_D - \frac{\alpha_1 \mu_T}{a - \alpha_1 \rho \delta T_D} = 0 \tag{16}$$

The time T_D of the crisis is determined:

$$T_D = \left[R_0 + a \pm \left[(R_0 - a)^2 + 4\alpha_1 \mu_T \right]^{\frac{1}{2}} \right] \frac{1}{2\alpha_1 \rho \delta} \tag{17}$$

In addition to the initial level of reserves, the timing of crisis now depends on the risk premium (ie indebtedness) and on the growth of domestic credit after the crisis.[11]

2.2 Foreign currency debt

Next we analyse the case where the borrowing is carried out with bonds denominated in foreign currency, B_t^*. We denote all in terms of domestic currency, but since we denote $\overline{S} = 1$, we drop the exchange rate away during the fixed exchange rate period. The increase in borrowing during the fixed exchange rate period is again constant

$$\Delta B_t^* = \xi_t + i_t B_{t-1} = \delta \tag{18}$$

And the debt stock at the end of a period

$$B_t^* = \delta t \tag{19}$$

When the borrowing is carried out in foreign currency bonds, the dynamics of reserves during the fixed exchange rate period are as follows

$$\begin{aligned} \Delta R_t &= -\alpha_1 \rho \delta - i_t B_{t-1}^* + \delta \\ &= -\alpha_1 \rho \delta + \xi_t \end{aligned} \tag{20}$$

where the second term is the interest payments and the third term the borrowing in foreign currency. And using equation (18) the dynamics of reserves can be also written in the form of primary deficit ξ_t. Indeed, the reserves increase until the decrease in money demand due to higher risk premium is equal to the primary deficit.[12] Afterwards reserves decline.

The primary deficit ξ_t equals the budget deficit δ at time zero and diminishes afterwards since the interest payments increase. Denoting

[11] If we assume $R_0 - \alpha_1 \mu_T / a > 0$ (crisis will not occur immediately), there are two positive solutions for T_D. We are more interested about the smaller one (this occurs earlier) and so the solution with the minus sign in the brackets is of interest.

[12] The result that reserves may increase with bond issues in foreign currency is quite obvious and resembles Buiter (1987).

ξ_a the average primary deficit between 0 and the time of the crisis $T_\$$ we write the dynamics of reserves[13]

$$\Delta R = -\alpha_1 \rho \delta + \xi_a \tag{21}$$

The condition on the attack is

$$R_0 - \alpha_1 \rho \delta T_\$ + \xi_a T_\$ - \Delta_T R_\$ = 0 \tag{22}$$

After the attack, the demand for real balances (equation 1) can be written in the format

$$D_t = \widetilde{S}_t \left[\alpha_0 - \alpha_1 \left(i^* + \frac{\Delta \widetilde{S}_{t+1}}{\widetilde{S}_t} + \rho \left(B_T^* + \frac{\Delta \widetilde{S}_{t+1}}{\widetilde{S}_t} B_T^* \right) \right) \right] \tag{23}$$

where the risk premium increases due to currency depreciation. The growth of domestic credit $\mu_{\$T}$ after the attack is[14]

$$D_{T+1} = D_T + \mu_{\$T} \tag{24}$$

The exchange rate that equilibrates the money market after the attack is again denoted by

$$\widetilde{S}_t = k_0 + k_1 D_t \tag{25}$$

Using $\Delta \widetilde{S}_{t+1}$ is equal $\mu_{\$T} k_1$ we can derive the coefficients

$$k_0 = \frac{\alpha_1 \mu_{\$T} (1 + \rho B_T^*)}{(a - \alpha_1 \rho B_T^*)^2} \tag{26}$$

and

[13] We will assume that ξ_a is smaller than the capital outflows, $\alpha_1 \rho \delta$, due to higher risk premium (equation 21 is negative). If we further assume that primary surpluses do not occur between zero and the time of the crisis $T_\$$, ξ_a receives a value between $[0, \alpha_1 \rho \delta]$.

[14] Again $\mu_{\$T}$ equals the budget deficit. Since the debt stock increases due to currency depreciation, the deficit and the credit growth after the attack might be higher than in the case where the debt is in domestic currency. See section 3 for a discussion.

$$k_1 = \frac{1}{a - \alpha_1 \rho B_T^*} \tag{27}$$

And to balance the money market at the instant of the crisis the magnitude of the attack becomes

$$\Delta_T R_\$ = \frac{\alpha_1 \mu_{\$T}}{a - \alpha_1 \rho B_T^*} \tag{28}$$

The condition of the attack, equation (22), can be written now in the format

$$R_0 - \alpha_1 \rho \delta T_\$ + \xi_a T_\$ - \frac{\alpha_1 \mu_{\$T}}{a - \alpha_1 \rho \delta T_\$} = 0 \tag{29}$$

And using equation (19) the time of the crisis is determined

$$T_\$ = \left[R_0 + a - \frac{\xi_a}{\alpha_1 \rho \delta} \pm \left[\left(R_0 + a - \frac{\xi_a}{\alpha_1 \rho \delta} \right)^2 - 4(\alpha_1 \rho \delta - \xi_a) \left(\frac{R_0 a - \alpha_1 \mu_{\$T}}{\alpha_1 \rho \delta} \right) \right]^{\frac{1}{2}} \right] \frac{1}{2(\alpha_1 \rho \delta - \xi_a)} \tag{30}$$

When the government deficits are financed with bonds denominated in foreign currency, the timing of crisis depends on the risk premium and domestic credit growth after the attack, and also on the amount of borrowing (ie government primary deficit, ξ_a).

2.3 Comparison

We compare the magnitude of the attack and the timing of the balance of payments crisis for the three cases we have studied: the budget deficits are financed by either domestic credit expansion (appendix 1), bonds denominated in domestic currency (section 2.1), or bonds denominated in foreign currency (section 2.2). Appendix 2

summarises the timing and magnitude of the attack for those three cases.[15]

Let us analyse first the timing of crisis with domestic credit expansion (T) and with bond financing in domestic currency (T_D).[16] We find that if $\mu < 2\alpha_1\rho\delta$, then the crisis may occur earlier with bond financing than with domestic credit expansion ($T_D < T$). That is to say, if the growth in domestic credit is modest, but the indebtedness and risk premium are high, borrowing in domestic currency may not postpone the crisis. But if the condition $\mu \geq 2\alpha_1\rho\delta$ holds, the opposite result emerges.[17] Indeed, if the needed domestic credit growth is relatively high and the risk premium (ie indebtedness) low, currency crisis occurs earlier with domestic credit expansion than with bond financing ($T < T_D$).[18]

When analysing the timing of crisis with bond issues in domestic currency (T_D) and in foreign currency ($T_\$$), we find the amount of foreign currency borrowing (the primary budget deficit, ξ_a) critical for the comparison. If the primary surplus is large (ie indebtedness and interest payments are small), the crisis is postponed by foreign currency borrowing ($T_\$ > T_D$).[19] The policy conclusion of the result is that when the country's indebtedness is still low, but the borrowing needs are large, borrowing in foreign currency postpones the crisis.[20]

We turn now to the magnitude of the crisis, which also reflects the amount of exchange rate depreciation during the crisis. The magnitude depends on the domestic credit growth after the attack (μ, μ_T, $\mu_{\$T}$). If we assume that these are equal (eg the budget deficit δ), we find that the magnitude is larger with borrowing ($\Delta_T R_\$$ or $\Delta_T R_D$) than with domestic credit expansion ($\Delta_T R$). If the time of crisis and the debt stock are larger with borrowing in foreign currency than in domestic

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[15] For purpose of the comparison in Appendix 2 we calculate the timing of crises in the format where the debt stock in k_1 is denoted B_T. When we are comparing T_D and $T_\$$ we may assume $B_T = B_T^*$ since they both equal δT.

[16] We compare equations (A1.5) and (17) with the minus sign.

[17] During normal times the decrease in money demand due to higher risk premium should be less than due to domestic credit growth, and this condition should hold. Nevertheless, recent crisis episodes have shown that interest rates may increase to very high levels in crisis times.

[18] We compare equations (A1.5) and (17) with the minus sign. We assumed that $\mu = \mu_T$ and $R_0 - \alpha_1\mu/a > 0$ (crisis would not occur immediately). Setting $\mu \geq 2\alpha_1\rho\delta$, we find $T_D > T$.

[19] We compare T_D and $T_\$$ in the appendix 2. Similar result is received when we compare the conditions on the attack, equations (16) and (29). There is one caveat, we assumed that $\mu_T = \mu_{\$T}$, see section 3 for a discussion.

[20] The other way around: if the indebtedness high and the interest payments are high, the crisis might occur earlier with borrowing in foreign currency.

currency, the magnitude of the crisis is also larger.[21] Indeed, due to a large decline in reserves and the large magnitude of currency depreciation, bond financing in foreign currency might entail the greatest welfare costs.

These results have some policy implications for countries with fiscal deficits and borrowing needs. In countries where public debt levels are low, the authorities can postpone the currency crisis if they borrow in foreign currency, especially if the expectations are that the fiscal adjustment will eventually take place and the crisis – with large devaluation – will not materialise. If the debt level is high and crisis expectations already exist, neither borrowing in domestic nor in foreign currency will help; it may even make the situation worse.

3 Discussion

We will shortly discuss the role of two parameters in the model: the risk premium and domestic credit after the attack. To illustrate the role of the risk premium, we will study two regimes with two different risk premia: during a stable period it is easier for an emerging market country to sell its bonds globally and the risk premium, $\rho_L B_t$, is low. But during turbulent times in global capital markets, capital inflows to emerging markets are low and the risk premium, $\rho_H B_t$, is high.[22] The consequence of flexible risk premium is studied in the model where the deficits are financed by bonds denominated in domestic currency. During turbulent times and with borrowing the reserves diminish at a faster pace

$$\Delta R = -\alpha_1 \rho_H \delta \tag{31}$$

With the two possible risk premiums, the timing is now determined with a range $[T_{min}, T_{max}]$, where the limit T_{min} denotes the times of crisis with a low risk premium and T_{max} the time of the crisis with a higher risk premium. The limits are determined by

[21] This result is further enhanced if we regard the domestic credit expansion after the crisis larger with borrowing in foreign currency than with borrowing in domestic currency.

[22] During the recent crisis episodes (especially after the Russian crisis), the spreads in emerging markets generally increased. See Dungey et al (2003) for evidence and Ghosh et al (2002) for discussion how these turbulent periods in emerging markets affected crisis vulnerability.

$$T_{max} = \left(R_0 - \frac{\alpha_1 \mu_T}{a - \alpha_1 \rho_L B_T} \right) \frac{1}{\alpha_1 \rho_L \delta} \tag{32}$$

and

$$T_{min} = \left(R_0 - \frac{\alpha_1 \mu_T}{a - \alpha_1 \rho_H B_T} \right) \frac{1}{\alpha_1 \rho_H \delta} \tag{33}$$

We observe that the risk premium is critical to the timing of crisis. If the risk premium is low, crisis can be nicely postponed with borrowing. But if the risk premium is high (during the turbulent times in emerging markets) crisis may occur much earlier. Furthermore, if the variation of the risk premium is increased (ie ρ_H is higher and ρ_L is lower, eg due to larger magnitude of capital flows), the range in which crisis may start widens. Indeed, with large and unstable capital movements (larger variation in risk premium), crises may occur earlier or later than the other fundamentals might predict.

The role of domestic credit growth after the crisis is also critical for our results. One solution is to determine the deficits after the attack to be equal, and so the credit growth would be equal in all three cases. However, if the bonds are denominated in foreign currency, the debt stock has increased in domestic currency due to currency depreciation and higher debt payments are needed. Thus, a larger increase in domestic credit might be needed with bonds denominated in foreign currency. This modifies our results: borrowing in foreign currency may require a larger credit growth after the attack, which advances the time of the crisis.

4 Conclusion

This short note extended in several ways the first-generation model of currency crises. We studied bond financing of fiscal deficits in both domestic and in foreign currency, and compared the timing and magnitude of the attack with the baseline case where the deficits are monetised. In addition, we discussed the role of risk premium, which depends on the government's indebtedness, to the timing of crisis. A number of results emerged. Bond financing may not necessarily delay currency crisis, since the lower money demand due to higher risk

premium brings the crisis forward. Indeed, with bond financing the timing of crisis depends also on the country's indebtedness and on the borrowing needs of the government. If the country's indebtedness is low but the borrowing needs are high, currency crisis is delayed by bond financing, especially if the borrowing is carried out with bonds denominated in foreign currency. The magnitude of the attack is however larger. With higher risk premium during turbulent times in emerging markets, the crisis occurs earlier, and a larger magnitude of capital flows (ie a larger variation of the risk premium) stretches the period during which currency crisis may start.

Obviously the model has its shortcomings and the results should be read carefully. We assumed that the time and the debt level after which investors are no longer prepared to finance the government is later than the start of the balance-of-payments crisis.[23] We also assumed that all the bond issues are held by foreigners, and that the budget deficit is fixed. In addition, we discussed uncertain capital movements through the risk premium. A different and richer approach could bring the model even closer to reality.

Anyhow, we believe that our extensions are necessary and do improve the first generation model on currency crisis. Although widely employed by governments, debt financing of fiscal deficits has not yet been adequately studied in the currency crisis literature. The model presented here explains why a currency crisis may occur, although the domestic credit growth before the crisis is modest or the banking sector healthy. Moreover, the addition of a risk premium enables us to explain the high interest rates and the suddenness of recent crises. These are all familiar circumstances in the recent crisis episodes in Russia, Turkey and Argentina, where fiscal deficits were financed by bond issues. The debt levels increased, and suddenly capital inflows ceased, interest rates jumped, and the currency crises materialised.

[23] The caveat might not be that serious since in our model the risk premium depends on the debt level.

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Appendix 1

Basic currency crisis model

We calculate the magnitude of the attack and the timing of crisis in the basic case where the fiscal deficits, δ, are financed by the growth of domestic credit, μ. Equations (1), (2) and (4) are still the same, but equation (3) now lacks the risk premium

$$i_t = i^* + \frac{\Delta S_{t+1}}{S_t} \tag{A1.1}$$

The dynamics of the reserves during the fixed rate period are given by

$$\Delta R = -\mu \tag{A1.2}$$

The shadow exchange rate, $\tilde{S}$, is determined by

$$\tilde{S} = \frac{\alpha_1 \mu}{(\alpha_0 - \alpha_1 i^*)^2} + \frac{D}{\alpha_0 - \alpha_1 i^*} \tag{A1.3}$$

To balance the money market (equation 1) at the instant of the crises, the drop in money supply will have to equal the drop in demand, and the magnitude of the attack is

$$\Delta_T R = \frac{\alpha_1 \mu}{\alpha_0 - \alpha_1 i^*} \tag{A1.4}$$

Denoting $a = \alpha_o - \alpha_1 i^* > 0$ and $P^* = 1$, the timing of the crisis T is determined by

$$T = \left(R_0 - \frac{\alpha_1 \mu}{a} \right) \frac{1}{\mu} \tag{A1.5}$$

The timing of crisis now depends only on the initial level of reserves, R_0, and the growth of domestic credit, μ.

Appendix 2

Timing and magnitude of crisis

Method of deficit financing	**Timing**
Domestic credit expansion	$T = \left(R_0 - \frac{\alpha_1 \mu}{a} \right) \frac{1}{\mu}$
Bonds in domestic currency	$T_D = \left(R_0 - \frac{\alpha_1 \mu_T}{a - \alpha_1 \rho B_T} \right) \frac{1}{\alpha_1 \rho \delta}$
Bonds in foreign currency	$T_\$ = \left(R_0 - \frac{\alpha_1 \mu_{\$T}}{a - \alpha_1 \rho B_T^*} \right) \frac{1}{\alpha_1 \rho \delta - \xi_a}$

Method of deficit financing	**Magnitude**
Domestic credit expansion	$\Delta_T R = \frac{\alpha_1 \mu}{a}$
Bonds in domestic currency	$\Delta_T R_D = \frac{\alpha_1 \mu_T}{a - \alpha_1 \rho B_T}$
Bonds in foreign currency	$\Delta_T R_\$ = \frac{\alpha_1 \mu_{\$T}}{a - \alpha_1 \rho B_T^*}$

Essay 2

Sudden stop of capital inflows and currency crises

Tuomas Komulainen

Abstract

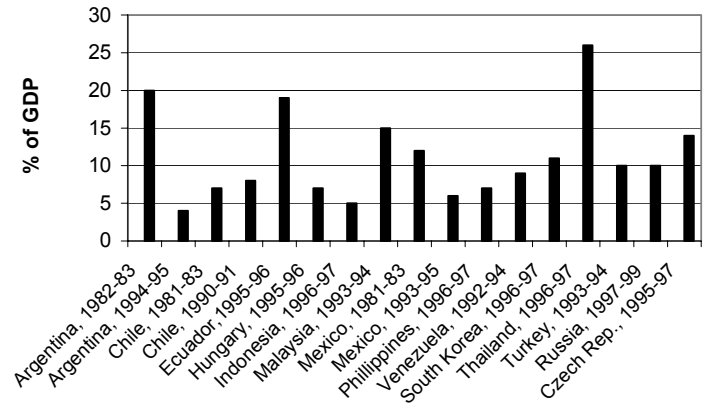
This study follows a currency crisis model by Masson (1999), but extends it with capital flows. If capital flows depend negatively on the probability of crisis, multiple equilibria arises. Furthermore, herding behaviour by the lenders creates a mechanism for sudden stop of capital inflows. When capital flows are included, the range of fundamentals where self-fulfilling crises are possible is larger. Consequently, the fundamentals have to be better, if the country wants to stay without crises. An application to the recent crises shows that the fundamentals of most emerging market countries were inside the range of multiple equilibria, and so crises were possible.

1 Introduction

1.1 Motivation

Sudden stop of capita inflows or capital account reversals has become the central issue in the financial crises of our day.[1] In almost all of the crises the capital account reversals were more than 10% of the country's output (figure 1). Another characteristic of today's crises is the swiftness and the magnitude of the crises.[2] Some blame market sentiment, but economists have created models, which allow multiple equilibria and sudden jumps from the good equilibrium to one with crisis. We introduce capital flows and the possibility of sudden stop of capital inflows as extensions into a currency crisis model. If capital flows depend negatively on the probability of crisis, multiple equilibria arises.

Figure 1. **Capital account reversals in emerging market countries**



Sources: Calvo and Reinhart (1999) and Nabli (1999).

[1] Calvo (1998) initiated the slogan sudden stop of capital inflows to the literature. See also Calvo and Reinhart (1999) for empirical evidence.

[2] And like other asset prices, the currencies fell dramatically. The Indonesian rupiah lost 80% of its value in less than a year and the Russian rouble plummeted 65% in a couple months. Daily collapses in the equity markets in some countries amounted to as much as 20–30% (see Kaminsky and Schmukler 1999).

Behind these sudden capital outflows were often foreign investors, who simultaneously withdrew from emerging markets. In the Latin American crisis especially U.S. investors and in the Asian crisis Japanese banks pulled out of these markets. Consequently, the emerging market countries totally lost their access to international capital markets (Calvo and Reinhart 1999, Kaminsky and Reinhart 1999b). This interdependence or herding behaviour by the investors might be another phenomenon that has been present in the crises. In the newly established emerging markets gathering and processing information on the fundamentals is difficult and expensive, whereas learning about other investors' decisions is cheap. Thus herding behaviour might be especially common in the emerging markets. We use herding behaviour by the lenders as a reason for the sudden stop of capital inflows.

Many blame capital movements for the recent crises. This study examines the role of capital movements in a model of self-fulfilling expectations and currency crisis: how the addition of capital flows affects the crisis vulnerability? What happens if the lenders are interdependent?

1.2 Empirical studies on the Asian crisis

The recent crises have motivated further empirical studies on financial crises.[3] Kaminsky and Reinhart (1999a) studied 76 currency crises and 26 banking crises in 1970–1995 using non-parametric approach to evaluate the usefulness of a number of different variables in signalling a pending or potential crisis. They found that financial liberalisation, real interest differentials, and current account deficits are accurate indicators of currency crises. In addition, a banking crisis usually starts before the balance of payments crisis. And 71% of these banking crises were preceded by financial liberalisation. Similarly Mahar and Williamson (1998) and Demirgüc-Kunt and Detriache (1998) have found that financial liberalisation has preceded many recent crises and has significantly increased the likelihood of crisis.

After liberalisation short-term foreign borrowing increased in many emerging market countries rapidly, which worsened the country fundamentals so that crises became possible (Rodrik and Velasco 1999, Goldstein 1998, Corsetti et al 1998). Most likely moral hazard

[3] Extensive surveys on empirical currency crisis studies can be find in Kaminsky et al (1998), Hawkins and Klau (2000), and Berg and Patillo (1999).

and corporate governance problems induced this excessive borrowing.[4] Corsetti et al (1998) stress the moral hazard problem entailed in a long tradition of public guarantees, which leads to over-lending by domestic banks and current account deficits. But they also point out the over-lending syndrome by international banks, which neglected the standards for sound risk assessments.

Several studies have found significant contagion effect during the Asian crisis, and crises were transmitted mainly through financial (Baig and Goldfajn 1999, 2000, Kaminsky and Reinhart 1999, 2000 and Van Rickeghem and Weder 2000).[5] Furthermore, Kaminsky and Reinhart (1999b) found that particularly Japanese banks drastically curtailed their lending to all other Asian countries after the devaluation of Thai baht. Baig and Goldfajn (2000) study the contagion from Russia to Brazil in late 1998. They examined cross-country correlations of stock indices, spreads on sovereign bonds and capital flows and conclude that, after the Russian crisis, panicking foreign investors triggered contagious currency crises in other emerging market countries.

Herding behaviour by the investors can be one reason for the sudden capital outflows and contagion during the recent crises. Although there are fairly many theoretical studies on herding behaviour, due to the practical problems involved, only a few empirical studies on herding behaviour have been carried out – and these have produced contradictory results. There is some empirical evidence on herding behaviour in emerging market countries, much of it related to crisis situations.[6]

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[4] Johnson et al (1999) construct a model where managerial agency problems and weak minority shareholder rights render emerging market countries vulnerable to sudden loss of investor confidence. They also study the practice of investor protection in 25 emerging market countries during the 1997–1999 crises and find that in countries with poor protection of minority shareholder rights the collapse of stock markets and depreciation of currencies was more severe.

[5] Usually the contagion term has been defined as a situation when a crisis one country causes an increase in cross-market correlation (Claessens and Forbes 2001). However, the exact reasons for simultaneous currency crises are hard to be determined. See also Eichengreen et al (1996), Forbes and Rigobon (1999) and Corsetti et al (2002) for empirical evidence and discussion on contagion.

[6] Rajan (1994) found some herding behaviour in bank's credit policies, especially during banking crises in New England in 1986–1992. Lakonishok et al (1991) studied 769 pension funds between 1985 and 1989 and found only weak evidence of herding and somewhat stronger evidence of positive feedback trading in shares of smaller companies. Choe et al (1998) found clear evidence of herding behaviour just before the Korean crisis in 1997. Chang et al (2000) found no evidence of herding among developed markets but did find herding behaviour in two emerging markets (South Korea and Taiwan) which was more pronounced when volatility was higher.

Based on these empirical studies and stylised facts one possible course of the recent crises in emerging markets can be discussed. The financial liberalisation combined with ineffective supervision created conditions for the private and public borrowers to use large amount of short-term foreign loans. The lenders in developed countries were few, interdependent and most likely without sufficient information. All this rendered borrowing countries vulnerable to self-fulfilling expectations, sudden capital outflows and currency crises.

1.3 Related theoretical literature and structure of the study

Currency crisis theories go back to the Salant and Henderson (1978) model of speculative attack on the gold market, which Krugman (1979) applied to the foreign exchange market. The first generation speculative attack models share the basic assumption of weak country fundamentals, which are known to be unsustainable with fixed exchange rate. This then establishes a unique relationship between fundamentals and timing of the crisis. The strength of the models is that a sudden speculative attack and loss of reserves occur even though all the behavioural functions are continuous and the fundamentals develop predictably.[7]

The limitations of first generation models became evident at latest after the EMS crisis in 1992–1993 since these models allowed only for an exchange rate peg, which either is or is not sustainable under the given fundamentals. The second generation models take into account the possibility of self-fulfilling crises.[8] An increase in devaluation expectations makes it more costly for the authorities to maintain an exchange rate peg. These costs rise eg as higher interest rates lead to unemployment. The government weighs the costs of

[7] See for a basic setup of first generation models in Calvo and Vegh (1999) or Flood and Marion (2001).

[8] See eg Obstfeld (1986, 1994, 1996) or Jeanne (1997) for second generation models. In 1996 an academic discussion emerged on whether a currency crisis can be caused by self-fulfilling expectations or solely by economic fundamentals (eg Krugman 1996, Obstfeld 1996b and Eichengreen et al 1996). Some recent theoretical studies have found that if investors face a small amount of noise in the signals regarding country fundamentals and are uncertain whether the information is common knowledge, a multiplicity of equilibria and self-fulfilling crisis need not obtain (Morris and Shin 1998).

defending the exchange rate against the benefits.[9] Investors anticipate the government's calculus and can raise the costs of defence (interest rates, unemployment) even further. This trade-off introduces the possibility of multiple equilibria: one in which there are no attacks, no change in fundamentals and indefinite maintenance of the peg and another in which investors expect an attack. The currency crisis is then modelled as a sudden jump from one equilibrium to another. And the timing of crisis is no longer uniquely determined.

There are several factors that can create a situation of multiple equilibria and may cause a self-fulfilling currency crisis.[10] Problematic is that the variety of fundamentals that influence the policymaker's decision can be quite large. These include 'hard' observable fundamentals, eg unemployment or trade balance, but also 'soft' fundamentals, such as the beliefs of foreign exchange market participants. Critical becomes how the fundamentals are chosen and what is the source for multiple equilibria in the model.

We use Jeanne (1997) as a basic currency crisis model, in which the conditions for multiple equilibria and self-fulfilling crises are derived. If country fundamentals are inside the grey area, whether or not devaluation occurs is determined by the markets' self-fulfilling mood. Since in emerging market country authorities' willingness to decrease unemployment was not a key aspect, we determine the fundamentals differently. We follow Masson (1999) and employ a balance of payments approach in determining the fundamentals. The source of multiple equilibria are the higher debt service costs due to depreciation expectations. We introduce capital flows into the model since the financial liberalisation preceded the recent crises and clearly was one important reason for the crises. If the exchange rate peg is not credible, capital outflows will weaken country fundamentals and may create a multiple equilibria situation.

Herding behaviour can be one reason for the large capital flows. Keynes (1936) already compared investors to beauty-contest judges who vote on the basis of the expected popularity of contestants with other judges rather than on the basis of absolute beauty. Later studies have found many theoretical reasons for this herding behaviour.[11]

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[9] Reasons for defending a fixed exchange rate are for example: it serves as a guarantor of low inflation or it facilitates international trade and investment (see eg Obstfeld 1994).

[10] See Obstfeld (1994, 1996a).

[11] See Schafstein and Stein (1990), Banerjee (1992), Trueman (1994) and Devenow and Welch (1996) for theoretical studies. Empirical research is still scarce, but usually herding behaviour has been found to be more common in respect of investments in smaller enterprises, emerging markets and crisis situations (Lakonishok et al 1991, Choe et al 1998 and Chang et al 2000).

Rational herding behaviour is usually modelled as being due to 1) payoff externalities, 2) principal-agent problems or 3) information externalities (Devenow and Welch 1996).[12] Calvo and Mendoza (2000) discuss optimal diversification as the number of possible investment countries grows. They show that costly information gathering might not be profitable when the number of countries grows. The costliness and inadequacy of information might well be a reason for herding behaviour in emerging markets. Financial liberalisation was often implemented without adequate supervisory bodies and information agencies. Governments, enterprises and investment banks were not able to inform investors adequately. Databases on clients' creditworthiness were missing, and so investors and lenders were unable to measure clients' risks accurately (Cavallo 1999). Instead, they might have been looking at what other investors were doing. Co-operative practices, like syndicated bond issues, can be a reason for the herding behaviour.[13]

We use herding behaviour by the lenders to describe the lack of information in emerging markets. In our extension Basu's (1991) loan pushing model determines the capital flows into a country, which creates a mechanism for the sudden stop. Lenders mimic other investors and are not searching for information by themselves. The model shows that if there is herding behaviour in the international capital markets, the credit supply curve becomes discontinuous. A slightly lower expected return in the borrowing country could lead to a sharp decline in loan supply and to capital outflows.

In the next section we first present the currency crisis model of Masson (1999) which work as a benchmark to our results. Further in the second section we present the contribution of this study, ie the addition of capital flows and herding behaviour. In the third section we give the empirical application of our model. In each section we compare our figures to the results by Masson. The last section presents concluding remarks and possible extensions.

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[12] Krugman (1997) gives two reasons for the herding behaviour in Asian crisis. First, there is a bandwagon effect driven by investors' awareness or expectations that other investors have private information. Secondly, much of the money invested in emerging markets is managed by agents rather than directly by principals. These agents are compensated in accord with comparisons with other money managers, and so herding behaviour is quite rational.

[13] Sachs (1984) points out that in a syndicated loan issue each participating bank tries to be a free rider, which leads to insufficient monitoring and supervision of the borrower.

2 A currency crisis model with multiple equilibria

The purpose of the currency crisis model presented in this chapter is to provide one explanation of why emerging market countries have been so vulnerable to currency crises during the last decade. We use a second generation model by Jeanne (1997) in which multiple equilibria are possible. Following Masson (1999), we use a balance of payments approach to specify the country fundamentals that are critical to crisis probability. We add capital flows and herding behaviour to this currency crisis model. Capital flows, which depend from the crisis probability, enable multiple equilibria. If a fixed exchange rate system is not credible, capital outflows will weaken country fundamentals. We also introduce investors' herding behaviour via Basu's (1991) loan pushing theory, which derives the reason and mechanisms for the sudden stop of capital flows. At the end of the chapter the model's implications are discussed.

2.1 The basic model

Following Jeanne (1997), we assume that an fixed exchange rate system is abandoned if the net benefits from maintaining the peg becomes negative ($B < 0$). The net benefits term includes both the gross benefits and the cost of the peg. The term is broken down into two terms, gross benefits (b_t) and credibility costs ($\alpha\pi_{t-1}$)

$$B_t = b_t - \alpha\pi_{t-1} \tag{1}$$

The gross benefit term (b_t) includes country fundamentals based on perfect credibility of the peg. In our case the term is simple determined by the balance of payment. The second term ($\alpha\pi_{t-1}$) implies that, for given macroeconomic fundamentals, lower credibility (ie higher probability of crisis, π_{t-1}) increases the cost and reduces the net benefit of the peg. There can be various reasons why lower credibility reduces the benefit and reduces the possibilities of

maintaining the exchange rate peg. In our model higher debt payments and capital outflows will increase the costs of the peg.[14]

The term π_{t-1} in equation (1) is the probability, as evaluated by the private sector at time t–1, that the country authorities will devalue by choice or be forced to do so at time t.[15] Since the model assumes rational expectations, it is also the probability that a currency crisis will occur at time t. The devaluation probability evaluated at time t must equal the probability that the peg's net benefit will be negative at time t+1

$$\pi_t = \text{prob}_t[B_{t+1} < 0] \tag{2}$$

Denoting $\phi_t = E_t b_{t+1}$, we write the difference between actual and expected variable

$$\varepsilon_t = b_t - \phi_{t-1} \tag{3}$$

The ε_t defined in equation (3) has a density function, f ( ), that is continuous, symmetric [$f(\varepsilon) = f(-\varepsilon)$], strictly increasing in $(-\infty, 0)$, and strictly decreasing in $(0, \infty)$. Using equations (1) and (3), equation (2) can be rewritten as

$$\pi_t = \text{prob}_t[\varepsilon_{t+1} < \alpha\pi_t - \phi_t] \tag{4}$$

We denote the cumulative distribution function of ε by F( ). Using the notation for innovations in equation (3), we express equation (4) in terms of the cumulative distribution function, F( )

$$\pi_t = F[\alpha\pi_t - \phi_t] \tag{5}$$

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[14] Often the gross benefit term is determined by macroeconomic variables such as unemployment or trade deficit. And also the credibility cost term will be determined accordingly. In the model by Jeanne (1997) the government has an interest in devaluing because it wants to reduce the unemployment rate. This then creates the credibility costs for the government.

[15] In Jeanne (1997), equation (2) also includes a parameter indicating the strength of the government's commitment to the exchange rate peg. Nowadays with free and sometimes large capital movements, governments and central banks in emerging market countries usually do not have enough resources to defend a peg, even though they would like to do so. And so more relevant issues are the current fundamentals and what investors expect them to be in the future. In addition, how investors expect other investors or capital flows to behave are important for crisis probability. Consequently, we do not include a parameter about the government's toughness in our model.

which is the key equation in this currency crisis model. Since both the RHS and LHS of the equation depend positively on π_t, there may be multiple solutions. The possibility of multiple solutions means that the given level of expected future fundamentals, ϕ_t, may be consistent with several devaluation probabilities at time t.

Following Masson (1999) we determine the fundamentals according to a simple balance of payments approach. The cost-benefit calculus by the private sector is determined by the sufficiency of foreign reserves. The reason for the possibility of multiple equilibria in Masson's model is higher debt service costs when devaluation is expected. This model and results work as a benchmark to our results when capital flows and herding behaviour are included.

The model includes a home country, which is an emerging market country, and an external environment that determines the risk-free interest rate. The return on home country assets (ex ante and in natural log form) is

$$\begin{aligned} E_t \ln[(1+r_t)/(e_{t+1}/e_t)] &\cong i_t - \pi_t \ln(e_{t+1}/e_t) - (1-\pi_t)\ln 1 \\ &= i_t - \pi_t \ln(1+\delta) \\ &\cong i_t - \pi_t \delta \end{aligned} \tag{6}$$

where e_t is today's spot exchange rate and e_{t+1} is its value in the next period in the event of devaluation (otherwise $e_{t+1} = e_t$) and i_t is the return on emerging market country assets denominated in domestic currency. Thus the expected return on emerging market country asset equals to the risk-free foreign return, r, plus the devaluation probability, π_t, times the expected percentage devaluation, δ.[16]

The home country fundamentals are determined according to a simple balance of payments approach. The change in reserves is given by

$$R_{t+1} - R_t = T_{t+1} - (r + \pi_t \delta)D \tag{7}$$

where T is the trade balance, D is the country's external indebtedness, and R denotes international reserves. A currency crisis occurs at t+1 if

[16] Here the devaluation percentage is assumed to be given and is not endogenously determined in the model, which is in contrast to some other studies and can be seen as a weakness of the model (see Flood and Garber 1984 for first generation and Obstfeld 1984 for second generation models). In the empirical application of the model, the devaluation percentage, δ, is assumed to be 25%. Implicitly the model includes a market among non-residents for the bonds that equalises their expected return with the foreign interest rate.

$R_{t+1} - \overline{R} < 0$. We denote by $\overline{R}$ the threshold level for reserves. The probability of crisis in period t+1, which is formed at time t, is

$$\pi_t = \Pr[T_{t+1} - (r + \pi_t \delta)D + R_t - \overline{R} < 0] \tag{8}$$

The gross benefits of the fixed exchange rate system (b_t) without the credibility problems is defined as

$$b_t = T_t - rD + R_{t-1} - \overline{R} \tag{9}$$

and its expected value is

$$\phi_t = E_t b_{t+1} \tag{10}$$

Thus, the value ϕ_t in equation (5) depends negatively on the level of reserves and expected trade balance and positively on the stock of debt and foreign interest rates. The cost of the fixed exchange rate system due to credibility problems is

$$\alpha = \delta D \tag{11}$$

Now we can write the crisis probability in the format

$$\pi_t = \Pr[T_{t+1} - rD + R_t - \overline{R} < \pi_t \delta D] = \Pr[b_{t+1} < \alpha \pi_t] \tag{12}$$

The source of uncertainty in this Masson's model is a shock to the trade balance (T), and σ denotes the standard deviation of this shock. Expressing equation (12) in terms of the cumulative distribution function, F( ), we obtain a formulation similar to that in equation (5): $\pi_t = F[\alpha \pi_t - \phi_t]$.

Following Jeanne (1997) the first condition for multiple says that the slope of the cumulative distribution function must be steeper than the 45° line from the origin. The LHS of equation (5) is the 45° line and cumulative distribution function the RHS. The slope of the cumulative distribution function is equal to $f(d\pi - \phi)$, which should thus be greater than 1.[17] It is assumed that the slope of f ( ) reaches its maximum at f(0) (where $\alpha\pi = \phi$). The slope at this point is equal to

[17] f ( ) is the derivative of the cumulative distribution function, F ( ).

α f(0). Accordingly, the first condition for multiple equilibria is: α f(0) > 1.

Masson (1999) assumes that ε_t is normally distributed with mean zero and variance σ^2. Accordingly, the first conditions on the multiple equilibria can be written as[18]

$$z_1 = \frac{\alpha}{\alpha\sqrt{2\Pi}} > 1 \tag{13}$$

where $\prod$ denotes the constant 3.141… Since $\alpha = \delta D$, the condition for multiple solution depends on the size of debt and extent of devaluation, relative to the standard deviation, σ, of shocks to the trade balance.

We further calculate the range for country fundamentals $[\overline{\phi}, \underline{\phi}]$. This range for multiple equilibria is defined by the two tangency points between $F[\alpha\pi_t - \phi_t]$ and the 45° line, ie cumulative distribution functions should be tangent to the 45° line at $(\overline{\pi}, \overline{\pi})$ and $(\underline{\pi}, \underline{\pi})$. Assuming that ε_t is normally distributed, the range for fundamentals can be written[19]

$$\sigma w_1 + \alpha F(-w_1) < \phi_t < (-\sigma w_1) + \alpha F(w_1) \tag{14}$$

where $w_1 = \sqrt{2\ln z_1}$. If the fundamentals, ϕ_t, are inside these critical values $[\overline{\phi}, \underline{\phi}]$, the country fundamentals are inside the grey area and multiple equilibria are possible. Note that if the fundamentals are even worse than $\underline{\phi}$, a currency crisis should be a certainty. The limits are symmetric and depend on the value of $\alpha = \delta D$ and σ.

[18] The normal distribution function has the value $1/\sigma\sqrt{2\pi}$ at f(0).

[19] See appendix 1 for details of the calculation. In appendix 1 the condition is derived without the normal distribution assumption.

Table 1. **An application to emerging market crises by Masson (1999)**

Country (σ)	Date	D_t	R_t	T_t	z_t	ϕt min	ϕt max	ϕt	
Argentina (2,12)	1994	31.90	5.10	–2.5	1.51	3.38	4.62	1.93	
	1996	34.40	6.10	–0.3	1.60	3.47	5.03	4.71	I
Brazil (1.69)	1994	28.00	6.60	1.10	1.65	2.80	4.20	6.04	
	1996	28.00	7.80	–1.8	1.65	2.80	4.20	5.83	
Chile (3.05)	1994	46.20	25.10	1.40	1.51	4.87	6.67	23.10	
	1996	37.10	20.60	–2.2	1.21	4.37	4.90	18.03	
Colombia (2.68)	1994	30.30	11.00	–3.1	1.13	3.68	3.90	6.40	
	1996	32.60	11.00	–2.1	1.21	3.84	4.31	7.44	
India (0.46)	1994	33.30	6.70	–0.7	7.22	1.11	7.22	3.50	I
	1996	27.20	5.80	–1.6	5.90	1.07	5.73	2.80	I
Indonesia (1.23)	1994	55.50	6.90	2.30	4.54	2.71	11.29	4.72	I
	1996	46.90	8.10	1.30	3.81	2.61	9.14	7.46	I
Korea (2.38)	1994	14.90	6.70	–0.7	0.62	–	–	5.43	
	1996	21.20	7.00	–4.9	0.88	–	–	3.20	
Malaysia (3.53)	1994	39.50	35.10	–1.6	1.12	4.85	5.15	31.97	
	1996	38.60	27.00	0.70	1.46	4.77	4.98	26.30	
Mexico (3.29)	1994	37.30	1.50	–4.9	1.13	4.50	4.75	–3.86	B
	1996	48.00	5.80	2.50	1.10	5.17	6.83	5.54	
Philippines (2.76)	1994	57.90	9.40	–6.3	2.10	4.98	9.52	–0.72	B
	1996	51.10	12.00	–9.8	1.84	4.77	7.98	0.44	B
S. Africa (3.05)	1994	15.30	1.40	1.80	0.50	–	–	3.08	
	1996	18.00	0.70	0.70	0.59	–	–	2.08	
Thailand (2.47)	1994	46.20	20.90	–4.3	1.86	4.28	7.22	13.57	
	1996	50.10	20.90	–5.7	2.02	4.40	8.10	13.47	
Turkey (1.91)	1994	50.10	5.50	–6.3	2.61	3.68	8.82	–5.15	B
	1996	44.30	9.10	–10	2.30	3.55	7.45	–1.73	B

Source: Masson (1999).
Note: B = fundamental is below the range of multiple equilibria
I = fundamental is inside the range of multiple equilibria
In the rest of the countries fundamentals are better than the range of multiple equilibria
Figures are in percent of GDP.

This model can easily be used in empirical studies, and Masson (1999) reports applications to the crises in Mexico 1995 and Asia 1997. The data and the results are given in table 1. The results indicate that the fundamentals of several crisis countries where either below the critical level (where a crisis should be certain) or between the critical values for multiple equilibria (where a crisis may occur due to self-fulfilling expectations). For example, in 1994 Mexico's fundamentals were clearly lower than $\underline{\phi}$, so a crisis was certain. However, some important crises, eg those in Brazil, Korea and Thailand, are not indicated by this model. One reason can be that

although capital flows played a critical role during the recent crises, these are not included into the model.[20]

2.2 Capital flows

Next we include capital flows into the model and study the consequence of capital flows to the crisis vulnerability. We assume that capital flows depend on the country's crisis probability, since devaluation reduces investors' returns.[21] If there are depreciation expectations, capital will flow out of the country. These outflows are usually in equity and short-term corporate and government bonds, and they must be compensated from the reserves if the exchange rate peg is to be maintained.[22] Accordingly, possible capital outflows weaken country fundamentals, ϕ_t.

We denote the capital account as $S_t(\pi)$ and capital flows depend negatively on crisis probability, $S'(\pi) < 0$. Devaluation expectations for period t+1, which surface at time t, cause a capital outflow in period t+1. The higher debt service cost is still represented by a separate parameter, $\alpha = \delta D$.[23] The net benefit of the peg is thus

$$B_t = b_t - \alpha\pi_{t-1} + S_t(\pi_{t-1}) \tag{16}$$

The fundamentals covered by the parameter b_t, with full credibility of the peg, can be expressed as

$$b_t = T_t - rD + R_{t-1} - \overline{R} \tag{17}$$

Denoting $\phi_t = E_t b_{t+1}$, the change in fundamentals takes a form similar to that in equation (3), ie $\varepsilon_t = b_t - \phi_{t-1}$.

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[20] The importance of capital flows is also noted by Masson (1999b).

[21] Using a different model, Sachs et al (1996) also note that capital flows depend on expected devaluation, which enables multiple equilibria.

[22] We could consider the capital account to consist of two terms, where the first term would be (exogenous) foreign direct investment and the second represents portfolio investment, which depends on the devaluation probability. For simplicity, we denote the capital account simply as $S(\pi)$ and ignore FDI's.

[23] Debt service costs, $(r + \pi_t\delta)D$, are part of the current account and hence are expressed as a separate term. An alternative method could be to regard the possible capital flows as an increase or decrease in D.

With no currency crisis expectations ($\pi_t = 0$), the change in reserves is the normal $T_{t+1} + rD$. But if $\pi_t > 0$, higher debt service costs and capital outflows will reduce the reserves. The change in reserves becomes[24]

$$R_{t+1} - R_t = T_{t+1} - (r + \pi_t \delta)D + S_{t+1}(\pi_t) \tag{18}$$

The probability of a crisis at time t+1 (formed at time t) is

$$\pi_t = \Pr[T_{t+1} - rD + R_t - \overline{R} < \pi_t \delta D - S_{t+1}(\pi_t)] \tag{19}$$

and the cumulative distribution function becomes

$$\pi_t = F[\alpha_1 \pi_t - S_{t+1}(\pi_t) - \phi_t] \tag{20}$$

We observe that the crisis probability, π_t, now appears two times on the RHS of equation (20). We now derive the conditions for multiple equilibria and solve first the condition for the slope on the RHS of equation (20). We obtain f(0) $[\alpha - S'(\pi_t)] > 1$. If it is assumed that ε_t is normally distributed with $(0, \sigma^2)$, the condition can be written

$$z_2 = \frac{1}{\sigma\sqrt{2\pi}}[\alpha - S'(\pi_t)] > 1 \tag{21}$$

where $S'(\pi) < 0$. We further solve the critical range $[\overline{\phi}, \underline{\phi}]$ for the fundamentals. Assuming again that ε_t is normally distributed and denoting $w_2 = \sqrt{2 \ln z_2}$, we can write the range for the fundamentals $[\overline{\phi}, \underline{\phi}]$ as[25]

$$\sigma w_2 + \alpha F(-w_2) - S(F(-w_2)) < \phi_t < (-\sigma w_2) + \alpha F(w_2) - S(F(w_2)) \tag{22}$$

Considering some of the results, first, we observe that *capital flows, which depend of devaluation probability, enable multiple equilibria.* This means that free capital flows per se can create the possibility of

[24] The S( ) term may be negative if devaluation expectations are sufficiently large.

[25] See appendix 2 for the calculation and for the range $[\overline{\phi}, \underline{\phi}]$ without the normal distribution assumption.

self-fulfilling currency crises. For example government incentives or excess indebtedness of the government are not necessary requirements for multiple equilibria.

We now compare the conditions obtained here for self-fulfilling crisis to our benchmark case without capital flows obtained in chapter 2.1. Looking at equations (21) and (13), we see that, due to capital flows, more countries may meet the first condition for a self-fulfilling crisis. This is because $S'(\pi)$ is negative (capital outflows) and z_2 is larger than z_1. Furthermore, the magnitude of capital account reversal or capital flows, $S'(\pi_t)$, becomes critical for crisis probability.

We also compare the condition on the limits of fundamentals (equations 22 and 14). We assume that at $\overline{\pi}$ there is a capital outflow and hence the S term is negative at the $\overline{\phi}$ limit. We observe that the $\overline{\phi}$ limit is now larger when possible capital flows are included in the model. This is because in $\overline{\phi}$ in equation (22) the second term dominates the first one and the S( ) term is negative.[26] *Compared to the situation without capital flows, country fundamentals must be better if the country is to completely avoid crisis.*

The change in the $\underline{\phi}$ limit is ambiguous. We cannot be sure how our alteration affects it, because the difficulty to determine S( ) function in the lower limit, $\underline{\phi}$.

In any case, since we obtained the new limits $[\overline{\phi},\underline{\phi}]$, the model improves the basis for empirical work. There might be more countries that could meet the conditions for a self-fulfilling crisis. For example, in the empirical results of Masson (1999; see Table 1), even more countries might meet the conditions for self-fulfilling crises.

Some caveats are in order. We have not considered where the capital inflows are invested in the economy and how this might change the country fundamentals.[27] Thus we are not able to say that currency crises are actually more common in the real word due to the liberalization of capital flows. Only if country fundamentals – trade balance, country indebtedness etc – are the same as before, will the country fall more readily into a self-fulfilling crisis. We have not yet studied the mechanism whereby capital outflows occur in crisis situations. In the next chapter we will determine the behaviour of

[26] The second term dominates, because $F(\ ) \geq f^{-1}(\ )$ see equation (A2.3) in appendix 2. In equation (22) the first and the second term will shift in opposite directions from the equation (14). At the $\overline{\phi}$ limit, the first term is smaller and the second term larger than in equation (14) (note that $w_2 > w_1$).

[27] Capital inflows probably improve country fundamentals, at least in the long run.

capital flows and introduce herding behaviour by the investors into the model which creates the mechanism for sudden stop of capital inflows.

2.3 Herding behaviour

Next we characterise the behaviour of capital flows into the emerging market country further and assume that the capital flows, $S_t(\pi)$, follow herding behaviour by the investors.[28] In the introduction we cited several arguments why herding behaviour might be present in the international capital markets and especially in emerging markets. Although there are many theoretical models on herding behaviour, and herding has been cited to be behind the recent crises in emerging markets (eg Masson 1999b), it has not previously been made a formal part of a currency crisis model.

Here we use the loan pushing model by Basu (1991), where investors base their strategies by imitating other investors, to introduce the herding behaviour.[29] When assessing the creditworthiness of the borrowers, lenders use excess supply of credit as a positive sign.[30] For example, an oversubscription of a bond issue can be regarded as a sign of creditworthiness and lead to a larger amount of lending to the country. It can be shown that this kind of lender's interdependence leads to discontinuous supply of credit. This behaviour creates a mechanism for the sudden capital outflows in our currency crisis model. The model also formalises the stylized fact that the sudden and simultaneous withdraws by foreign lenders induced the recent crises.

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[28] Of course in reality the capital account balance is affected by several other factors as well. In order to study herding behaviour, we restrict these variables and assume that the capital account balance is determined solely by the loan pushing model. We should, however, keep in mind that the loan pushing model is an extreme case.

[29] The loan pushing theory indicates that lenders or banks are supplying more credit to the borrowing country than the latter would voluntarily take at the prevailing interest rate. The notion that countries are pushed to take more loans than they are willing to take might not be accurate. It may be closer to the truth to say that local banks and enterprises are willing to take these loans but that it is not appropriate for the country as a whole to take them, and maybe for the lenders to grant them.

[30] Whether the country is illiquid or insolvent depends on lenders' beliefs. If they think the country is simply illiquid, they will continue to lend, which will prevent insolvency and justify their view. If they think the country is insolvent, the lenders will refuse to lend and the country will turn out to be insolvent (Basu 1991). These beliefs can be quite fragile, and changes in them may cause capital outflows and currency crises. Consequently, the structure of international credit markets and the process of forming beliefs affect countries' vulnerability to large changes in capital flows.

Appendix 4 discusses the loan pushing model by Basu (1991) more extensively and characterises the equilibrium in the credit market.

In the loan pushing model the borrower announces (L, i), where L is the amount the borrower wants to borrow and i is the interest rate he is willing to pay. Let H be the set of potential lenders to the country. Each lender j has doubts about the quality of the borrower and therefore monitors the excess supply of credit to the country. Let w^e be the expected excess supply of credit and ρ_j the lowest rate at which the lender j is willing to lend to the borrower. The supply of credit to the country is determined as

$$s = s(w^e, i_t - \pi_t\delta) = \#\{j \varepsilon H \mid \rho_j(w^e) \leq i_t - \pi_t\delta\} \tag{23}$$

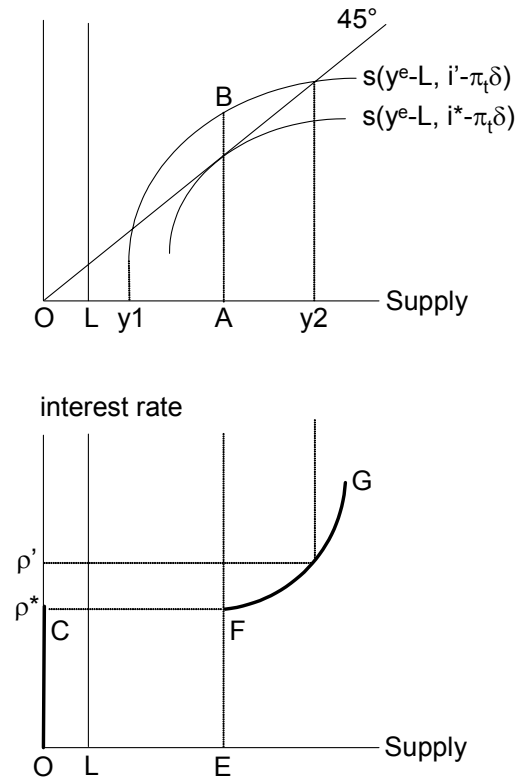
where $\partial s/\partial w^e \geq 0$, $\partial s/\partial I \geq 0$, the lender's return $\rho_t = i_t - \pi_t\delta$ and #A denotes the number of elements in the set A. Investors regard the excess supply as a sign of the country's creditworthiness and so $\partial s/\partial w^e$ is positive.

The actual supply of credit which equals to the expected supply is compatible with rational expectations. We denote the largest supply of credit according to rational expectations

$$S = S(S^e - L, i_t - \pi_t\delta) \tag{24}$$

Figure 2 and Appendix 4 shows that this supply curve will be discontinuous even though the supply curve in equation (23) is assumed to be continuous. If the lenders are interdependent (the supply S depends on the excess supply S^e–L), an equilibrium in the credit market can easily occur when there is an excess supply of credit to the country. Despite excess supply, the borrower cannot lower the interest rate, because this would totally eliminate the supply of credit to the country. Like shown in figure 2a slight lower interest rate than i* may cease the supply of credit. The reason is the interdependence between lenders. The equilibrium is fragile, as figure 2 illustrates. Small disturbances or news can lead to a total cessation of lending to the country.

Figure 2. **Supply of credit**



Source: Basu (1991).

We can formally express the supply of new loans as

$$S_{t+1} = \begin{cases} 0, \text{ if } i_t - \pi_t\delta < \rho^* \text{ or } S^e < \overline{S} \\ S_{t+1}(S^e - L, i_t - \pi_t\delta) \text{ if } i_t - \pi_t\delta \geq \rho^* \text{ and } S^e \geq \overline{S} \end{cases} \tag{25}$$

If the expectation variable, S^e, and the return variable, $i_t - \pi_t\delta$, exceed their threshold levels, $\overline{S}$ and ρ^*, the country receives foreign loans. If not, no new loans are supplied. Accordingly, the supply of credit function becomes discontinuous at the threshold levels. The model presents an extreme case of herding behaviour, since a small decrease in return will cause the supply of credit to drop to zero. The strength of the model is that this discontinuity and the sudden stop of loans are explained endogenously even though all the primitive behavioural functions in the model are continuous.

Next assume that the loan pushing model determines the capital flows and the country's capital account balance, S_{t+1}. Capital flows, S_{t+1}, depend on the behaviour of other investors $(S^e - L)$ and the return term $(i_t - \pi_t\delta)$. These are evaluated at the first period t. We assume further that in the period t the threshold values are exceeded and capital inflow at least in the amount OE occurs (like in figure 2).

In the next period, t+1, capital inflow continues, if the expectation variable, S^e, and the return variable, $(i_t - \pi_t\delta)$, exceed their threshold levels, $\overline{S}$ and ρ*. Capital outflows in the amount of OE occur if the threshold values are not exceeded. The change in reserves now becomes

$$R_{t+1} - R_t = T_{t+1} - (r + \pi_t\delta)D + S_{t+1}(S^e - L, i_t - \pi_t\delta) \tag{26}$$

where S_{t+1} corresponds to equation (25) and i_t to the interest rate on domestic (domestic-currency-denominated) bonds announced at time t. The probability of a crisis at time t+1, formed at time t, becomes

$$\pi_t = \Pr[T_{t+1} - (r + \pi_t\delta)D + S_{t+1}(S^e - L, i_t - \pi_t\delta) + R_t - \overline{R} < 0] \tag{27}$$

Since we are mostly interested in the $i_t - \pi_t\delta$ term, we write the cumulative distribution function in the form

$$\pi_t = F[\alpha_1\pi_t - S_{t+1}(i_t - \pi_t\delta) - \phi_t] \tag{28}$$

We have again multiple equilibria, one with positive investor expectations ($\pi_t = 0$), and another with currency crisis expectations ($\pi_t > 0$). In the first case, a lending boom to the country occurs and there is a capital inflow ($S_{t+1} \geq$ OE). In the second (bad) equilibrium, no new loans are supplied and a capital outflow occurs ($S_{t+1} = -$OE). A small decrease in the expected return in the emerging market country may move the country to the bad equilibrium, where capital outflows occur. These capital outflows must be financed by a current account surplus or change in reserves. If these are not sufficiently large, currency crisis expectations will be realised, ie a crisis will occur.

Next we derive the conditions for a self-fulfilling crisis, and compare them to our benchmark case without capital flows and herding behaviour. We assume that in the first period, t, the return exceeds the threshold level, ie $i - \pi_t\delta \geq \rho^*$, and that $S^e - L \geq \overline{S}$. The

country attracts foreign investment, and the capital inflow in period t is denoted OE (as in figure 2). Assuming again that ε_t is normally distributed the first condition for the slope of F( ) is

$$z_3 = \frac{1}{\sigma\sqrt{2\pi}}\left[\alpha - S'(\overline{\pi})\right] \tag{29}$$

where $S'(\overline{\pi}) < 0$. We denote $w_3 = \sqrt{2\ln\frac{\alpha - S'(\overline{\pi})}{\sigma\sqrt{2\pi}}}$ and $w_4 = \sqrt{2\ln\frac{\alpha + OE}{\sigma\sqrt{2\pi}}}$, and we are now able to write the limits for the fundamentals as[31]

$$\alpha F(-w_3) + \sigma w_3 - S(F(-w_3)) < \phi_t < \alpha F(w_4) - \sigma w_4 - S(F(w_4)) \tag{30}$$

We compare this condition for a self-fulfilling crisis to the benchmark case without herding behaviour and capital flows. The term $\overline{\phi}$ is now larger and the fundamentals must be better if the country is to totally avoid a crisis. We further assume that the capital inflows, S( ), and the increase in debt payments, α, are together at least as large as the variance in trade balance, σ.[32] Given this assumption the lower limit, $\underline{\phi}$, is now smaller. Thus countries with relatively bad fundamentals can avoid crises. And since the range for fundamentals $[\overline{\phi}, \underline{\phi}]$ widens as compared to equation (14), self-fulfilling crises are now more common if herding behaviour and capital flows are included in the model.

Using this framework we can also study the boom-bust cycle of capital flows after liberalisation. In the first period, t, the return exceeds the threshold level, $i - \pi_t\delta \geq \rho^*$, and $S^e - L \geq \overline{S}$. The country attracts capital inflows and the capital account surplus is at least OE (as in figure 2). In the next period, t+1, the return term may again exceed the threshold level, $i - \pi_t\delta \geq \rho^*$, in which case the country continues to receive capital inflows. However, if $i - \pi_t\delta < \rho^*$ sudden capital outflows occur. And these outflows can be quite large.[33] Thus,

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[31] See appendix 3 for the calculation and range for fundamentals $[\overline{\phi}, \underline{\phi}]$ without the normal distribution assumption.

[32] This is quite reasonable assumption, given the large capital inflows to many emerging markets after the liberalizations, which was preceded by large capital outflows.

[33] In the model the amount of loans supplied is larger than the demanded (OE > L).

in the second period after liberalisation, there is a risk of a large capital outflows and currency crisis.

In the model with herding behaviour, changes in expectations about the loan supply (S^e) also affect crisis vulnerability. Even a lower subscription of a bond issue (a lower S^e–L) could change these expectations. A negative change in these variables may cause S^e to drop below the threshold level, $\overline{S}$, and cause currency crises in emerging market countries. Also changes in external variables, like in interest rates in developed countries or in the worldwide savings rate, may cause currency crises in emerging market countries.[34]

To summarise, the loan pushing model shows that 1) *herding behaviour creates a mechanism for the large capital outflows experienced in emerging market countries in recent years*. The fragile equilibrium in the debt market renders the borrowing country vulnerable to capital outflows and currency crisis. The country may receive large capital inflows, which can suddenly reverse direction. Moreover, this capital account reversal can be quite large relative to the size of the country. 2) *In the currency crisis model the range of self-fulfilling crises becomes larger than without capital flows and herding behaviour*. Countries with quite good fundamentals may fall into crises while countries with relatively bad fundamentals avoid crises.[35] 3) *The supply of loans, S_{t+1}, depends on several factors, some of which are exogenous to the authorities in the borrowing country*. In the model even a smaller than expected subscription to a bond issue can cause capital outflows and a currency crisis in the country. 4) *The model directs our attention to the current situation in the international loan markets, where the different lenders are often interdependent*. Institutional aspects, eg the current practice of syndicate loan issues or the lack of an institution to provide accurate information, might be important reasons for herding behaviour and factors behind the recent crises.

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[34] Unfortunately, we are not able here to study these effects more thoroughly. In any case, empirical results by Dooley et al (1996) show that interest rates in developed countries have been significant factors in explaining government bond prices in emerging market countries.

[35] Given our assumption about the size of capital flows and change in fundamentals (σ). The intuition behind the result is that capital flows which do not depend from country fundamentals may 'punish' or 'save' countries. The result supports the view that although country fundamentals are important and country authorities are taking quite good care of them, a currency crisis may still occur. The result that capital flows widen the range for multiple equilibria is similar to the results received by Chang and Velasco (2001).

3 An application to the crises in emerging markets

Next we apply the model with our extension to emerging market crises in 1995 and 1997. Masson (1999) also provides an enlightening empirical application of his model to the Mexican and Asian crises. However, in his results the fundamentals of some crisis countries were not within the range for multiple equilibria or were not worse than the critical level. Our calculation method is similar to that in Masson (1999) and hence we are able to examine whether our extension, capital flows, improves the results.

We use equation (30), where normal distribution of ε_t is assumed, and fundamentals determined according to b_t. Our calculations are done for yearend, 1994 and 1996.[36] The data on trade balance, reserves and debt are from Masson (1999), and those on capital flows are from the IFS. We determine Smin as capital outflows under currency crisis expectations, and Smax as capital inflows in the absence of such expectations.[37] For Smax, we use the capital inflows in 1994 or 1996, which are expected to continue if currency crisis expectations do not materialise. For possible capital outflows, Smin, we use the portfolio liabilities from balance of payment data in 1994 or 1996, which are expected to become capital outflows if currency crisis expectations materialise.[38] In addition, direct investments are assumed to fall to zero. These assumptions would seem to reflect the loan pushing theory by Basu (1991).

The results of our calculations are presented in table 2. There the variable D denotes debt, R reserves, T trade balance, and S capital account balance. All figures are in per cent of GDP. S( )' denotes the,

[36] The time period over, which π_t is calculated, surely is critical to the results. We use the same method than by Masson where both short-term and long-term debt is included. For capital flows we use the yearly flows from the balance of payments. An alternative method would be to use the crisis onset years for a particular country or use just monthly data.

[37] Smin denotes the S( ) function at the $\overline{\phi}$ limit and Smax the S( ) function at the $\underline{\phi}$ limit in equation (30).

[38] In many of the countries studied, the inflows of portfolio investment become massive capital outflows during the crisis year. For example in Mexico the actual outflows in 1995 fit our assumptions. For Russia and Thailand, the data are not from the IFC but rather from IMF (2000) and IMF (1998), respectively. We calculated Smin for Thailand somewhat differently as the sum of private sector loans, other portfolio investments, other short-term investments, and other capital (incl. non-residents' baht accounts).

possibly negative, capital account reversal between 1994 and 1995 or between 1996 and 1997. Smax is the capital inflow when currency crisis expectations do not materialise and Smin the capital outflow when they materialise.[39] The variable z_t is calculated according to equation (29) and should be greater than one to enable multiple equilibria and self-fulfilling crises. The variable ϕ_t denotes country fundamentals in the given year and [ϕmax, ϕmin] is the range for multiple equilibria.

The main observation is that in almost all the countries studied the fundamentals were inside the range of multiple equilibria and hence self-fulfilling currency crises were possible. Only for Chile, Columbia and Malaysia, in both years, and in South Africa and Korea in 1994, were the fundamentals better than the ϕmax limit, indicating that currency crisis should not occur. The fundamentals for Mexico in 1994 and Turkey in 1994 were below the ϕmin limit, indicating that crisis should be certain. In all other countries the fundamentals were inside the range of multiple equilibria. This lends some support to the conclusion that a self-fulfilling currency crisis can be a common phenomenon in emerging market countries.[40] Compared to the results in Masson (1999), the fundamentals of several crisis countries (Brazil, Indonesia and Korea in 1996, Turkey in 1996, and Thailand in 1996) are now inside the range of multiple equilibria, indicating the possibility of self-fulfilling crisis.

[39] It is possible to view [Smax, Smin] as the range for possible capital flows during the next year.

[40] Clearly more sophisticated methods are needed to test whether the crises occurred due to self-fulfilling expectations. See eg Kajanoja (2001) and Jeanne and Masson (1998) who use models where the trigger value for the fundamentals follows a Markov process. They regress realignment expectations on macroeconomic variables, using both linear and regime switching models. Their conclusion is that regime switches may reflect self-fulfilling changes in expectations.

Table 2. **An application to emerging market crises when capital flows are included**

		D	R	T	S	S( )'	Smax	Smin	z_t	ϕt	ϕmax	ϕmin	
Argentina	1994	31.90	5.10	–2.50	4.33	8.17	4.33	–3.83	3.04	0.53	8.11	–0.63	I
	1996	34.40	6.10	–0.30	6.18	10.74	6.18	–4.56	3.64	4.56	9.28	–2.31	I
Brazil	1994	28.00	6.60	1.10	1.95	13.58	1.95	–11.64	4.87	5.88	15.37	1.32	I
	1996	28.00	7.80	–1.80	4.41	7.22	4.41	–2.82	3.36	4.99	6.77	–1.36	I
Chile	1994	46.20	25.10	1.40	9.99	12.37	9.99	–2.38	3.13	23.50	8.57	–4.63	
	1996	37.10	20.60	–2.20	10.01	11.86	10.01	–1.85	2.76	17.06	6.06	–4.95	
Columbia	1994	30.30	11.00	–3.10	4.35	6.19	4.35	–1.85	2.05	5.93	5.34	–0.26	
	1996	32.60	11.00	–2.10	6.37	8.60	6.37	–2.24	2.49	7.73	6.04	–2.02	
India	1994	33.30	6.70	–0.70	3.29	4.99	3.29	–1.71	11.55	3.84	8.90	–2.16	I
	1996	27.20	5.80	–1.60	3.13	4.17	3.13	–1.04	9.52	3.22	6.75	–2.04	I
Indonesia	1994	55.50	6.90	2.30	2.21	4.44	2.21	–2.23	5.94	5.59	13.38	0.52	I
	1996	46.90	8.10	1.30	4.85	7.09	4.85	–2.24	6.10	7.71	11.29	–2.18	I
Korea	1994	14.90	6.70	–0.70	2.61	4.73	2.61	–2.12	1.42	5.03	3.11	0.13	
	1996	21.20	7.00	–4.00	4.82	9.16	4.82	–4.34	2.42	2.24	5.98	–1.17	I
Malaysia	1994	39.50	35.10	–1.60	1.69	3.85	1.69	–2.16	1.55	30.93	7.01	3.34	
	1996	38.60	27.00	0.70	9.45	9.72	9.45	–0.27	2.19	26.31	4.48	–4.01	
Mexico	1994	37.30	1.50	–4.90	3.95	5.99	3.95	–2.05	1.86	–5.82	6.47	0.95	B
	1996	48.00	5.80	2.50	1.36	4.34	1.36	–2.98	1.98	6.57	9.68	3.94	I
Philippine	1994	57.90	9.40	–6.30	7.38	8.68	7.38	–1.30	3.35	–0.66	10.61	–2.23	I
	1996	51.10	12.00	–9.80	13.65	19.86	13.65	–6.21	4.72	0.36	13.62	–8.29	I
Russia	1994	46.00	3.78	10.10	–7.56	0.17	1.09	–7.56	1.55	10.89	14.24	3.72	I
	1996	52.00	3.97	5.82	–4.92	0.60	0.55	–4.92	1.81	7.92	12.86	4.51	I
S. Africa	1994	15.30	1.40	1.80	0.81	2.96	0.81	–2.06	0.89	2.21	–	–	
	1996	18.00	0.70	0.70	2.29	5.66	2.29	–1.61	1.33	0.75	4.56	1.03	I
Thailand	1994	46.20	20.90	–4.30	8.49	16.31	8.48	–2.00	4.50	13.60	14.60	–3.73	I
	1996	50.10	20.90	–5.70	10.83	20.00	10.83	–6.67	5.25	13.40	16.76	–5.91	I
Turkey	1994	50.10	5.50	–6.30	–4.19	1.12	4.65	–5.32	2.85	–4.06	14.15	–0.96	B
	1996	44.30	9.10	–10.0	6.39	7.81	6.39	–1.42	3.95	–2.49	8.79	–2.69	I

Sources: Masson (1999), IMF (2000), IMF (1998) and IFS.
Note: Except for Russia and Thailand, data for capital flows are from IFS.
For Russia: IMF (2000) Russian Federation: Selected Issues. Staff Country Report No. 00/15.
For Thailand: IMF (1998) Statistical Appendix. Staff country report No 98/119.
B = fundamental is below the range of multiple equilibria
I = fundamental is inside the range of multiple equilibria
In the rest of the countries fundamentals are better than the range of multiple equilibria
Figures are in percent of GDP.

4 Conclusion and discussion

The currency crises in 1997–1999 were in many countries preceded by the liberalisation of capital flows and financial markets, which enabled capital inflows in emerging market countries. The financial sectors in these countries were often undeveloped and poorly supervised which resulted in weak investor-rights protection, insufficient information and moral hazard problems. Excessive foreign borrowing and indebtedness in these economies followed. Recent empirical studies show that the crises were finally induced by the sudden decrease in foreign financing by international banks, which caused a sudden stop of capital inflows in emerging markets.

This study used a currency crisis model by Jeanne (1997), that derives conditions that enable a self-fulfilling crisis. These conditions for multiple equilibria and self-fulfilling crises are based on country fundamentals. Following Masson (1999), we employed a balance of payments approach to determine these country fundamentals. In his model, higher debt service costs are the reason for multiple equilibria. We used the model and the results by Masson (1999) also as a benchmark case.

In this study we extended the model by introducing capital flows, which depend on crisis probability. If the exchange rate peg is not credible, capital outflows weaken country fundamentals and may induce currency crisis. Multiple equilibria situation and self-fulfilling crisis may now occur even without high unemployment or excess indebtedness of the government. Compared to the benchmark case without capital flows, the country fundamentals must be now better if the country is to totally avoid a crisis. The magnitude of possible capital outflows becomes critical for crisis probability.

We also employed herding behaviour by the lenders as the causal mechanism for the sudden stop of capital inflows that marked the recent crises. This was accomplished via Basu's (1991) loan pushing model, where the interdependency of lenders causes a discontinuous supply of credit to the country. The fragility of the credit market equilibrium renders the country vulnerable to sudden changes in capital flows. The range of country fundamentals for which multiple equilibria and self-fulfilling crises are possible is now wider when capital flows are included in the model. Consequently, with given fundamentals more countries may end up in crises. Furthermore, even a smaller-than-expected subscription for a bond issue or lower expected returns generally in emerging markets may cause a total cessation of foreign financing and a currency crisis. The model further

indicates that lender interdependence, as exemplified by syndicated loan issues, can be one shortcoming of the present structure of international financial markets.

We applied our model for several emerging market countries just before the crises in Mexico (1995) and Asia (1997). The main observation is that in almost all of these countries the fundamentals were inside the range of multiple equilibria and hence self-fulfilling crises were possible. This somewhat improves the findings of Masson (1999) where some crisis countries were not indicated. Moreover, the results here suggest that self-fulfilling crises might be more common.

The model in this study could be improved in various ways. First, the manner in which capital inflows affect country fundamentals could be studied within the context of the model. A natural extension would be to include a banking sector. Second, the reasons for herding behaviour could be better formalized, which might introduce microeconomic explanations for the sharp shifts in investor expectations and capital flows. The contagion effect could also be formalized in the model. A foreign crisis could cause large capital outflows and currency crises in all the emerging market countries whose fundamentals are inside the grey are, where self-fulfilling crisis is possible.

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Appendix 1

The range for country fundamentals

We calculate first the larger limit $\overline{\phi}$. The conditions for $\overline{\phi}$ and $\overline{\pi}$ can be written as

$$\overline{\pi} = F[\alpha\overline{\pi} - \overline{\phi}] \tag{A1.1}$$

$$1 = \alpha f[\alpha\overline{\pi} - \overline{\phi}] \tag{A1.2}$$

The equation (A1.1) states that the LHS of equation (5) is equal the RHS and the equation (A1.2) comes from the tangency condition. From the latter, we obtain

$$f^{-1}\left(\frac{1}{\alpha}\right) = \alpha\overline{\pi} - \overline{\phi} \tag{A1.3}$$

where f^{-1} denotes the inverse function of f( ) and takes only positive values. Using equations (A1.1) and (A1.3), we obtain

$$\overline{\pi} = F\left(f^{-1}\left(\frac{1}{\alpha}\right)\right) \tag{A1.4}$$

which we put back into equation (A1.1) and obtain now the critical value $\overline{\phi}$ (above which, no crisis). By similar calculations, we obtain the other critical value, $\underline{\phi}$ (below which, a crisis is certain), and the range for country fundamentals is determined

$$\begin{aligned} &\overline{\phi} = -f^{-1}\left[\frac{1}{\alpha}\right] + \alpha F\left(f^{-1}\left(\frac{1}{\alpha}\right)\right) \\ &> \phi_t > \\ &\underline{\phi} = f^{-1}\left[\frac{1}{\alpha}\right] + \alpha F\left(-f^{-1}\left(\frac{1}{\alpha}\right)\right) \end{aligned} \tag{A1.5}$$

If the fundamentals, ϕ_t, are inside these critical values $[\overline{\phi}, \underline{\phi}]$, the country fundamentals are inside the grey area and multiple equilibria are possible. Assuming normal distribution of ε we are able to write this condition in the format in the equation (14).

Appendix 2

The range for country fundamentals with capital flows

When the capital flow term $S_{t+1}(\pi_t)$ is included, the conditions for $\overline{\phi}$ and $\overline{\pi}$ are

$$\overline{\pi} = F[\alpha\overline{\pi} - \overline{\phi} - S(\overline{\pi})] \tag{A2.1}$$

$$1 = \alpha f[\alpha\overline{\pi} - \overline{\phi} - S(\overline{\pi})][\alpha - S'(\overline{\pi})] \tag{A2.2}$$

Via a calculation similar to appendix 1, we obtain and derive the following condition for the fundamentals, ϕ_t

$$\overline{\phi} = -f^{-1}\left[\frac{1}{\alpha - S'(\overline{\pi})}\right] + \alpha F\left[f^{-1}\left(\frac{1}{\alpha - S'(\overline{\pi})}\right)\right] - S\left[F\left[f^{-1}\left(\frac{1}{\alpha - S'(\overline{\pi})}\right)\right]\right]$$

$$> \phi_t > \tag{A2.3}$$

$$\underline{\phi} = f^{-1}\left[\frac{1}{\alpha - S'(\underline{\pi})}\right] + \alpha F\left[-f^{-1}\left(\frac{1}{\alpha - S'(\underline{\pi})}\right)\right] - S\left[F\left[-f^{-1}\left(\frac{1}{\alpha - S'(\underline{\pi})}\right)\right]\right]$$

Assuming normal distribution of ε we are able to write this condition in the format in the equation (22).

Appendix 3

The range for country fundamentals with capital flows and herding

We consider the situation for two cases: 1) $i - \pi_t\delta \geq \rho^*$ and 2) $i - \pi_t\delta < \rho^*$. In the first case, where the return exceeds the threshold level $(i - \pi_t\delta \geq \rho^*)$, the country continues to have a capital inflow $[S(i - \pi_t\delta) \geq OE)]$. $S'(\overline{\pi})$ and $S'(\underline{\pi})$ are both < 0. The condition for the country fundamentals ϕ is now

$$\overline{\phi} = -f^{-1}\left[\frac{1}{\alpha - S'(\overline{\pi})}\right] + \alpha F\left[f^{-1}\left(\frac{1}{\alpha - S'(\overline{\pi})}\right)\right] - S\left[F\left[f^{-1}\left(\frac{1}{\alpha - S'(\overline{\pi})}\right)\right]\right]$$

$$> \phi_t > \tag{A3.1}$$

$$\underline{\phi} = f^{-1}\left[\frac{1}{\alpha - S'(\underline{\pi})}\right] + \alpha F\left[-f^{-1}\left(\frac{1}{\alpha - S'(\underline{\pi})}\right)\right] - S\left[F\left[-f^{-1}\left(\frac{1}{\alpha - S'(\underline{\pi})}\right)\right]\right]$$

In the second case return is lower than the threshold $(i - \pi_t\delta < \rho^*)$. No new capital flows occurs to the country and the capital inflow in the earlier period turns to capital outflow. We denote $S'(\underline{\pi})$ and $S'(\overline{\pi}) = -OE$. The condition for country fundamentals ϕ is now

$$\overline{\phi} = -f^{-1}\left[\frac{1}{\alpha + OE}\right] + \alpha * F\left[f^{-1}\left(\frac{1}{\alpha + OE}\right)\right]$$
$$- S\left[F\left[f^{-1}\left(\frac{1}{\alpha + OE}\right)\right]\right]$$

$$> \phi_t > \qquad \text{(A3.2)}$$

$$\underline{\phi} = f^{-1}\left[\frac{1}{\alpha + OE}\right] + \alpha * F\left[-f^{-1}\left(\frac{1}{\alpha + OE}\right)\right]$$
$$- S\left[F\left[-f^{-1}\left(\frac{1}{\alpha + OE}\right)\right]\right]$$

We must choose the lower limit, $\underline{\phi}$, from the first case (equation A3.1) and the upper limit, $\overline{\phi}$, from the second case (equation A3.2).[41] The limits for the country fundamentals $[\overline{\phi}, \underline{\phi}]$ are now

$$\overline{\phi} = -f^{-1}\left[\frac{1}{\alpha + OE}\right] + \alpha * F\left[f^{-1}\left(\frac{1}{\alpha + OE}\right)\right]$$
$$- S\left[F\left[f^{-1}\left(\frac{1}{\alpha + OE}\right)\right]\right]$$

$$> \phi_t > \qquad \text{(A3.3)}$$

$$\underline{\phi} = f^{-1}\left[\frac{1}{\alpha - S'(\underline{\pi})}\right] + \alpha F\left[-f^{-1}\left(\frac{1}{\alpha - S'(\underline{\pi})}\right)\right]$$
$$- S\left[F\left[-f^{-1}\left(\frac{1}{\alpha - S'(\underline{\pi})}\right)\right]\right]$$

Assuming normal distribution of ε we are able to write this condition in the format in the equation (30).

[41] If the fundamentals are better than the $\overline{\phi}$ limit, there should be no crisis. Thus the $\overline{\phi}$ limit must be from the second case. At the $\underline{\phi}$ limit a crisis should be certain; hence the limit is from the first case.

Appendix 4

Loan pushing model by Basu (1991)

In the loan pushing model by Basu (1991) single borrower confronts several lenders, but the lenders' decision is interdependent on each other. The borrower announces (L, i_t), where L is the amount the borrower wants to borrow and i is the interest rate he is willing to pay. Each lender supplies either one unit of credit or nothing. Let H be the set of potential lenders to the country. Each lender j in H has doubts about the quality of the borrower and therefore monitors the excess supply of credit to the country. Let w^e be the expected excess supply of credit and ρ_j the lowest rate at which the lender j is willing to lend to the borrower. The ρ_j can be treated as being inversely related to excess supply, w^e

$$\rho_j = \rho_j(w^e) \tag{A4.1}$$

Given the expected excess supply (w^e) and the interest rate (i) that the borrower is willing to pay, the total supply of credit to the country is determined is

$$s = s(w^e, i_t - \pi_t\delta) = \#\{j\varepsilon H \big| \rho_j(w^e) \leq i_t - \pi_t\delta\} \tag{A4.2}$$

where $\partial s/\partial w^e \geq 0$, $\partial s/\partial I \geq 0$, the lender's return $\rho_t = i_t - \pi_t\delta$ and #A denotes the number of elements in the set A. Investors regard the excess supply (w^e) as a sign of the country's creditworthiness and so $\partial S/\partial w^e$ is positive.

The single borrower announces (L, i_t), and the supply y can be said to represent rational expectations if

$$y = s(y^e - L, i_t - \pi_t\delta) \tag{A4.3}$$

where y^e is the expected supply of funds, L is the demand for credit and i is the interest rate the borrower is willing to pay. If lenders expect that y^e will be the total supply of credit (excess supply y^e–L), they will end supplying y units of credit. Lenders will end up supplying y units of credit only if this amount satisfies equation (A4.3), and we denote y^e the largest y^e representing this rational expectation. They choose the largest supply which satisfies equation (A4.3), which we denote the supply of credit S_{t+1}

$$S_{t+1} = S(Y^e - L, i_t - \pi_t\delta) \tag{A4.4}$$

It can be shown graphically that this supply curve will be discontinuous even though the supply in equation (A4.2) is assumed to be continuous. Figure 2 shows the lender interdependence and supply of credit. In the upper panel of figure 2 the expected supply is on the horizontal axis, the actual supply on the vertical axis, and the supply according to rational expectations can be found at the 45° line. With L fixed and interest rate also fixed the s-curve (A4.2) can be drawn as a function of the expected supply of credit. If the expected supply is OA, the interest i', the supply of credit is given by $s(y^e - L, i' - \pi_t \delta)$ and the amount supplied is given by AB. But because B lies above the 45° line, the expected supply, OA, is not consistent with rational expectations. The equilibria that are consistent with rational expectations are 0, y1 and y2. The lender chooses the largest of these, ie y2.

If the interest rate is lowered to i* and the return to ρ*, the supply of credit consistent with rational expectations is OA, which will also be the actual amount supplied. The thick line in the lower panel of figure 2 shows the relationship between the interest rate and the amount of credit supplied under rational expectations. The aggregate supply of credit is now discontinuous and in figure 2 is determined according to OC and FG.

The borrowing country chooses and announces (L, i_t) so as to achieve maximum utility

$$\max U[C1 + \min\{L, S(L,i)\}, C2 - (1+i)\min\{L, S(L,i)\}] \qquad \text{(A4.5)}$$

The solution and the equilibrium in the credit market can easily occur when there is an excess supply of credit to the country, ie $S(Y^e - L, i_t - \pi_t \delta) > L$. As in figure 2, one class of solutions consists of those where the demand for credit is OL, the amount supplied OE and the return ρ*. Here, despite excess supply, the borrower cannot lower the interest rate, because this would totally eliminate the supply of credit to the country. The reason is the interdependence between lenders; the supply of credit depends from the expected excess supply. The equilibrium is fragile, as figure 2 illustrates.

Essay 3

Contagion via financial linkages

Tuomas Komulainen

Abstract

The study builds a simple model of the international financial system, which includes several local emerging market banks and one international bank. The international bank and the local banks may use leverage. The amount of borrowing is based on banks' collateral, which is determined in a simple asset market. Asset and collateral prices comprise the main linkage for contagion. Bank runs and asset liquidations in one country reduce the collateral of all banks. Because banks' indebtedness can not exceed their collateral, further liquidations and bank runs may occur. The use of leverage by local banks induces a more severe contagion than leveraging by the international bank. When both the international bank and the local emerging market banks leverage, the international financial system becomes highly vulnerable to contagion.

1 Introduction

1.1 Stylised facts on contagion

In 1997–1999 financial crises spread from one emerging market (EM) country to another. Shortly after the crisis in Thailand, four other Asian countries (Philippines, Malaysia, Indonesia and Korea) were forced to float their currencies. This wave of crises triggered reserve losses and financial problems in other Asian countries as well as in Russia and Latin America. Later, in August 1998, depreciation of the Russian rouble triggered crises in Latin America and financial turmoil even in some developed countries, eg in Hong Kong and the United States.

Several empirical studies have found this contagion effect significant. Most studies also show that the recent crises were transmitted mainly through financial linkages.[1] Earlier literature also point out some stylized facts or pre-conditions for contagion. For example, Kaminsky and Reinhart (1999), Mahar and Williamson (1998) and Demirgüc-Kunt and Detriache (1998) found that financial liberalisation preceded many of the recent crises. After liberalisation, foreign borrowing often increased so that country fundamentals worsened and crises followed (Rodrik and Velasco 1999 and Komulainen and Lukkarila 2003). In the Asian crisis countries, banks accounted for most of this borrowing.

In addition to domestic problems, also foreign factors, eg weaknesses in the international financial system, have been blamed for the recent crises. Some empirical studies show that banks based in developed countries drastically decreased their lending to all emerging market countries after a crisis in one country. Kaminsky and Reinhart (1999b) found that particularly Japanese banks curtailed their lending to all other Asian countries after the devaluation of Thai bath. Similarly US banks decreased their lending to emerging markets after the crisis in Mexico in 1995. After controlling for several domestic and external variables Caramazza et al (2004) found that strong

[1] See Baig and Goldfajn (2000), Kaminsky and Reinhart (2000), Van Rickeghem and Weder (2000), and Caramazza et al (2004). According to the usual definition of contagion, it increases cross-market linkages after one crisis (Claessens et al 2001). In this paper contagion refers to situations where bank runs in one country spread to other countries. In this study we concentrate on fundamental reasons and channels for contagion and do not discuss changes in market sentiment as a reason for contagion.

financial linkages through common creditor is the most significant variable to explain contagion.

The illiquidity of investment funds which specialise in emerging markets may be one reason for contagion. Kaminsky et al (2001 and 2003) show that emerging market funds liquidated their holdings in other countries after losses in one crisis country. In other words, crisis in one country or in several countries decreases the value of the investment fund, for which it has to compensate by selling of assets in other countries if investors withdraw. Schinasi and Smith (2000) found that this effect is greatly enhanced if the investment fund is leveraged.[2] Moreover, since a bank's or investment fund's collateral usually determines how much foreign financing is available, decreases in asset prices may readily induce contagion.

These empirical studies and stylised facts point out three main reasons for contagion: 1) over-borrowing by local EM banks, 2) the use of leverage by the global banks and investment funds concentrating on EMs, and 3) a common lender that suddenly withdraws from EMs after one crisis. Although a wide empirical literature on contagion exists, theoretical studies are still rare. This study builds a model of the international financial system which describes these problems and seeks to find the main channels and reasons for contagion.

The recent crises and the contagion effect have intensified the discussion on how to reform the current international financial system.[3] However, the exact reasons for contagion are not known (eg Claessens et al 2001). Is something institutionally wrong in the current international financial system? Is the common lender a key reason for contagion? How important are leverage and collateral constraints? Is a global lender of last resort needed to curtail financial contagion, or is better information enough? Since the exact reasons for contagion are not known, the discussed measures for reforming the international financial system may not be adequate. This study tries to shed some light on where reform in the international financial system might be needed.

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[2] Schinasi and Smith (2000) study also different portfolio management rules. Bris et al (2001) study the negative effect of leverage at enterprise level in some emerging market countries.

[3] See eg Fisher (1999), Bhattacharya and Miller (2001) and Rogoff (2001).

1.2 Related literature

Since the recent crises seem to have spread through financial linkages, we use a model on financial intermediation and bank runs to explain the contagion.[4] We use the Allen and Gale (1998) version of the Diamond and Dybvig (1983) model as our basic set-up. In Allen and Gale (1998) the return on the long-term asset is risky and the bank run is induced by a low return on the long-term asset. They also introduce a simple asset market, where the liquidation price of the risky asset is determined. They find that if the liquidation is costly, monetary interventions by the central bank can be optimal.

Some recent studies have extended the Diamond and Dybvig model to an open economy setting. Velasco (1987) explains currency crises with a model where banks invest in illiquid production by issuing liquid bonds. Over-borrowing by these banks then causes a government bailout and currency crisis. In Goldfajn and Valdes (1997) foreign investors deposit into a local financial intermediator, this reinvests the funds in a risky illiquid asset. Low return on the risky asset may induce a bank run, capital outflow and currency crisis. In one emerging market country setting, Chang and Velasco (2001) study the consequences of panics by foreign creditors. In their model the domestic bank invests in illiquid domestic production and issues domestic deposits, but borrows also in foreign short-term debt. Capital outflows induced by foreign investors may now coincide with a bank run induced by domestic depositors.

Similar to our study, Allen and Gale (2000a) extend the Diamond and Dybvig model to several banks and study the possibility of

[4] The illiquidity problem and the need for lender of last resort were originally discussed in Bagehot (1873). Diamond and Dybvig (1983) formalised a model on bank runs, where bank assets are invested in illiquid production technology, but the banks provide liquid deposits for consumers. This renders the banking system vulnerable to a multiple equilibria situation, where in the 'bad' equilibrium depositors induce a bank run. The basic Diamond and Dybvig model does not entail aggregate risk and is unrelated to business cycle. The bank run is a self-fulfilling phenomenon. Some follow-up studies, like Wallace (1988), Chari and Jagannathan (1988) and Hellwig (1994), have introduced aggregate risk into the model. See Feixas and Rochet (1997), Allen and Gale (1998), and Niinimäki (2000) for surveys of bank run models.

financial contagion.[5] In their model, banks diversify by holding short-term deposits in other banks. They study the fragility of the financial system by introducing a state of the economy with zero ex ante probability of the aggregate demand for liquidity being greater than the supply. The possibility of contagious banking crises now depends on the completeness of the interregional claim market. If the banks hold deposits only in some neighbouring banks, the banking system is more fragile and financial contagion more probable than in a more complete market structure.[6] Bank runs are caused by idiosyncratic shocks and are unrelated to the return on the long-term asset.

Although used in banking studies, no earlier study on financial crises has used the value of banks' assets to determine a limit for foreign borrowing.[7] Maybe closest to our study is Caballero and Krishnamurthy (2001), where firms have two types of collateral constraints: international collateral that determines the amount of foreign financing and domestic collateral that determines how much financing the firms can obtain from each other. They find that the tightening of international collateral causes an increase in domestic interest rates, loss of domestic assets and a fall in output. Sales of domestic assets cause a drop in international collateral and a further loss in output. In this study banks' collateral, or more precisely, banks' assets determine the amount of foreign borrowing available. Banks' assets are further valued in a simple asset market.

Only a few studies have examined the role of the international financial system in contagion. Calvo and Mendoza (2000) discuss optimal diversification and show that costly information gathering might not be profitable when the number of countries is large. This

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[5] Bhattacharya and Gale (1987) also build a model where several banks operate. The liquidity need at the aggregate level is fixed but each bank encounters local demand for liquidity. Through an interbank market, banks are able to offer deposit contracts which are based on the average proposition of withdrawals. Banks facing liquidity needs are able to borrow from those with excess liquidity. They show that banks have an incentive to invest too little in a short-term and too much in a long-term asset, which provides a reason for regulatory agency.

[6] Similarly Dasgubta (2003) studies a model of two banks with interbank deposits, but with incomplete information. He finds that there are regions of fundamentals in which the bank fails only if the other fails as well.

[7] Bernanke and Gertler (1989) introduce agency costs, which create costly verification of the borrower. These costs depend negatively on the borrowers' net wealth. The collateral is now high during the good times and low during bad times, which may cause output fluctuations. In Kiyotaki and Moore (1997) asset prices serve as collateral. Consequently, illiquidity for one bank (or somewhere in the investment chain) may cause illiquidity for other banks. In Aghion et al (2000) devaluation together with sticky prices increases the debt payments of domestic firms. This lowers their wealth, creates credit constraints and lowers domestic output.

can cause herding behaviour and contagion. Calvo (1999) uses the slogan 'Wall Street as a carrier' with a model where informed investors face margin calls after one crisis. The uninformed investors interpret the margin calls and the following sell-off as a decrease in the expected return on emerging market assets and mimic the actions by informed investors. In our simple model of an international financial system, an international bank represents the global banks and investment funds which specialise in emerging markets but are located in developed countries.

1.3 What this study contributes?

This study builds a simple model of the international financial system and examines how bank runs are able to spread from one (several) EM country to others. The model links together the literature on financial intermediation and credit constraints. More precisely, it follows the model by Allen and Gale (1998) with the following extensions: 1) several emerging market countries and banks, 2) an international bank, which represents all banks and investment funds operating in emerging markets globally, 3) the possibility of obtaining foreign financing. The local EM banks, and in the second case the international bank, are able to use foreign borrowing. Banks' assets determine the amount of foreign financing available. With these extensions, we aim to create a model that characterises the international financial system in which emerging market countries operate, and discover those weaknesses and mechanisms by which contagion might occur.

This study finds two main linkages for contagion: 1) international illiquidity: Bank runs in some EM countries cause liquidity problems in the international bank. This may induce early liquidations of long-term assets also in the other EM countries. Since the late consumers in these countries are now receiving less, further bank runs may occur; 2) leverage and a drop in asset prices: Bank runs and early liquidations lower the asset and collateral values in the initial problem countries. But since the banks – local and international – are not allowed to borrow more than the collateral value of their assets, lower debt roll-over and early liquidations in the other EM countries may follow. Again, the lower asset values provide a rationale for the late consumers to withdraw early.

In the following section we set out the basic model, where the long-term asset is still totally illiquid and foreign financing is not yet

introduced. We study the solution with the deposit contract offered by the local EM banks, which works as a benchmark for the following sections. In the third section we allow early liquidation of the long-term asset. In the fourth section the local EM banks are able to use outside borrowing and in the fifth section the international bank borrows against its collateral. And finally, both the international bank and the local EM banks are able to borrow. In each section we examine the conditions for contagion and the fragility of the international financial system. The final section summarises our results.

2 Basic model

Our model follows Allen and Gale (1998), but we extend it to form a simple model of the international financial system. The results in this section, where the long-term asset is still illiquid and outside borrowing is not yet possible, are used as a benchmark for the rest of the study.

2.1 Investment technologies

The domestic production in emerging market (EM) countries needs two periods to mature. This creates a long-term asset, whose return is illiquid. The local EM banks invest in long-term production but also have deposits at the international bank. The international bank is able to invest in the long-term assets of all n EM countries. Consequently, the assets of the international bank are well diversified, but illiquid. The international bank promises a fixed return of r per period to the local EM banks. This deposit contract creates a liquid asset for the local EM banks and a liability for the international bank. It is possible for the local EM banks to place savings in the international bank at both date 0 and date 1. A storage technology, ie cash, is another liquid short-term asset.

2.2 Asset returns

Investment x in the long-term asset of country i provides xR^i consumption at date 2. The factor R^i is a random variable, with density function f(R) and support $[0, R^H]$, where $0 < R^H < \infty$. The expected mean, R^a, is known at date 0. It is also known at date 0 that in s number of countries R^i is between $[R^*, R^H]$ where $0 < R^* < R^a < R^H < \infty$, and in the remaining $(n - s)$ number of countries R^i is below R^*. But in which countries R^i is below R^* is not known before date 1. A signal at date 1 predicts the return of the long-term asset, R^i, accurately. The signal is common knowledge. At date 1 the n EM countries can be ranked according to the return on the long-term asset, $0 \leq \ldots \leq R^H$. Also at date 1, based on the signal late consumers in each country decide whether to hold deposits until date 2.

Savings y_t in the international bank at date t provide ry_t consumption at date t+1. The return, r, is the one-period average return on the long-term asset minus cost d (per unit of investment): $(r+d)^2 = R^a$. As the number of EM countries goes to infinity, the expected variance of the international bank's asset converges to zero, and savings held in the international bank are expected to be risk-free.

At date 0 the ranking of expected return factors is

$$e[R^i] > e[r^2] > 1 \tag{1}$$

The expected return on the long-term asset dominates the other assets, and the savings held in the international bank dominate cash.

2.3 Consumers

In EM countries there is a continuum of ex ante identical consumers. At date 0 the consumers know that there is an equal probability of being either an early or late consumer. The early consumers expire at date 1 and the late consumer at date 2. At date 1 the consumers learn their respective types. The typical consumer's utility function can be written as

$$U(c_1, c_2) = \begin{cases} u(c_1), \text{ prob. } ½ \\ u(c_2), \text{ prob. } ½ \end{cases} \tag{2}$$

where c_t denotes consumption at date 1 or date 2. The period utility functions are assumed to be twice continuously differentiable, increasing, and strictly concave. A consumer's type is not observable to others, so late consumers can always consume early. Therefore, contracts cannot be written contingent on consumption type.

2.4 Assumptions

In Allen and Gale (1998) the deposit contract offered by the local EM banks can not be made contingent on the long-term asset or on the leading indicator. The deposit contract promises a fixed amount, $\bar{c}$, to consumers who withdraw early, and the late consumers receive what is left at date 2. However, depositors can observe the indicator at date 1 and make their withdrawal decision contingent on it. It is further assumed that in a bank run situation the available liquidity is split equally among those withdrawing early. This is different from the first-come, first-served assumption made in Diamond and Dybvig (1983). It is further assumed that only banks can distinguish the useful risky assets from assets that have no value, so in practice only banks will hold the risky asset.

We further assume that the local EM banks are not able to invest directly in the long-term production in other countries. They can only invest via the international bank, which has the technology to diversify internationally. At date 0 depositors or the local EM banks do not have information on the vulnerability of the international bank or the whole international financial system. Consequently, at date 0 savings held in the international bank are regarded as risk-free. And since the expected return on the long-term asset and savings held in the international bank dominate cash, local EM banks do not hold any cash between date 0 and 1. At date 1 the return on long-term assets (R^i) and the vulnerability of the international financial system become common knowledge.

We also regard it is non-optimal to invest all assets in the risky long-term project. We assume that the utility function satisfies

$$u'(0) > e[u'(RE)R] \tag{3}$$

which states that if the full endowment (E) is invested in long-term asset and the early consumption is zero, a slight reduction in long-term asset holdings and a similar increase in early consumption is optimal.

2.5 International bank

The international bank diversifies its investments among all n emerging market countries. At date 0, it is expected that R^i will equal the average return factor, R^a. The international bank invests the same amount, X, in each of the EM countries, so that

$$ny_0 = nX \tag{4}$$

The international bank must hold a fixed reserve requirement, K, between dates 0 and 1.[8] At date 1 the budget constraint of the international bank is determined according to

$$K + sy_1 \geq nry_0 \tag{5}$$

where s is the number of EM countries in which $R^i \in [R^*, R^H]$, and local EM banks are still operating and saving y_1 at date 1. The return r, which the international bank promises for the local EM banks, is the maximum fixed return the international bank is able to offer, given the expected return on the long-term asset $[e(R^i) = R^a]$ and fixed buffer b(K, d).

The international bank's cash flow situation, ie buffer, at date 1 determines the international liquidity in our model. We will denote the expected case, b(K, d, s), when s local EM banks are still saving at the international bank, as

$$b(K, d, s) = K + sy_1 - nry_0 \tag{6}$$

This depends positively on the reserve requirement K, the number of countries saving at date 1, and the spread d received by the international bank $(\sqrt{R^a} - r)$. If the buffer is exhausted, there is illiquidity of the international bank, ie international illiquidity.

At date 2 the return on the long-term asset materialises and the cash flow constraint of the international bank is

[8] We excluded the reserve requirement K from equation (4) since we assume that the bank is not allowed to use it for investments in EM countries. We assume that the international bank fulfils its payments at date 1 before making date 2 payments.

$$X\sum_{i=1}^{s} R^i \geq sry_1 \tag{7}$$

If the economy actualises according to expectations, the constraint (7) will hold with equality. If there is some profit left for the international bank, we assume the owners of international bank receive the profit and it is excluded from the model. If the constraint does not hold and the international bank is not able to pay sry_1 to the local EM banks at date 2, the local EM banks will receive less and bank runs may occur.

2.6 Risk-sharing problem and equilibrium

As a baseline case, we examine the risk-sharing problem in which the decision-making is decentralised through the local EM banks and the long-term asset still totally illiquid.[9] In this section we still assume that banks are not are able to liquidate the long-term asset at date 1, but in the rest of the study liquidation of the long-term assets is possible.

The local EM banks share the risk and optimise on behalf of consumers. The local EM banks collect the endowments from consumers, and invest them in the long-term asset, x, and in savings at the international bank (y_0, y_1), and offer the deposit contract (c_1, c_2) to the consumers. Given the assumptions, a similar deposit contract is offered in each of the n countries by the n representative banks. The risk-sharing problem (P1) of the local EM banks can be written

$$\text{Max } e[u(c_1(R^i)) + u(c_2(R^i))] \tag{8}$$

$$x + y_0 \leq E \tag{8.1}$$

$$c_1^i(R^i) + \alpha(R^i)c_2(R^i) \leq ry_0 \tag{8.2}$$

$$(1-\alpha)c_2^i(R^i) \leq r[ry_0 - c_1^i(R^i) - \alpha(R^i)c_2(R^i)] + xR^i \tag{8.3}$$

[9] See appendix 1 for the optimal solution as a planner problem without local EM banks. In appendix 2 we present all decisions in chronological order, and appendix 3 lists all the variables used.

$$c_1^i(R^i) \leq \bar{c} \tag{8.4}$$

$$c_2^i(R^i) \geq c_1^i(R^i) \tag{8.5}$$

$$y_0 r = c_1^i(R^i) + \alpha(R^i)c_2(R^i), \quad \text{if } c_1 < \bar{c} \tag{8.6}$$

$$c_1(R^i) = c_2(R^i), \quad \text{if } \alpha(R^i) > 0 \tag{8.7}$$

The first constraint (8.1) indicates that the amount invested cannot exceed the endowments at date 0. At date 1 consumption by early consumers [c_1] and early withdrawing late consumers [$\alpha(R^i)c_2$] cannot exceed the liquid assets of the local EM banks (constraint 8.2). The difference between consumption and liquid assets (ry_0) will be saved for date 2. At date 2 the late consumers consume what is left: the savings and the return on the long-term asset (8.3). The early consumer is not able to consume more than the deposit contract (8.4). The constraint (8.5) is the incentive compatibility constraint, which states that for every value R^i the late consumer must be at least as well off as the early consumer. Constraint (8.6) states that if the local EM bank cannot pay the agreed deposit, it must pay all its liquid assets to withdrawing consumers. The constraint (8.7) is an equal-treatment condition, which states that the local EM banks cannot distinguish between early and late consumers if they withdraw early.

The indicator for R^i determines the optimal share of withdrawals $\alpha(R^i)$ at date 1. If the indicator signals a high R^i, so that EM banks are able to pay at least $\bar{c}$, no late consumer withdraws [$\alpha(R^i) = 0$]. If the signal is lower, an optimal amount of late consumers withdraw [$\alpha(R^i) > 0$], so that early and late consumption will be equal.[10] The critical value R* is the limit when local EM banks are just able to pay $\bar{c}$ to both early and late consumers and hence, if $R^i \geq R^*$, bank runs should not occur.[11] We assume that local EM banks are able to choose the equilibrium which is preferred by consumers. We ignore the possibility of multiple equilibria, and thus runs occur only if they are not avoidable.

[10] If there is some return from the long-term asset arriving ($R^i > 0$) at date 2 and it is not liquidated, it is optimal for some late consumers to hold on to their bank deposits.

[11] Setting the consumption in both periods (c_1, c_2) equal and with $\alpha = 0$, the critical value R* can be calculated from constraint (8.3). Note that R* is endogenous in the model and is less than R^a, since consumers are risk-averse.

The consumption functions c_1 and c_2 that solve the risk-sharing problem with deposit contract (P1) are defined as[12]

$$c_1^i(R^i) = \begin{cases} \bar{c} & \text{if } R^i \geq R^* \\ \dfrac{ry_0}{1+\alpha(R^i)} & \text{if } R^i < R^* \end{cases} \tag{9}$$

$$c_2^i(R^i) = \begin{cases} xR^i + r(ry_0 - \bar{c}) & \text{if } R^i \geq R^* \\ \dfrac{xR^i}{1-\alpha(R^i)} & \text{if } R^i < R^* \end{cases} \tag{10}$$

where

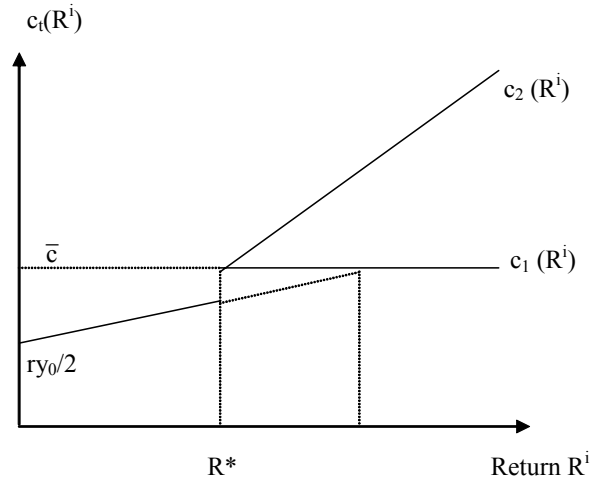
$$R^* = \frac{\bar{c} - r(ry_0 - \bar{c})}{x} \tag{11}$$

Equations (9) and (10) characterise the deposit contract (c_1, c_2). The portfolio allocation (x, y_0) with deposit contract remains to be described. Since $\bar{c} > (ry_0 + xR^*)/2$, the functions $c_1(R^i)$ and $c_2(R^i)$ are discontinuous at R* and the first-order conditions without banks are violated (see appendix 1). However, from assumptions (1) and (3), it follows that $y_0 > 0$ and $x > 0$. The first order condition $e[u'(c_1(R^i))] = e[u'(c_2(R^i)R)]$ will be satisfied and the condition $y_0 + x = E$ holds. The portfolio allocation with deposit contract is an interior portfolio, where the whole endowment is invested in both asset types and not solely in one.

We illustrate the equilibrium and consumption pattern further in figure 1. If R^i is low and less than R*, early and late consumers divide ry_0. As R^i increases, the optimal degree of risk sharing is achieved by reducing $\alpha(R^i)$, and both consumers can use up more. When the indicator signals that R^i will be higher than R*, there will be not be any early withdrawing late consumers and $\alpha(R^i)$ will equal zero. In countries where $R^i \geq R^*$, no bank runs should occur.

[12] In general there are two types of solutions to the problem; see Allen and Gale (1998) for discussion. In the first the banks do not save at date 1 ($\bar{c} = ry_0$) and in the second they do save ($\bar{c} < ry_0$). Since in our study consumers are risk-averse and $r^2 = R^a - d > 1$, it is optimal for local EM banks to save at least something ($y_1 = ry_0 - \bar{c} > 0$) and try to prevent a run. With a deposit contract, the first order conditions of the optimal risk-sharing (see appendix 1) are violated; for example, when $R^i < R^*$ local EM banks are not able to distinguish between consumers; see also Allen and Gale (1998).

Figure 1. **Risk-sharing allocation without early liquidation and outside borrowing (P1)**



2.7 Fragility

In each section we examine how fragile and vulnerable to contagion the international financial system is given the risk-sharing and deposit contract. According to expectations, in $(n-s)$ countries the return on the long-term asset, R^i, is lower than R* and in the rest of the countries $(s)R^i$ is higher than $R^*[R^*, R^H]$. Thus, the number of countries where bank runs are expected is $(n-s)$.

We introduce an unexpected event with zero probability ex ante, when in an additional m countries the return on the long-term asset drops below R*. The unexpected event could be eg an oil shock, lower world economic growth, a currency crisis, or a war in some emerging market countries.[13] In this state, $\bar{S}$, of the economy, some of the late consumers in m countries withdraw early $[\alpha(R^{*-e})c_2]$ and cause bank runs. But can these early withdrawals cause bank runs in the other $(s-m)$ countries as well?

[13] See Calvo (2002) for a discussion of crises as low-probability events. Contracts in emerging markets are usually not contingent on these events. See Allen and Gale (2000a) for a similar method to study the fragility of the financial system when an unexpected event is introduced.

Naturally the problems in m countries must be sufficiently severe. In these m countries, banks are insolvent at date 1 iff

$$\alpha(R^{*-e})c_2 > ry_0 - \bar{c} \tag{12}$$

If the condition holds, the consumption patterns in m countries are $\alpha(R^{*-e})c_2 + c_1 = ry_0$ at date 1 and $(1-\alpha(R^{*-e}))c_2 = xR^{*-e}$ at date 2. Although a bank is insolvent and the deposit contract has been violated, the long-term asset can not yet be liquidated in this version of the model. Even in m countries late consumers are still receiving xR^{*-e} at date 2, and so it is not optimal for all of them to withdraw early.

If inequality (12) holds, local EM banks in m countries do not hold any savings in the international bank at date 1 ($y_1 = 0$). The total savings at the international bank are reduced to $(s-m)\ y_1$ at date 1. The international bank is insolvent and faces a liquidity crisis at date 1, iff

$$b(K,d) - my_1 < 0 \tag{13}$$

Proposition 1: *Assume an international financial system with many local EM banks and an international bank, but without early liquidation and without outside borrowing. Suppose that each local EM bank chooses investment portfolio (x, y_0) and offers deposit contract (c_1, c_2) determined in the risk-sharing problem (P1). Suppose condition (13) on international illiquidity is satisfied. With the unexpected event, state $\bar{S}$ of the economy, no financial contagion, however, takes place.*

Proof: If the number of countries (m) where problems occur is high and the buffer b(K, d) small, liquidity crisis occurs at the international bank. However, the international bank cannot liquidate the long-term assets. At date 2 the cash-flow constraint of the international bank holds

$$X\sum_{i=1}^{N} R^i - mX(R^a - R^{*-e}) \geq (s-m)ry_1 \tag{14}$$

Because the international bank could not liquidate its long-term assets at date 1, it is able to pay ry_1 to $(s-m)$ local EM banks at date 2. In

the limiting country, where the return of the long-term asset is R*, the late consumers consume

$$c_2^i(R^*) = ry_1 + xR^* \tag{15}$$

Even with the unexpected event, late consumers in $(s-m)$ countries receive at least $\bar{c}$ and are no worse off.[14] Consequently, no further bank runs or financial contagion occurs. The maximum consequence is lower early consumption in all EM countries.

3 Costly liquidation

3.1 Liquidation price and asset valuation

Next we relax the assumption that the long-term asset is totally illiquid. We introduce a simplistic market where the liquidation price is determined. If a local EM bank is not able to honor the deposit contract at date 1, the bank must offer all its long-term assets, x, for liquidation. In the market, only a group of risk-neutral investors are ready to buy the assets offered for liquidation. These investors have a fixed amount, L_s, to invest.[15] This creates a snowball effect where the liquidation price drops heavily when more and more assets are offered for liquidation.

If there is liquidation in one country, the liquidation price is determined simply as $P_1^L = L_s / x$. If local banks in m countries are insolvent and liquidate their long-term assets, the liquidation price drops to $P_1^L = L_s / mx$, where $0 \le m \le n$. If local banks in a further g countries have to liquidate, the liquidation price naturally falls further. Similarly, if the international bank does not have enough liquidity at date 1, it will liquidate its long-term assets in EM countries at the

[14] The late consumption in (s–m) countries is similar to that in equation (10) when $R^i \ge R^*$.

[15] This is of course a strong assumption, but it describes the segmentation of asset markets and large drop in asset prices in emerging markets during a period of crises. A necessary condition for the risk-neutral investors to hold both cash and risky-assets between date 0 and date 1 is: $E[1/P_1^i] = E[R^i]$. We further assume that at date 0 the consumers and the local EM banks do not know the amount L_s, which is available for liquidations. At date 1 the amount L_s becomes common knowledge.

price P_1^L, until the needed cash flows are obtained. It liquidates the assets X from those j countries where the return on the long-term asset, R^i, is lowest. The number of additional countries with early liquidations will be endogenously determined by the model (j and g, and the limit R^{*+eL}).

The liquidation price P_1^L for the long-term asset is determined as

$$P_1^L(m, j, g) = \frac{Ls}{(m+g)x + jX} \tag{16}$$

The liquidation price P_1^L is naturally lower than the expected fundamental value, xR^i. If the international bank liquidates its long-term assets in j countries, the value of long-term assets held by local EM banks will also drop at date 1. The long-term assets in EM countries are thus valued according to:

$$P_1^i(R^i) = \begin{cases} R^i, & \text{if } R^i > R^{*+eL} \\ P_1^L, & \text{if } R^i \leq R^{*+eL} \end{cases} \tag{17}$$

where the limit R^{*+eL} depends on the number of countries in which the long-term asset will be liquidated early.

The value of the international bank, P_1, is naturally based on the value of its assets in EM countries. If there are liquidations in (m+j+g) countries, the value of the international bank (P_1) also falls:

$$P_1(m, j) = \begin{cases} sR^a X, & \text{if } m, g \text{ and } j = 0 \\ \sum_{i=1+(m+j+g)}^{s} R^i X + (m+j+g) P_1^L \frac{X}{x}, & \text{if } m, g \text{ or } j > 0 \end{cases} \tag{18}$$

If some local EM banks liquidate their long-term assets, the assets of the international bank will also be liquidated and the international bank receives its share, $P_1^L X / x$, from these countries.

At date 2, the outcome for the long-term asset depends on who has liquidated the asset. If a local EM bank has liquidated it, the production is eliminated and nothing is left for date 2. If only the international bank has liquidated, the local EM bank is still able to

keep the production operating in its country and receives xR^i at date 2.[16]

3.2 Risk-sharing problem and equilibrium

When early liquidation of the long-term asset is possible, the local EM banks' decision problem (P2) can be written

$$\text{Max } e\left[u(c_1(R^i)) + u(c_2(R^i))\right] \tag{19}$$

$$\text{s.t. (i)} \quad x^L + y_0^L \leq 0$$

$$\text{(ii)} \quad c_1^i(R^i) = \begin{cases} \bar{c}^L & \text{if } R^i \geq R^* \\ \frac{1}{2}(ry_0^L + P_1^L) & \text{if } R^i < R^* \end{cases}$$

$$\text{(iii)} \quad c_2^i(R^i) = \begin{cases} x^L R^i + r(ry_0^L - \bar{c}^L) & \text{if } R^i \geq R^* \\ \frac{1}{2}(ry_0^L + P_1^L) & \text{if } R^1 < R^* \end{cases}$$

$$\text{(iv)} \quad c_2^i(R^i) \geq c_1^i(R^i)$$

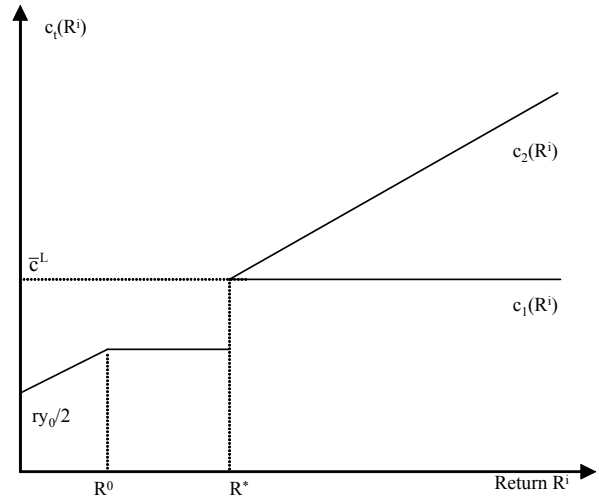
where

$$R^* = \frac{\bar{c}^L - r(ry_0^L - \bar{c}^L)}{x^L} \tag{20}$$

The risk-sharing solution consists of the portfolio of risk-neutral investors, initial investments (x^L, y_0^L), the price function in equation (17), and the deposit contract (y_1^L, y_2^L) that solves problem (P2). The deposit contract is characterised in figure 2. The solution in (P1) differs in that if a bank run occurs no assets remain for consumption at date 2. For low values [$R^i < R^*$], the assets are divided equally between early and late consumers.

[16] We assume that the local EM banks are majority owners of the local production, ie long-term assets, and that their control determines the outcome of long-term production.

Figure 2. **Risk-sharing allocation with early liquidation (P2)**



Note: The figure is basically similar if outside borrowing by local EM banks (P3) or international bank (P4) or both (P5) is allowed.

3.3 Fragility

As in the preceding section we study the outcome when the unexpected event occurs and the return on the long-term asset in m countries is less than anticipated [$R^{*-e} < R^*$]. Since the lower return in m countries is common knowledge, the condition for bank runs and early liquidations holds in m countries:

$$\bar{c}^L > r(ry_0^L - \bar{c}^L) + x^L R^{*-e} \tag{21}$$

Indeed, all late consumers in m countries withdraw early ($\alpha = 1$) and banks are closed. But will these bank closures have a contagion effect on the other $(s - m)$ countries? The condition for the illiquidity of the international bank is now determined as

$$b(K, d) - my_1^L + mP_1^L \frac{X}{x^L} < 0 \tag{22}$$

where the liquidation price P_1^L is determined in equation (16). The international bank receives cash $[mP_1^L X / x^L]$ from the liquidations in m countries. In comparing condition (22) to condition (13), without costly liquidation, we find that the international bank is now less likely to experience illiquidity. But if it does, this will now have an impact to other $(n - m)$ countries.

Proposition 2: *Consider the international financial system with local EM banks and the international bank, but without outside borrowing. The liquidation price of the long-term asset is determined in equation (16). Suppose that each local EM bank chooses investment portfolio* (x^L, y_0^L) *and offers the deposit contract* (c_1, c_2) *determined in risk-sharing problem (P2). Suppose condition (22) on international illiquidity is satisfied. Then, with the unexpected event, ie state* $\overline{S}$ *of the economy, financial contagion occurs.*

Proof: If condition (22) holds, the international bank must liquidate its long-term assets in j countries.[17] The liquidations of long-term assets in m+j countries diminish the assets of the international bank, and it is not able to pay ry_1^L to the local EM banks at date 2. If late consumers in some additional countries are not expecting to receive at least $\overline{c}^L$ at date 2, further bank runs occur. The condition for this financial contagion in the limiting country (return on the long-term asset equal to R*) is

$$y_1^L \frac{X \sum_{i=m+j}^{S} R^i}{(s-m)} + xR^* < \overline{c}^L \tag{23}$$

When j > 0, the condition holds in the limiting country R*. Because ry_1^L is less than expected, equation (20) is violated. Indeed, in some other countries late consumers receive less than $\overline{c}^L$ and financial contagion occurs.

Bank runs and contagion in EM countries occur until late consumers in country i receive at least $\overline{c}^L$. The contagion occurs up to

[17] The international bank liquidates from those j countries where $R^i \geq R^*$ and are ranked next after (n–s) countries. These early liquidations in j countries also lower the liquidation price in equation (16).

country i, where the return factor for the long-term asset, R^i, equals the limit, R^{*+eL}, and the following condition holds

$$y_1^L \frac{X \sum_{i=m+j}^{S} R^i}{(s-m)} + xR^{*+eL} \geq \bar{c}^L \tag{24}$$

Indeed, contagion affects an additional g countries, where the return of long-term asset is between [R*, R^{*+eL}]. However, the only linkage for contagion is the illiquidity of the international bank. If inequality (22) does not hold and the international bank is not illiquid (j = 0), no contagion takes place in the model (g = 0).

4 Local EM banks borrow

In this section we allow outside borrowing and examine the case where local EM banks borrow against their collateral. The local EM banks issue bonds in the amount of qb_0^{LB} at date 0 and qb_1^{LB} at date 1.[18] With these funds the local EM banks are able to invest more in the long-term asset in their home country [x^{LB}] and to save more at the international bank [y_0^{LB}]. The additional capital now flows directly to local EM banks and not through the international bank. The international bank only diversifies the savings of the local EM banks.

4.1 Collateral

The local EM banks issue the foreign bonds against their collateral. More precisely, the assets of local EM banks are used as collateral and determine the amount of financing available. The amount of debt, b_0^{LB}, can not exceed the value of collateral

[18] The q term is the price of a bond and b_0 is the number of bonds issued at date 0. We assume that q is fixed; $0 < q \leq 1$ and $E(R) > 1/q^2$. For simplicity we may assume that q is close to one. The loans are provided outside the international bank and local EM banks. For simplicity we ignore exchange rates. We further assume that at date 1 the amount of borrowing is determined before the decisions of local consumers.

$$b_0^{LB} \leq \lambda(R * x^{LB} + ry_1^{LB}) \equiv \bar{a} \tag{25}$$

where the domestic long-term assets $[x^{LB}]$ are valued at the lowest level without bank runs and foreign savings $[y_1^{LB}]$ are valued according to their expected values. A fixed coefficient $\lambda[0 < \lambda < 1]$ is included to take into account the credit risk and bank's other liabilities.[19] We denote $\bar{a}$ the collateral value of local EM banks' assets at date 0. We assume that the cost of borrowing is less than the expected return on domestic assets and at date 0 the local EM banks borrow the maximum amount.

At date 1, R^i is revealed and in country i the local EM banks borrowing can not exceed the actual value of the collateral

$$qb_1^i(P_1^i, P_1) \leq \lambda\left(P_1^i x^{LB} + \frac{P_1}{s-m} y_1^{LB}\right) \equiv a_1^i \tag{26}$$

At date 1 the value of long-term assets $[P_1^i]$ in country i and the value of foreign savings $[P_1 y_1^{LB}]$ are determined in equations (17) and (18), respectively. The maximum borrowing at date 1, or debt rollover, is denoted as $qb_1^i = b_0^{LB}$. If the value of collateral at date 1 exceeds the limit $[a_1^i \geq \bar{a}]$, the local EM bank is able to roll-over the entire debt until date 2 $[qb_1^i = b_0]$. If the value of collateral is valued less than the limit $\bar{a}$, the debt roll-over is diminished

$$qb_1^i(P_1^i, P_1) = \begin{cases} b_0, & \text{if } a_1^i \geq \bar{a} \\ \lambda\left(P_1^i x^{LB} + \frac{P_1}{s-m} y_1^{LB}\right), & \text{if } a_1^i < \bar{a} \end{cases} \tag{27}$$

This less-than-expected debt roll-over is a critical ingredient of the model and enhances the contagion.

[19] The deposits are also banks liabilities. We assume that the coefficient λ is constant for all our time periods. We denote as collateral the value, where the coefficient λ is included.

4.2 Risk-sharing problem and equilibrium

The local EM banks' decision problem (P3), when early liquidation of the long-term asset is possible and the local EM banks are able to borrow, is

$$\text{Max } e\left[u(c_1(R^i)) + u(c_2(R^i))\right] \tag{28}$$

$$\text{s.t. (i)} \quad x^{LB} + y_0^{LB} = E + qb_0$$

$$\text{(ii)} \quad c_1^i(R^i) = \begin{cases} \bar{c}^{LB} & \text{if } R^i \geq R^* \\ \frac{1}{2}\left(ry_0^{LB} + P_1^L - b_0\right) & \text{if } R^i < R^* \end{cases}$$

$$\text{(iii)} \quad c_2^i(R^i) = \begin{cases} x^{LB}R^i + r(ry_0^{LB} - \bar{c}^{LB} + qb_1^i(P_1^i, P_1) - b_0) & \text{if } R^i \geq R^* \\ -b_1^i(P_1^i, P_1) & \\ \frac{1}{2}(ry_0^{LB} + P_1^L - b_0) & \text{if } R^i < R^* \end{cases}$$

$$\text{(iv)} \quad c_2^i(R^i) \geq c_1^i(R^i)$$

where

$$R^* = \frac{\bar{c}^{LB} - r\left(ry_0^{LB} - \bar{c}^{LB}\right) + \frac{b_0}{q}}{x^{LB}} \tag{29}$$

With the borrowing possibility now included, the initial investments are higher (x^{LB}, $y_0^{LB} > x, y_0$). Furthermore, since the cost of borrowing is less than the expected return on the long-term asset [$E[R^i] > 1/q^2$], local EM banks are able to promise a better contract to depositors ($\bar{c}^{LB} > \bar{c}$).[20] The expected consumption amounts, c_1 and c_2, [when $R^i \geq R^*$] are higher than without foreign borrowing. But with borrowing and higher initial investments, local EM banks also take further risk. If $R^i < R^*$ and early liquidation of the long-term asset

[20] These results are similar to McKinnon and Pill (1997), who study liberalisation and outside borrowing with a different type of model.

occurs, new loans are naturally not granted to the local EM bank at date 1 ($b_1 = 0$).[21]

4.3 Fragility

The unexpected event occurs and in m countries the return on long-term asset turns out to be lower than anticipated ($R^{*-e} < R^*$). This is common knowledge at date 1 and in m countries the condition on early liquidation holds. In m countries all late consumers withdraw early ($\alpha = 1$), the long-term assets are liquidated and there is no further outside borrowing ($b_1 = 0$). The consumption patterns in m countries are according to (ii) and (iii) in (P3), where $R^i < R^*$.

The condition for illiquidity of the international bank is determined

$$b(K,d) - my_1^{LB} + mP_1^L \frac{X}{x^{LB}} < 0 \tag{30}$$

Due to higher initial investments, x^{LB}, the liquidation price, P_1^L, is now lower than without foreign borrowing, and the illiquidity of the international bank occurs slightly more readily than without outside borrowing (inequality 30 compared with 22). If inequality (30) holds, the international bank liquidates its long-term assets in j countries. These early liquidations in j countries also decrease the value of the international bank (P1).

Proposition 3: *Consider the international financial system where the local EM banks are able to borrow. The amount of borrowing at dates 0 and 1 are determined in equations (25) and (27). Suppose that each local EM bank chooses investment portfolio (x^{LB}, y_0^{LB}) and offers the deposit contract (c_1, c_2) determined in risk-sharing problem (P3). Suppose the condition on international illiquidity (30) holds. Then, with the unexpected event, contagion occurs also through lower collateral prices, and the contagion affects more countries than without foreign borrowing by local EM banks.*

Proof: With the unexpected event and illiquidity of the international bank in j countries, the value of local EM banks' assets will fall to P_1^L. In these j countries the debt roll-over is less than expected

[21] This creates a sudden stop of capital flows into the country.

$$qb_1^i(P_1^i, P_1) = \lambda\left(P_1^L + \frac{P_1 y_1}{s-m}\right) < \lambda(R * x^{LB} + ry_1) = b_0 \tag{31}$$

Indeed, in j countries local EM banks receive a smaller rollover $[qb_1^i(\lambda^i) < b_0]$ and must reduce their investments.[22] First these local EM banks reduce their savings, y_1^{LB}, at the international bank. However, when savings are lowered – say to Δy_1 – bank runs occur, since in the limiting country $[R^i = R^*]$ the following condition holds

$$\bar{c}^{LB} > R * x^{LB} + r\Delta y_1 \tag{32}$$

In some of the (s–m) countries, local EM banks must liquidate their long-term assets early and contagion occurs. These bank runs in EM countries occur up to country i, where the following condition holds[23]

$$y_1^i \frac{X \sum_{i=1+(m+j)}^{S} R^i}{(s-m)} + x^{LB} R^i - b_1^i(P_1^i, P_1) \geq \bar{c}^{LB} \tag{33}$$

Furthermore, if the drop in debt rollover exceeds the foreign savings, local EM banks face directly liquidity crisis at date 1. If the savings are not enough to cover the drop in debt rollover, the local EM banks have to liquidate their long-term assets. The upper limit for this contagion is determined by

$$ry_0^{LB} - \bar{c}^{LB} \geq b_0 - qb_1^i(P_1^i, P^i) \tag{34}$$

This contagion occurs directly due to lower collateral prices and lower debt roll-over. These two conditions (equations 33 and 34) together determine the range $[R^*, R^{*+eLB}]$ and the number g of countries where

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[22] Condition $\bar{c} + b_0 + y_1 > ry_0 + qb_1(P_1^i, P_1)$ holds in j countries and in some additional (s–m) countries, since in those countries $qb_1(P_1^i, P_1) < b_0$. The order of actions for the local EM banks is: first reduce savings at the international bank (y_1), and then liquidate the long-term asset in their own country.

[23] In inequality (33) the savings at the international bank are reduced to $y_1^i = ry_0^{LB} - \bar{c}^{LB} - (b_0 - qb_1^i(P_1^i, P_1))$.

contagion occurs in state $\overline{S}$. The new equilibrium is reached when conditions (33) and (34) hold with equality.

More countries are now affected by the contagion ($R^{*+eLB} > R^{*+eL}$) than in the financial system without outside borrowing.[24] Indeed, the indebtedness of local EM banks renders the financial system more fragile and contagion is more severe. In this financial system the main linkage for contagion is the lower asset and collateral prices. The early liquidations of the international bank cause a drop in collateral prices and lower debt roll-over of the local EM banks. The fall in collateral prices and lower debt roll-over (the difference in equation 31) are crucial for contagion, and determine its severity. The contagion is less severe if the reserves of local EM banks $[ry_0 - \overline{c}^{LB}]$ are large enough to cover the lower debt roll-over.

5 International bank borrows

In this section the international bank borrows (qB_0 and qB_1) against its collateral and invests in long-term production in all n countries. The capital to emerging markets flows now through the international bank.

5.1 Collateral

The amount of borrowing is determined by the assets of the international bank. The debt payments due to borrowing at date 0 can not exceed the value of the collateral

$$B_0 \leq \lambda(sR^a X^{IB}) \equiv \overline{A} \tag{35}$$

At date 0 the international bank is assumed to borrow the maximum, and the amount of debt equals the collateral value, which we denote $\overline{A}$.[25]

[24] The linkage through lower collateral prices does not exist in the financial system without outside borrowing (P2). In (P2), the sole linkage for contagion is the lower return from the international bank. But here the international bank's liquidations in j countries decrease the assets of local EM banks (especially in j countries) and cause the contagion.

[25] The cost of borrowing is less than the expected return from the investments in EM: $(1/q)^2 < E[R^i]$. The initial investments to EM are now higher ($X^{IB} > X$).

It is expected that at date 1 the international bank is able to roll-over its debt payments until date 2 ($B_0 = qB_1$). However, at date 1 the asset market determines the value of the assets of the international bank (P_1 in equation 18), and the borrowing at date 1 can not exceed the value of the collateral

$$qB_1(P_1) \leq \lambda P_1 \equiv A_1 \tag{36}$$

If the value of the collateral at date 1 is less than the limit $\overline{A}$, the international bank receives a lower roll-over [$qB_1(P_1) < B_0$]. If not, the international bank receives the roll-over according to expectations [$qB_1(P_1) = B_0$]. At date 1 the debt roll-over is determined

$$qB_1(\lambda_1) = \begin{cases} B_0, & \text{if } A_1 \geq \overline{A} \\ \lambda P_1 & \text{if } A_1 < \overline{A} \end{cases} \tag{37}$$

where the assets of the international bank, P_1, are valued in equation (18). Again the possibility of lower-than-expected debt roll-over is a critical part of the model.

5.2 International bank

With borrowing, the international bank is able to invest more in emerging markets at date 0 ($X^{IB} > X$)

$$ny_0^{IB} + qB_0 = nX^{IB} \tag{38}$$

With the higher initial investments, the international bank is able to promise a higher return ($r^{IB} > r$) to the local EM banks. At date 1 the budget constraint of the international bank is

$$K + sy_1^{IB} + qB_1(P_1) \geq nr^{IB}y_0^{IB} + B_0 \tag{39}$$

where the rollover (qB_1) depends from the value of the assets of the international bank (P_1). At date 0 it is expected that the maximum debt roll-over will be received at date 1 [$qB_1 = B_0$] and that equation (39) holds with equality.

At date 2 the cash flow constraint of the international bank is

$$X^{IB}\sum_{i=1}^{S} R^i \geq sr^{IB}y_1^{IB} + B_1 \tag{40}$$

Again the expectation is that the constraint (40) holds with equality.

5.3 Risk-sharing problem and equilibrium

If the international bank is able to use leverage, the risk-sharing problem (P4) of local EM banks is

$$\text{Max } e[u(c_1(R^i)) + u(c_2(R^i))] \tag{41}$$

s.t. (i) $x^{IB} + y_0^{IB} \leq E$

(ii) $c_1^i(R^i) = \begin{cases} \bar{c}^{IB} & \text{if } R^i \geq R^* \\ \frac{1}{2}(r^{IB}y_0^{IB} + P_1^L) & \text{if } R^i < R^* \end{cases}$

(iii) $c_2^i(R^i) = \begin{cases} x^{IB}R^i + r^{IB}(r^{IB}y_0^{IB} - \bar{c}^{IB}) & \text{if } R^i \geq R^* \\ \frac{1}{2}(r^{IB}y_0^{IB} + P_1^L) & \text{if } R^i < R^* \end{cases}$

(iv) $c_2^i(R^i) \geq c_1^i(R^i)$

where

$$R^* = \frac{\bar{c}^{IB} - r^{IB}(ry_0^{IB} - \bar{c}^{IB})}{x^{IB}} \tag{42}$$

If the international bank is able to use leverage, the risk-sharing problem (P4) of local EM banks is similar to (P2). However, since the return on savings in the international bank are now larger [$r^{IB} > r$], the deposit contract is larger than without any borrowing but less than when the local EM banks are borrowing [$\bar{c}^B > \bar{c}^{IB} > \bar{c}^L$].

5.4 Fragility

Again we examine the fragility of the international financial system when in m countries the indicator signals a lower than expected return on the long-term asset. Since in m countries R^{*-e} is less than R*, the condition for bank runs and early liquidation of long-term assets in m countries holds. Liquidations in m countries occur and the assets of the international bank are diminished in equation (18).

Proposition 4: *Consider an international financial system in which only the international bank uses leverage. The amount of borrowing at dates 0 and 1 are determined in equations (35) and (37). Suppose that each local EM bank chooses the investment portfolio* (x^{IB}, y_0^{IB}) *and offers the deposit contract* (c_1, c_2) *determined in the risk-sharing problem (P4). Then, with the unexpected event, the financial system is more vulnerable to international illiquidity, but less vulnerable to bank runs by local depositors than the system where local EM banks incur debts.*

Proof: With the unexpected event at date 1 the collateral value of the international bank is less than expected and less than the limit $\overline{A}$. Consequently, the debt roll-over is less than expected $[B_0 > qB_1(P1)]$. The condition for liquidity crisis of the international bank at date 1 is

$$b(K,d) - my_1^{IB} + mP_1^L \frac{X^{IB}}{x^{IB}} + qB_1(P_1) - B_0 - (r^{IB} - r)y_0 < 0 \qquad (43)$$

Indeed, the condition on international illiquidity now holds more readily than if the local EM banks borrow, since the debt roll-over is less than expected $[B_0 > qB_1(P_1)]$.[26]

If condition (43) holds, the international bank must liquidate its long-term holdings in j countries. When j > 0, the international bank is not able to pay ry_1 for the local EM banks at date 2. In the limiting country (R*) equation (42) is violated and bank runs occur. These bank runs in EM countries occur until the country i, where the return of the long-term asset is R^{*+eIB}

[26] The higher probability of international illiquidity is caused by lower value of the collateral, which allows a smaller debt roll-over for the international bank. The lower debt roll-over can be interpreted also as a margin call for the international bank.

$$y_1^{IB} \frac{X^{IB} \sum_{i=1+(m+j)}^{S} R^i - B_1(P_1)}{(s-m)} + xR^{*+eIB} \geq \bar{c}^{IB} \tag{44}$$

The new equilibrium is reached, when contagion reaches EM countries where the return of long-term asset is in [R*, R^{*+eIB}]. The contagion is now more severe than without any foreign borrowing (equation 24).[27] However, if the international illiquidity is of similar size, the contagion is less severe than in the financial system where local EM banks borrow.[28] The reason is that when local EM banks borrow, international illiquidity causes immediate problems for local EM banks through lower asset prices and collateral.

6 International bank and local EM banks borrow

In this section we will study the fragility of the international financial system when both the local EM banks and the international bank borrow. This illustrates the real world situation when global banks that concentrate on emerging markets use leverage and the local EM banks issue foreign bonds. All this outside capital is invested in emerging market countries.

6.1 Collateral and borrowing

Similar to earlier risk-sharing problems (P3, P4) the local EM banks and the international bank issue bonds against their collateral. At date 0 the local EM banks borrow the maximum that their collateral $\bar{a}^{BB}$ allows

[27] Compare equation (44) with (24). Because the number of countries, j, where the international bank liquidates is higher in equation (44), the contagion is more severe with than without outside borrowing.

[28] Compare equation (44) with (33). If the illiquidity of the international bank is of a similar magnitude, contagion with local EM banks borrowing is more severe, since in equation (44) only the return term is reduced, while in equation (33) the y_1 term diminishes.

$$b_0^{BB} = \lambda(R^* x^{BB} + r^{BB} y_1^{BB}) \equiv \bar{a}^{BB} \tag{45}$$

Since the expected returns are high at both dates 1 and 2 [$r^{BB}y_0$, R^*x^{BB}], the local EM banks borrow more than when only the local EM banks borrow [$b_0^{BB} > b_0^{LB}$]. Similarly, at date 0 the international bank borrows the maximum amount its collateral permits

$$B_0^{BB} = \lambda(sR^a X^{BB}) \equiv \overline{A}^{BB} \tag{46}$$

The initial investments [$X^{BB} > X^{IB}$] and the borrowing are now greater than when only the international bank borrows [$B_0^{BB} > B_0^{IB}$].

6.2 Risk-sharing problem and equilibrium

When both the local EM banks and the international bank borrow, the risk-sharing problem (P5) takes the form

$$\text{Max } e[u(c_1(R^i)) + u(c_2(R^i))] \tag{47}$$

s.t. (i) $x^{BB} + y_0^{BB} = E + qb_0^{BB}$

(ii) $c_1^i(R^i) = \begin{cases} \bar{c}^{BB} & \text{if } R^i \geq R^* \\ \frac{1}{2}(r^{BB}y_0^{BB} + P_1^L - b_0^{BB}) & \text{if } R^i < R^* \end{cases}$

(iii) $c_2^i(R^i) = \begin{cases} x^{BB}R^i + r^{BB}(r^{BB}y_0^{BB} - \bar{c}^{BB} \\ + qb_1^i(P_1^i, P_1) - b_0^{BB}) - b_1^i(P_1^i, P_1) & \text{if } R^i \geq R^* \\ \frac{1}{2}(r^{BB}y_0^{BB} + P_1^L - b_0^{BB}) & \text{if } R^i < R^* \end{cases}$

(iv) $c_2^i(R^i) \geq c_1^i(R^i)$

where

$$R^* = \frac{\bar{c}^{BB} - r^{BB}(ry_0^{BB} - \bar{c}^{BB}) - \frac{b_0}{q}}{x^{BB}} \tag{48}$$

Because the borrowing and sum of initial investments (x^{BB}, y_0^{BB}) are the largest, also the deposit contract (c_1, c_2) promised by the local EM banks, is the largest among the financial system we have studied.[29]

6.3 Fragility

Again we consider the unexpected event when in m countries the return on the long-term asset is less than expected ($R^{*-e} < R^*$). Since this is common knowledge at date 1, the condition on bank runs in m countries holds. With bank runs and early liquidations in m countries, the asset value of the international bank (P_1) diminishes, and the debt roll-over is less than expected

$$qB_1^{BB} = \lambda P_1 < \lambda(sR^a X^{BB}) = B_0^{BB} \tag{49}$$

The condition for the illiquidity of the international bank is

$$b(K,d) - my_1^{BB} + mP_1^L \frac{X^{BB}}{x^{BB}} + qB_1^{BB}(P_1) - B_0^{BB} - (r^{BB} - r)y_0^{BB} < 0 \tag{50}$$

Proposition 5: *Consider the international financial system, where both the local EM banks and the international bank use leverage. The borrowing of the local EM banks and the international bank are determined by the collateral value of their assets. Suppose that each local EM bank chooses investment portfolio (x^{BB}, y_0^{BB}) and offers deposit contract (c_1, c_2) determined in the risk-sharing problem (P5). Then, with the unexpected event, the system is the most fragile and the contagion the most severe of the financial systems we studied.*

Proof: If the condition (50) holds, the international bank liquidates in j countries. In these j countries the collateral value of the long-term asset falls to P_1^L, and the value of local EM banks' collateral drops

[29] The sum of initial investments can be ranked: (x^{BB}, y_0^{BB}) > (x^{LB}, y_0^{LB}) > (x^{IB}, x^{IB}) > (x, y_0).

below $\bar{a}^{BB}$. Indeed, in these j countries the debt roll-over is less than expected

$$qb_1^i(P_1^i, P_1) = \lambda\left(P_1^L + \frac{P_1 y_1}{s-m}\right) < \lambda(R^* x^{BB} + ry_1) = b_0^{BB} \tag{51}$$

In these j countries the local EM banks must decrease their savings, y_1, at the international bank. Contagion occurs, since ry_1 is diminished and equation (48) is violated and in the limiting country (R*) bank runs occur. These bank runs occur until in country i the following condition holds with equality

$$y_1 \frac{X^{BB} \sum_{i=l+(m+j)}^{S} R^i - B_1(P_1)}{(s-m)} + x^{BB} R^i - b_1^i(P_1^i, P_1) \le \bar{c}^{BB} \tag{52}$$

where the savings at the international bank are reduced to $y_1 = r^{BB}(r^{BB} y_0^{BB} - \bar{c}^{BB} - (b_0^{BB} - qb_1^i(\lambda_1^i)))$.

Due to lower debt roll-over and illiquidity of the local EM banks, additional bank runs and contagion may occur already at date 1. If in country i the decline in collateral and in debt roll-over are large enough, the local EM bank must liquidate early. This contagion occurs up to country i, where the following condition holds

$$r^{BB} y_0^{BB} - \bar{c}^{BB} \ge b_0^{BB} - qb_1^i(P_1^i, P_1) \tag{53}$$

These two conditions (52 and 53) together determine the range and number of countries where contagion occurs. The new equilibrium is reached when the conditions (52) and (53) hold with equality. This process determines the range [R*, R^{*+eBB}] and number of countries [g] where contagion occurs.

6.4 Comparison of financial systems

We study the severity of contagion in four financial systems. We compare the number of countries where contagion occurs by studying the upper limits of long-term assets before contagion occurs. Ranking from the most fragile financial system, we obtain

$$R^{*+eBB} > R^{*+eLB} \sim R^{*+eIB} > R^{*+eL} \quad (54)$$

The contagion is most severe in the international financial system in which the local EM banks and international bank borrow [limit R^{*+eBB}].[30] The rankings of R^{*+eLB} and R^{*+eIB} is less clear. But if the illiquidity of the international bank is of similar size, the limit R^{*+eLB} is higher than R^{*+eIB}. Leverage by local EM banks seems to produce more severe contagion than does leverage by the international bank, ie leverage by the global investment banks and funds. However, international illiquidity is more probable when the international bank uses leverage than when only the local EM banks borrow. Finally, if the financial system operates without any outside borrowing by the local EM banks or by the international bank, the contagion is not likely and will not spread to many countries.

7 Conclusion and discussion

The exact reasons for the contagion of financial crises in 1997–1999 are not well known. The empirical studies and stylised facts suggest that borrowing by local banks, a common lender, and the use of leverage by global banks and investment funds are possible reasons behind the contagion. Although several empirical studies have verified the contagion, theoretical studies are still scarce. This study developed a simple model of the international financial system, which describes the stylised facts discussed. We extended Allen and Gale (1998) to several local EM banks and included an international bank to represent all the global banks and investment funds operating in EMs. These banks are able to use outside borrowing, the amount of which is determined by the value of their collateral.

We studied the fragility of the international financial system and the linkages through which the crises can spread. Based on the model, a number of results emerged. First, costly liquidation of the long-term

[30] In the financial system in which both the international bank and the local EM banks use leverage, the lower asset prices render the international bank illiquid. The illiquidity of the international bank is more probable in equation (50) than when only the international bank borrows (equation 43). Thus, j is highest here among the financial systems studied. Furthermore, the collateral prices of both the international bank and local EM banks are diminished and, consequently, in (52) and (53) the debt roll-overs are less than expected. Indeed, conditions (52) and (53) hold with greater likelihood than (33) and (34), and so contagion is most probable when both the international bank and local EM banks borrow.

asset is a precondition for contagion. Second, without the use of leverage by either the local EM banks or the global banks, the international financial system is not very fragile, and contagion is unlikely. Third, the fall in asset and collateral prices is a vital linkage for contagion. Fourth, contagion is more severe when local EM banks use leverage than when global banks borrow. Fifth, when both the local EM banks and the global banks use leverage, the international financial system is highly vulnerable to contagion and crises may spread to several countries.[31]

Based on the results, some tentative policy implications can be drawn. Excessive borrowing by global banks and local banks in emerging economies may render the international financial system highly vulnerable to contagion. Authorities should be careful not to create incentives for excessive borrowing by banks. On the other hand, international financial institutions need to monitor the financial constraints in emerging markets more carefully. Liquidity conditions during crisis and boom periods, asset and collateral prices, and the financial reserves of global banks' subsidiaries could be more systematically monitored and analysed. The new IMF lending facility, contingent credit lines, may prove to be a useful tool in preventing contagion in the future.

Several caveats are in order. Our model is clearly a simplification of the actual international financial system, and our results depend on the assumptions. For example, we assumed that the amount of liquidity available for early liquidation of long-term assets is fixed. Clearly, no severe fall in asset prices would occur if the emerging markets had boundless amounts of liquidity available for purchasing these assets at date 1. We also assumed that banks borrow the maximum amount at date 0, ie the less-than-expected value of collateral at date 1 induces bank runs and contagion. Nor are banks allowed to borrow at date 1 more than the debt stock inherited from the earlier period ($qb_1 = b_0$). Without these assumptions, the liquidity constraint would naturally be less severe and contagion less probable. However, our assumptions reflect the credit constraints and lack of markets and information with which investors in emerging markets

[31] During the crises in Mexico, Asia and Russia a common leveraged creditor existed and local banks or governments were using large amounts of foreign borrowing. Thus, during these crises contagion spread to several countries. Before the crises in Brazil, Turkey and Argentina, capital inflows and indebtedness of local banks were much lower, and so these crises had minimal effects on other countries. See Kaminsky et al (2003) for a survey.

have to cope. And finally, the introduction of a state of the economy with zero probability ex ante is an assumption open to criticism.[32]

Despite these caveats, this study has shed some light on why financial crises may spread from one country to others. The model particularly pinpoints the use of leverage and the fall in collateral prices as an important channel and reason for contagion.

[32] But in emerging markets this does not necessarily reflect irrational behavior, and it is an illustrative means of studying the incomplete structure of financial markets in these economies. For example, in emerging markets, contracts are not contingent on low-probability events, and the cost of insurance can be high; see also Allen and Gale (2002a).

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Appendix 1

Optimal risk sharing

Following Allen and Gale (1998), the optimal risk sharing as a planning problem can be written as

$$\text{Max } e[u(c_1(R^i)) + u(c_2(R^i))] \tag{A1.1}$$

$$\begin{aligned} \text{s.t. (i)} \quad & x + y_0 \le E \\ \text{(ii)} \quad & c_1^i(R^i) \le ry_0 \\ \text{(iii)} \quad & c_2^i(R^i) \le r(ry_0 - c_1^i(R^i)) + xR^i \\ \text{(iv)} \quad & c_2^i(R^i) \ge c_1^i(R^i) \end{aligned}$$

The optimal risk-sharing must satisfy

$$u'(c_1^i(R)) = ru'(c_2^i(R)), \qquad \text{if } R^i < R^* \tag{A1.2}$$

$$c_1^i(R) = ry_0 \text{ and } c_2^i(R) = xR, \qquad \text{if } R^i \ge R^* \tag{A1.3}$$

$$e[u'(c_1(R))] = e[u'(c_2(R))R] \tag{A1.4}$$

The optimal risk-sharing problem can be written more compactly

$$\begin{aligned} &\max \int_0^{R^*} 2u\left(\frac{ry_0 + xR}{2}\right) f(R)dR \\ &+ \int_{R^*}^{\infty} \{u(\bar{c}) + u(r(ry_0 - \bar{c}) + xR)\} f(R)dR \end{aligned} \tag{A1.5}$$

$$\text{s.t. (i) } x + y_0 \le E$$

The optimal solution (y, x, c_1, c_2) to the risk-sharing problem is characterised by the consumption patterns (c_1, c_2) and portfolio allocation (y, x). The necessary conditions for the interior solutions are

$$\int u'(c_1(R))f(R)dR = \lambda \tag{A1.6}$$

$$\int u'(c_1(R))Rf(R)dR = \lambda \qquad \text{(A1.7)}$$

where λ is the Lagrange multiplier of the constraint $y_0 + x = E$. Under the strict concavity of u(.), these conditions uniquely determine the optimal portfolio (y_0, x), which in turn determines $c_1(R^i)$, $c_2(R^i)$ and R*.

Appendix 2

The timing of investment decisions

Date 0	**Date 1**	**Date 2**
x	P_1^L	xR^i
X	X / xP_1^L	XR^i
y_0	$y_0 r$ y_1	$y_1 r$
(c_1, c_2)	$\bar{c}$	c_2

Appendix 3

List of variables

x	Local EM banks holding of the long-term assets. The superscripts (x^{LB}, x^{IB} and x^{BB}) denote holdings of local EM banks in different international financial systems we studied.
y_0, y_1	Local EM banks holding of the short-term assets at date 0 and date 1. These are deposited in the international bank. The superscripts mark the holdings in different financial systems.
X	Long-term investment of the international bank to emerging market countries.
E	Endowment of consumers, which are deposited in local EM banks at date 0.
R^i	Return factor of the long-term asset in country i.
R^a	The average and expected return factor of the long-term asset.
r	Return factor of the short-term asset.
P_1^L	Liquidation price of the long-term asset if it is liquidated already at date 1.
c_1, c_2	Consumption at date 1 and at date 2.
$\bar{c}$	Fixed deposit payment promised by the local EM banks.
$\alpha(R^i)$	The fraction of late consumers who decide to withdraw early.
b_0, b_1	The amount of borrowing by the local EM banks at date 0 and 1.
B_0, B_1	The amount of borrowing by the international bank at date 0 and 1.
R^*	Critical level of long-term asset return; below which local EM banks are not able to pay $\bar{c}$ for early consumers.
R^{*-e}	When studying fragility we introduce an unexpected event, when in m countries the return on long-term asset drops to $R^{*-e} < R^*$.
R^{*+eBB}, R^{*+eLB}, R^{*+eIB}, R^{*+eL}	The limits of return on long-term asset below which contagion occurs. The superscripts denote the different international financial systems we studied.
n	The total number of EM countries and local EM banks.
s	The expected number of EM countries where $R^i \geq R^*$ and no bank runs should occur.
m	The number of EM countries which are affected by the unexpected event and $R^i < R^*$.

j	In case of illiquidity, the number of EM countries where the international bank liquidates.
g	In case of contagion, the number of countries where runs occur and local EM banks liquidate.
L_s	The amount available to buy the long-term assets offered for early liquidation.
$b(K, d, s)$	The expected cash flow situation of the international bank. $b(K, d, s) = K + sy_1 - nry_0$, where K is the reserve requirement and d the fee received by the international bank.
λ	The value of banks' asset is multiplied by the coefficient λ $(0 < \lambda < 1)$ so that the collateral value is received.
$\bar{a}$	The collateral value of local banks' assets at date 0.
a_1^i	The collateral value of local banks' assets at date 1.
$\bar{A}$	The collateral value of international bank's assets at date 0.
A_1	The collateral value of international bank's assets at date 1.

Essay 4

What drives financial crises in emerging markets?*

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Abstract

The study examines the causes of financial crises in 31 emerging market countries during 1980–2001. It estimates a probit model using 23 macroeconomic and financial sector variables. Traditional variables such as unemployment and inflation, as well as several indicators of indebtedness such as private sector liabilities and the foreign liabilities of banks explain currency crises rather well, and it appears currency crises occur in tandem with banking crises. Indeed, in emerging market countries the vulnerability to crisis is exacerbated by situations involving large liabilities that permit sudden capital outflows. Increases in indebtedness followed the liberalisation of capital flows and domestic financial sectors.

1 Introduction

During 1995–2001, over a dozen emerging market countries experienced severe financial crises. Arguably, these recent crises were more frequent and more painful than in the past, so it may be appropriate to ask whether something has changed in the economic environment. Are the reasons for these crises somehow different from earlier financial crises?

Although numerous empirical studies seek to identify causes for past crises and early-warning indicators that might be used to avoid future crises,[1] only few studies apply commonly used indicators simultaneously. A further shortcoming of the literature is that only a small number of studies focus solely on emerging market or developing countries. The ways in which liberalisation of capital flows and financial sectors change the economic environment – and influence the likelihood of crisis – has yet to be adequately addressed.

This study contributes to the literature in various ways. First, we apply several banking sector indicators, which have been shown as reasons for recent crises although not widely used in the empirical studies. Second, we simultaneously study the most commonly used macroeconomic indicators. We hope to detect the interaction of the variables and distinguish the actual causes of recent crises. Third, according to one line of argument financial liberalisation (which occurred in the 1980s or in early 1990s in most of the countries we discuss) rendered the emerging economies vulnerable to sudden capital outflows and crises. This is the first study that divides the sample into pre- and post-liberalisation periods and examines whether financial liberalisation has modified the causes for crises. Finally, we exclusively focus on emerging market countries to identify reasons for their crises. We are able to include recent crisis episodes from 1997–2001.

This study examines financial crises in 31 emerging market countries during the period 1980:1–2001:12. It estimates a probit model using 23 macroeconomic and financial sector indicators, including dummy variables for banking crises, exchange rate regime, and financial liberalisation. We find certain traditional variables, eg unemployment and inflation, but also several indicators of indebtedness, eg private sector liabilities and the foreign liabilities of banks to explain currency crises fairly well. The result that various

[1] See Chui (2002), Goldstein et al (2000) and Vlaar (2002) for surveys.

indicators of indebtedness – especially after financial liberalisation – induce crises is an interesting novelty of our study.

This paper is structured so that the following section presents an overview of the existing literature. Section 3 considers methodological questions, our indicators and data sets, while section 4 discusses the results. Section 5 examines the role of liberalisation in greater depth and suggests a prescription for a typical crisis. Section 6 provides out-of-sample forecasts of the estimated model. The final section concludes.

2 Literature review

The empirical literature on currency and financial crises can be categorized according to three methodological approaches. The first branch comprises case studies that concentrate on specific crisis episodes. These studies, while highly informative, usually do not seek to isolate general causes of crises, but rather analyze particular episodes. Notable examples are Sachs, Tornell and Velasco (1996), Glick and Rose (1998), and Blanco and Garber (1986).

The second group of studies is based on the 'signal approach' devised by Kaminsky and Reinhart (1996, 1999). The basic premise is that an economy behaves differently on the eve of a financial crisis than during times of normalcy. These studies identify variables that catch systematically deviant behavior prior to crisis episodes. The signal approach is a bilateral model – it examines one particular economic variable individually. A variable is said to issue a signal when it departs from its mean beyond a certain threshold. The threshold level is chosen for each indicator in a way that minimizes the risk of false signals and the risk of missing crises, ie it minimizes the 'signal-to-noise ratio'.

Kaminsky et al (1998) use the signal approach to predict currency crises for a sample of five industrial and 15 developing countries during the years 1970–1995. In their study, an indicator exceeding a specified threshold is interpreted as a warning signal that a currency crisis may take place within the following 24 months. They find that variables with the greatest explanatory power include exports, deviation of the real exchange rate from trend, the ratio of broad

money to reserves, output, and equity prices.[2] The signal approach is further applied in Kaminsky (1999) and Brüggemann and Linne (2002a). Perhaps the most careful attempt to craft an early-warning system is found in Goldstein et al (2000).

A major advantage of the signal method is the evaluation of each indicator's individual predictive power, which provides easily understandable results for policy purposes. However, since the interaction among variables is ignored, the actual reasons for crises may be obscured. A further drawback of the signal method is that the explanatory variables, as well as the probability of a crisis, are defined as a step function. Thus, the model fails to distinguish whether the value of the variable barely or greatly exceeds the threshold.[3] Finally, standard statistical tests are inapplicable to the signal approach.

Some of the problems in the signal approach are solved with limited-dependent or discrete-choice models. This method uses logit or probit functions and the predicted outcome, ie probability of crises, is constrained between zero and one.[4] The overall effect of the explanatory variables is evaluated simultaneously. Standard statistical tests are also possible. Since our aim is to identify reasons for crises, ie select appropriate variables and control for simultaneity, we use probit model for estimating the crisis indicators.

Among the earliest studies of this type, Eichengreen et al (1995) use data from 1959 through 1993 for industrial countries to characterize the common causes for currency crises and illuminate the contagious nature of currency crises. Frankel and Rose (1996) use a probit model to estimate the probability of crisis in an annual sample of 105 developing countries covering the period 1971–1992. They note that currency crises tend to occur when growth of domestic credit and foreign interest rates are high, and FDI and output growth are low. Kumar et al (2002) concentrate on forecasting crises and use logit model to study currency crises in 32 developing countries during the years from 1985 to 1999. They evaluate forecasts on an out-of-sample basis, estimating the model for one part of the sample, and then

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[2] Berg and Pattillo (1999) re-estimated the approach of Kaminsky et al (1998) to study whether the Asian crises would have been predictable using their approach. They obtained varying results. Most crises were not signaled in advance, and there were several false signals. However, the predictions were still better than random guesses.

[3] The step function takes a value of zero when the indicator variable is below the threshold and a value of one when it is above the threshold.

[4] Some studies, like Tanner (2001) and Bussière and Mulder (1999), use continuous exchange market pressure index and apply standard regression models to analyze the depreciation and loss of reserves.

forecasting crashes in the remaining sample period. Their model has relatively good forecasting power.

Nevertheless, the literature remains nearly devoid of studies that apply commonly used indicators simultaneously, so it is hard to say whether the appropriate indictors have actually been identified. The exception appears to be Bussiere and Fratzscher (2002). They consider 27 commonly used indicators, but report only the six variables that were found significant.[5]

Banking sector indicators, notably, are rarely applied in the crisis literature. Moreover, the empirical literature on banking crises is almost entirely limited to the studies of Demirgüc-Kunt and Detragiache (1997, 1999). These studies apply several variables and study how a multivariate logit model explains banking sector fragility. Examining a panel of 53 developed and developing countries over the period 1980–1995, they find that low GDP growth, high real interest rates, a high M2 to reserves ratio and the deposit insurance dummy are significant in explaining banking crises.

To improve the status of the current literature we study the causes of currency crises by estimating a probit model with 23 of the most commonly used macroeconomic and financial sector indicators. We also explore the underlying causes of banking crises.

3 Methodology and indicators

3.1 Methodology

We use a panel regression model to estimate the main reasons for financial crises in emerging markets. Given our indicators, the model estimates the probability for crisis. The estimated model takes the form

$$\text{Prob.}\,(y_{it} = 1 | x_t, \beta_t) = F(x_t, \beta_t) \tag{1}$$

where x_t corresponds to our set of indicators and β_t is a vector of unknown parameters. The observed variable y_{it} receives a value of 0 or 1 depending on whether a crisis has occurred or not. With a probit

[5] For further probit models see eg Berg and Pattillo (1999), Brüggemann and Linne (2002b), and Milesi-Ferretti and Razin (1998).

or logit model, the righthand side of the model is constrained between 0 and 1, and is compared to the observed value y_{it}. The probit model assumes that the probability distribution function (y_{it} conditional on x_{it}) corresponds to normal distribution.[6]

Since in currency crisis situation a successful attack leads to sharp currency depreciation and substantial reserve losses, both the signal approach and limited-dependent models traditionally define a currency crisis as a discrete event. One common technique is to construct an index of exchange market pressure as a weighted average of exchange rate changes and reserves changes (as well as interest rates in some cases). The crisis is said to occur when the index exceeds a country-specific threshold level.[7]

We calculate an exchange market pressure index (EMP) for each country. The index includes exchange rate depreciation and loss of reserves, which are weighted to influence equally. The exchange market pressure index takes the form

$$\mathrm{EMP} = \Delta e - (\sigma_e / \sigma_r) * \Delta r \qquad (2)$$

where Δe denotes the change in exchange rate and Δr in international reserves, σ_e and σ_r denote the standard deviation of exchange rate alteration and reserves respectively. We determine the values of the EMP index more than two standard deviations above the mean as a crisis.[8]

Since macroeconomic variables often worsen prior to the actual crisis, we define as a crisis not only the crisis month but also the

[6] We also applied logit model. The results are fairly similar to those of the probit model and they are available upon request. Since in the probit model the conditional probability approaches one or zero with higher rate, it might yield better estimation results when studying financial crises. Previous studies mainly use probit models.

[7] One problem in this definition is that it disregards the depth of the crisis.

[8] We also experimented with multiplying the standard deviation by one-half and three, but the coefficient two seems to best capture actual crises. With the coefficient one-half, we felt we detected too many crises (263), and with the coefficient three some major crises were missed eg Russia in 1994–1995, Czech Republic in 1997 and Mexico in 1985. See Table A3 in the appendix for results, and Wyplosz (1998) for similar examples. Altogether we identified 139 currency crises, but since the EMP index often exceeds the threshold level several times after another, we have only 78 separate 12-month long crisis periods.

eleven months before. In other words, we use a one-year window for our variables.[9]

3.2 Indicators

The tested indicators are selected on the basis of currency crisis theories and previous empirical literature.[10] Banking sector problems, for example, have been blamed for the recent financial crises in Asia, so, in addition to the traditional macroeconomic variables, we include several indicators describing the vulnerability of domestic banks.[11] These indicators include the growth of bank deposits, the ratio of the lending rate to the deposit rate, the ratio of bank reserves to assets, and the ratio of bank foreign liabilities to GDP. To study the twin-crisis hypothesis, ie whether banking and currency crises are related, we include a banking crisis dummy. The timing of banking crises is based on previous studies.[12] We also employ variables that indicate vulnerability to a sudden stop of capital inflows. These variables are shortterm capital inflows, public debt, broad money to reserves, and private sector liabilities.[13]

To study foreign influences on crises, we include the US interest rate and the Standard & Poors / IFC equity market index for emerging markets.[14] As a public debate over the wisdom of the chosen exchange rate regime often ensues after a crisis, we divided the exchange rate regimes into fixed, intermediate or floating, and included dummy variables for fixed and intermediate regimes.[15]

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[9] We tested our model with a one-month crisis period. But since one month is a short period, such results are unlikely to expose variables causing the crisis. Thus, we chose twelve months as our crisis period. Earlier literature uses either one- or two-year crisis periods. See eg Goldstein et al (2000).

[10] For each indicator table A2 gives a reference to empirical or theoretical literature.

[11] Table A2 in the appendix gives a list and the explanations of the indicators. Figure A1 shows the median values of the indicators in the whole sample and for the periods before and after liberalization.

[12] The timing of banking crises is taken from Kaminsky and Reinhart (1999), Lindgren et al (1996) and Mahar and Williamson (1998).

[13] We use banks' claims on the private sector to measure the liabilities or indebtedness of the private sector.

[14] The index measures contagion indirectly, ie the index decreases when major crises take place in emerging markets. Unfortunately, the index starts from 1984:12, so we calculated it from the individual markets backward to 1980:1.

[15] The data for exchange rate regimes is taken from Reinhart and Rogoff (2002) and IMF country reports.

Some scholars single out financial liberalisation as a possible cause for crises, noting most emerging markets liberalized their financial sectors and capital flows during the 1980s and early 1990s. That deregulation was followed by a period of capital inflows that reversed at the threat of an impending crisis. Thus, we include dummies to measure the internal and external liberalisation. External liberalisation is measured by liberalisation of capital account and internal by deregulation of domestic interest rates.[16]

Our study thus incorporates a total of 23 macroeconomic and financial variables, including dummy variables for exchange rate regime, banking crises, and liberalisation. Since we study all these variables simultaneously, we hope to distinguish those indicators that reflect actual causes of the recent crises in emerging markets. We further attempt to verify the correctness of findings of earlier studies.

3.3 Sample and data

The model is estimated for a panel of monthly observations for 31 emerging or developing countries and covers the period 1980:1–2001:12. Our sample includes those Latin American, Asian, African and European countries defined as middle-income countries under the World Bank's classification system. The data for transition countries naturally does not start before 1991.[17] While annual data gives access to a larger set of indicators and countries, monthly data better captures the sudden nature of crises and variance of indicators.[18]

Most data are gathered from International Financial Statistics. The data for unemployment rate are taken from ILO databases, while government debt figures come from several sources, including IFS,

[16] The timing of liberalization is taken from Mahar and Williamson (1998), EBRD transition reports and Kaminsky et al (2000).

[17] See Table A1 in the appendix for a complete list of countries. Due to data problems, only Morocco and South Africa are included from Africa. The data for Poland and Hungary start from 1991; for other transition countries, it begins in 1993. We also estimated our model without transition countries, when the sample is more balanced. The results are generally similar and available upon request.

[18] Where monthly data was unavailable, the monthly series were generated by linear interpolation from quarterly or annual data. In some cases, the data have been garnered from IMF country reports. For some countries unemployment figures, interest rates or government debt was unavailable for some periods. In those cases, the missing data were generated with the impute command of Stata software. Unemployment and public debt were limited to positive values. As stated above, we chose to use monthly data, because it better captures the sudden nature of crises. Also earlier studies have received better results with monthly data. See Goldstein et al (2000) for discussion.

the World Bank's WDI and IMF country reports. The detailed description of the data is provided in Table A1 in the appendix.

First, we examine the causes of currency and banking crises occurring throughout the sample period, ie 1980:1–2001:12. Next, we divide the sample into pre- and post-liberalisation periods. Since financial liberalisation can cause problems for the countries after the initial capital inflow period, we also study liberalisation with various lags.

4 Results

This section presents the reasons for currency and banking crises received with the used method, and the following section discusses the role of liberalisation more profoundly. The main results for the entire sample 1980:1–2001:12 are summarized in Table 1. The signs of our indicators are mostly as expected. Regarding the individual indicators, we find that the probability of currency crises increases along with public debt, private sector liabilities, current account deficits, the ratio of M2 to reserves, foreign liabilities of banks, inflation, unemployment, and overvaluation of the real exchange rate.[19] In addition, currency crises seem to be highly related to banking crises, which supports the twin-crisis argument proposed by Kaminsky and Reinhart (1996). Higher US interest rates and a decreasing EM market index also seem to foreshadow currency crises. The exact results are reported in Table A4 in the appendix.

Table A4 also reports the marginal effects of individual variables (column (dy/dx)X) at the point where the fundamentals are weak.[20] The results indicate that private sector liabilities, US interest rates, unemployment, foreign liabilities of banks, and inflation have the highest effect on crisis probability. The high significance of private sector indebtedness and foreign liabilities of banks is particularly interesting and supports the arguments that extensive borrowing by domestic banks or private enterprises, ie large financial markets, render emerging economies susceptible to crises.

[19] These results include only the indicators with the expected sign and significance of 1% level. The real exchange rate is calculated vis-à-vis the US dollar. Overvaluation is determined as the negative difference from a trend during 1980:1–2001:12.

[20] The marginal effects are calculated at a point where the fundamentals are weak, ie the indicators are calculated at the weakest quintile (the exact values are reported in Table A4 in column X).

Table 1. **Probit model, 1980:1–2001:12, currency crises**

BOP	Indicators	Expected sign	Found sign	Significance
Government	Budget balance / GDP	–	–	
	Public debt / GDP	+	+	***
	M2 / Reserves	+	+	***
Real sector	Industrial production	–	–	
+ traditional	Inflation	+	+	***
	Unemployment rate	+	+	***
	Domestic credit growth	+	+	**
	Exports	–	+	**
	Current account / GDP	–	–	***
	Real exchange rate	–	–	***
Financial sector	Banks deposits	–	–	
	Claims on private s. / GDP	+	+	***
	Banks for. liabilities / GDP	+	+	***
	Lending rate / deposit rate	– +	–	**
	Banks reserves / assets	–	+	
	Banking crisis dummy	+	+	***
Capital flows	FDI / GDP	–	–	***
	Short-term capital inflows/ GDP	– +	–	*
	Interest rate differential	– +	–	**
Foreign	US interest rate	+	+	***
	EM index	–	–	**
Exchange rate	Fixed exchange rate		–	
	Intermediate regime		–	***
Liberalization	Liberalization, internal	– +	–	
	Liberalization, external	– +	–	***

One, two, and three asterisks denote significance at the 10, 5 and 1 percent level, respectively.

The results also indicate that external liberalisation reduces the probability of currency crisis – at least, for the next twelve months. This might be expected, since a capital inflow period usually follows liberalisation of the capital account.[21] Moreover, a high interest rate differential seems to reduce the probability of crises, indicating that higher domestic interest rates attract capital inflows and help avoid crises. Surprisingly, growth of exports seems to increase the probability of crisis. For the entire sample, an intermediate exchange rate regime reduces the probability of crisis.

[21] When interpreting the results for capital account liberalisation, note that we simultaneously control the influence of short-term capital inflows, foreign liabilities of banks and the interest rate differential.

Table A4 reports also the goodness-of-fit of our model. Given the cut-off probability of 50%, the model correctly calls 32% of the crises and 98% of the tranquil periods. When the cut-off probability is lowered to 20%, the model correctly indicates 56% of the crises and 92% of the tranquil periods. These results are slightly better than those surveyed by Berg and Patillo (1999).

Comparing our results to earlier studies of Frankel and Rose (1996), Berg and Pattillo (1999), and the survey by Kaminsky et al (2000), we notice they are fairly similar. The macroeconomic indicators found significant in both earlier studies and this study are overvaluation of the real exchange rate, the M2 to reserves ratio, inflation, and the current account deficit. To a lesser extent, we note low FDI and high public debt also signal impending crises. Moreover, we find significant certain financial sector variables that were not generally included in earlier studies.[22] Our finding of strong importance of private sector liabilities, foreign liabilities of banks, and unemployment, differs from earlier studies.

Indicators deemed significant in earlier studies but not in ours are industrial production and domestic credit growth. Growth of exports had a different sign. These indicators may drop out in our study due to the fact we study many indicators simultaneously. Another plausible explanation for this difference is that we are using only emerging market countries, and the causes of crises may be different from those in developed countries.

Next we examine the reasons for banking crises, and study whether the explanatory variables are similar to currency crises. To do this, we estimate the probit model for banking crises occurring within the entire sample period 1980–2001 (Table A5). As expected, most of our banking sector indicators explain banking crises quite well.[23] The effect of low lending to deposit rate and high private sector liabilities to banking sector problems is particularly strong. Apparently, high private sector liabilities increase the probability of banking and currency crises with large magnitude. Also some macroeconomic variables and the dummy for currency crises increase the probability of banking crises.[24] The large importance of public debt and low

[22] High foreign liabilities of banks, a low lending to deposit ratio and banking crisis dummy seem to increase the probability of currency crises.

[23] In our study the probability of the banking crises increases when deposits, lending rate to deposit rate and banks' reserves to assets are decreasing, and claims on private sector are high. The sign of foreign liabilities of banks is surprisingly negative. Fluctuations in the exchange rate may play a role here.

[24] Macroeconomic variables that significantly increase the probability of banking crises are high public debt, high M2 to reserves and low FDI.

importance of industrial production differ from earlier studies and suggest interesting areas for further investigation.

5 Liberalisation and the course of a typical crisis

To study whether the liberalisation of capital flows has changed the reasons for crises, we divide our sample into two sub-samples, whereby the data for each country is divided into pre- and post-liberalisation of capital flows. In most of the countries, the deregulation of capital flows took place in the late 1980s or early 1990s. By 1998, all countries in our sample had liberalized their capital accounts. The results are reported in Tables A6 and A7.[25] Prior to liberalisation, unemployment, current account deficits, US interest rates, and the foreign liabilities of banks have the highest effect on the probability of a currency crisis. After liberalisation, high indebtedness of the private sector, high US interest rates, high public debt, and high foreign liabilities of banks significantly increase the probability of a currency crisis. In both samples, a banking crisis substantially increases the likelihood of a currency crisis. The effects of a current account deficit, inflation, and FDI are much lower after the liberalisation of capital flows than before.

The largest difference between the periods, however, is seen in private sector liabilities. Before liberalisation, private sector liabilities decrease the probability of a crisis, but after liberalisation higher private sector indebtedness increases with large magnitude the probability of a crisis. One reason for this difference is the significantly higher level of indebtedness after liberalisation. Between periods, the median of private sector liabilities increased from 16% to 29% of GDP (appendix Figure A1).[26]

Another notable difference between these periods concerns the role of exchange rate regime. In the overall sample, as well as in the pre-liberalisation period, an intermediate exchange rate regime

[25] The prior-liberalization sample includes 42 crisis periods and the post-liberalization sample 36 crisis periods (Table A3). We also estimated our model for the sub-samples 1980:1–1990:12 and 1991:1–2001:12. The results are available upon request. The results are mostly similar to the division according to liberalisation dates.

[26] Similarly foreign liabilities of banks and public sector indebtedness have increased after the liberalization of capital flows (See Figure A1).

decreases the currency crisis probability. After liberalisation, an intermediate regime significantly increases the probability of a crisis. This result supports the 'two corners' hypothesis, ie the corner regimes (a hard fix and a floating exchange rate) are safer than intermediate regimes (eg a crawling peg or band).

We also examine how the overall crisis probability changed with the liberalisation of capital flows. First, for both samples we use the median level of fundamentals prevailing before liberalisation. In other words, ceteris paribus, how does the liberalisation of capital flows change the probability of crisis? With the median level of fundamentals the crisis probability turns out to be much lower in the post-liberalisation period than prior to liberalisation (1.4% and 20.9%, respectively). When we used the weak levels of fundamentals, the crisis probabilities are almost similar pre- and post-liberalisation (37% and 33%).[27] These results suggest that liberalisation of capital flows in itself did not cause the recent crises in emerging markets, but the actual cause of the crises probably were the deteriorated fundamentals.

To examine the role of liberalisation in depth, we lag the liberalisation variables (both internal and external). The most interesting results are obtained when we use a two-year lag for internal liberalisation and a four-and-a-half-year lag for external liberalisation, and examine our model for the complete sample 1980–2001 (Table A8). The results indicate that liberalisation of interest rates and capital flows decreases crisis vulnerability for a year, but crises follow approximately two years after internal liberalisation and four-and-a-half years after liberalisation of capital flows.[28] The positive effect of capital account liberalisation on crisis probability is significant and relatively large.

Our results might best be summarised with a description of a typical emerging market crisis. In this example, the capital account is liberalized approximately four to five years before the actual currency crisis strikes. Deregulation allows foreign portfolio investments into the country and a large increase in private and public sector indebtedness. Under these circumstances an intermediate exchange regime becomes fragile for crises. Approximately two years before the crisis, the domestic financial sector is also liberalised. In the final

[27] These crisis probabilities (37% and 33%) are calculated with the weakest quintile values of the indicators (the exact values and results are reported in Tables A6 and A7).

[28] The result for internal liberalisation is quite similar to Wyplosz (2002). Our results indicate that the positive effect of capital account liberalisation on currency crises begins after four years and vanishes after five-and-a-half years. The exact timing of crises after liberalisation is obviously hard to estimate.

months leading up to the crisis, the level of indebtedness (private and public sector liabilities, and the foreign liabilities of banks) rise to a point where investors start to doubt the sustainability of the system. Consequently, a sudden capital outflow from these debt instruments may follow. Simultaneously – and partly as a result of the currency depreciation – the banking crisis becomes visible. The final push precipitating the crisis might be high interest rates in the US or a knock-on effect from a crisis elsewhere in emerging markets.

Although our characterization of a typical crisis is a generalization and all crises have had their own features, many recent crisis episodes follow the description quite well. In Asia, foreign borrowing by the private sector made the economies vulnerable to crises. The increase in indebtedness was preceded in the early 1990's by further liberalisation of capital accounts and financial sectors. In Russia large budget deficits and government's borrowing mainly caused the 1998 crisis. Interestingly, the market for treasury bills, GKO's, was liberalized for non-residents in 1996 and banking sector problems were revealed after the currency devaluation. Similar high indebtedness was also seen in Brazil, Turkey and Argentina.

6 Out-of-sample forecasts

We test the predictive power of our model by estimating the model on the restricted period 1980:1–1996:12 and conducting an out-of-sample forecast for the remaining five years. According to our crisis definition 1997:1–2001:12 includes eighteen currency crises. The performance of our predictions is reported in table 2. With the cut-off probability of 25% our model correctly calls half of the crises and 95% of the tranquil periods. If the cut-off is decreased to 15%, our model is able to forecast 61% of the crises and 81% of the tranquil periods. Figure A2 also shows the estimated out-of-sample crisis probabilities for three countries: Thailand, Russia and Turkey. For these crisis countries our out-of-sample forecasts fit fairly well.

Table 2. **Predictive power, currency crises, out-of-sample**

1997:1 - 2001:12	tranquil	crisis
cut-off prob. 50%		
predicts tranquil	99.5 %	61.1 %
predicts crisis	0.5 %	38.9 %
observations correctly called		91.5 %
cut-off prob. 25%	tranquil	crisis
predicts tranquil	95.2 %	50.0 %
predicts crisis	4.8 %	50.0 %
observations correctly called		89.2 %
cut-off prob. 15%	tranquil	crisis
predicts tranquil	80.8 %	38.9 %
predicts crisis	19.2 %	61.1 %
observations correctly called		78.2 %

1998:1 - 2001:12	tranquil	crisis
cut-off prob. 50%		
predicts tranquil	99.9 %	58.3 %
predicts crisis	0.1 %	41.7 %
observations correctly called		94.5 %
cut-off prob. 25%	tranquil	crisis
predicts tranquil	87.9 %	41.7 %
predicts crisis	12.1 %	58.3 %
observations correctly called		85.1 %
cut-off prob. 15%	tranquil	crisis
predicts tranquil	52.6 %	8.3 %
predicts crisis	47.4 %	91.7 %
observations correctly called		56.2 %

Note: A pre-crisis period is correctly called when the estimated probability of crisis is above the cut-off during the 12 months window and currency crisis occurs.

Since most of the crises in Asia occurred during the year 1997, we estimate our model also for the period 1980:1–1997:12 and construct an out-of-sample forecast for the remaining years. In those four years our sample contains twelve currency crises. At the 25% cut-off our model correctly calls 58% of the crises and 88% of the tranquil periods. If the cut-off probability is 15%, our model misses only one currency crisis out of twelve and provides a correct signal in 53% of the tranquil times. Altogether, the ability of our model to forecast crises is reasonably good, especially if the crises in Asia are included into the estimation period.

7 Conclusions

The study analysed the causes of financial crises in 31 emerging market countries during 1980:1–2001:12. It estimated a probit model using 23 macroeconomic and financial sector indicators, including dummy variables for banking crises, exchange rate regime, and liberalisation. A number of conclusions emerged. First, an increase in private sector liabilities, public debt, foreign liabilities of banks, unemployment, and inflation raises the probability of a currency crisis. Also changes in the US interest rates influence the occurrence of currency crises in emerging markets. Second, currency and banking crises are closely linked. Problems in the banking sector are well reflected in high private sector liabilities, high public indebtedness and a low lending to deposit rate.

Third, differently from the existing literature we divided the sample into pre- and post-liberalisation period. The indicators of indebtedness become more important in predicting crisis during the post-liberalisation period, while the real variables diminish in significance. The importance of indicators of indebtedness is an interesting and novel result, and might indicate a structural change in the global capital markets. The issuance by the authorities or domestic agents of large amounts of financial liabilities may today easily lead to a sudden capital outflow and crisis. Fourth, capital account liberalisation in the intermediate exchange rate regimes makes them more vulnerable to currency crises. Finally, in terms of the timing, currency crisis tends to occur approximately two years after the liberalisation of domestic financial sectors and four-and-a-half years after the liberalisation of capital flows. No support is evident for the argument that the deregulation of capital flows in itself was the cause of recent crises in the emerging markets.

In conclusion, the results emphasize the need for a careful monitoring of various indicators of indebtedness. Given the high degree of international capital mobility, this is especially relevant for the emerging markets in general, and countries intending to liberalise, in particular.

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Appendix 1

Table A1 **Countries**

Latin-America	Asia	Europe	Africa
Argentina	India	Bulgaria	Morocco
Brazil	Indonesia	Czech Republic	South Africa
Bolivia	Israel	Estonia	
Chile	Korea	Hungary	
Colombia	Malaysia	Latvia	
Ecuador	Philippines	Lithuania	
Guatemala	Singapore	Poland	
Mexico	Thailand	Russia	
Peru		Slovenia	
Uruguay		Turkey	
Venezuela			

Indicators

Budget deficit/GDP: IFS line 80 divide by line 99b.
Public debt/GDP: IFS line 88z divided by line 99b.
M2/international reserves: IFS line 34 plus 35 converted to dollars divided by line 1L.d.
Growth of industrial production: IFS line 66. If unavailable, then line 66aa.
Unemployment: IFS line 67r.
Inflation (CPI): IFS line 64.
Domestic credit growth: IFS line 32.
Growth of exports: IFS line 70d.
Current account balance/GDP: IFS line 78ald divided by IFS line 99b.
Overvaluation of exchange rate: IFS line ae deflated by consumer prices. Deviations from the trend were computed by HP filter.
Growth in bank deposits: IFS line 24 plus line 25.
Claims on private sector/GDP: IFS line 32d divided by IFS line 99b.
Banks foreign liabilities/GDP: IFS line 26c.
Ratio of lending rate to deposit rate: IFS line 60p divided by IFS line 60l.
Banks reserves/assets: IFS line 20 divided by the sum of lines 21 and 22a–22g.

Banking crisis dummy: Timing for banking crises determined by previous studies.
Portfolio investment liabilities/GDP: IFS line 78bgd divided by IFS line 99b.
Foreign direct investments/GDP: IFS line 78bed divided by IFS line 99b.
Interest rate differential: IFS line 60b for the country minus line 60b for USA.
US interest rate: IFS line 60b for USA.
EM index: Standard & Poors / IFC Emerging market index
Exchange rate regimes: We follow the classification by Reinhart and Rogoff (2002), but divide the regimes into three categories (fixed, intermediate and floating); currency board, peg and horizontal band narrower or equal to 2% were classified as fixed regimes; crawling pegs and bands narrower or equal to 5% were classified as intermediate regimes; managed and freely floating were classified as floating regimes. If Reinhart and Rogoff use a freely falling regime (eg inflation over 40%), we follow the classification of IMF country reports.
Liberalisation: Timing for internal and external liberalisation determined by Mahar–Williamson (1998), EBRD's transition reports and Kaminsky et al (2000).

Table A2 **The indicators**

Indicators	**Expected sign**	**Reference + explanation**
Government finance		
Budget balance / GDP	–	Krugman (1979), 1. generation theory
Debt / GDP	+	Krugman (1979), 1. generation theory
M2 / reserves	+	Calvo (1998), creates vulnerability to sudden stops
Real sector + traditional		
Industrial production	–	Obstfeld (1986), 2. generation theory
Unemployment	+	Obstfeld (1986), 2. generation theory
Inflation	+	Obstfeld (1986), 2. generation theory
Domestic credit growth	+	Krugman (1979), 1. generation theory
Exports	–	Berg and Patillo (1999)
Current account / GDP	–	Frankel and Rose (1996), Berg and Patillo (1999)
Overvaluation of RER	–	Frankel and Rose (1996), Berg and Patillo (1999)
Financial sector		
Bank deposits	–	Velasco (1987), Chang and Velasco (2000)
Claims on private sector/ GDP	+	Corsetti et al. (1998), measures lending boom
Banks foreign liabilities/ GDP	+	Chang and Velasco (2000), vulnerable to sudden stops
Lending rate / deposit rate	– +	Low ratio signals unprofitable banks During recession banks increase lending rates
Banks reserves / assets	–	Wyplosz (2002), indicate banking sector soundness
Banking crisis dummy	+	Kaminsky and Reinhart (1998), twin crises
Capital flows		
Short-term capital inflows / GDP	+ –	Radelet and Sachs (1998), induce vulnerability Capital inflows are beneficial
FDI / GDP	–	Milesi-Ferretti and Razin (1998), stable FDIs
Interest rate differential	+ –	Signals devaluation expectations Attracts capital inflows
International		
US interest rate	+	Milesi-Ferretti and Razin (1998)
EM index	–	Measures contagion indirectly
Others		
Fixed exchange rate regime		Krugman (1979), with weak fundamentals induce crises
Intermediate exchange rate		Eichengreen (1994), two poles will remain
Liberalisation: internal	+	Mahar and Williamson (1998), after boom crisis
Liberalisation: external	+ –	Mahar and Williamson (1998), after boom crisis Capital inflows can help avoid crisis

Table A3 **Number of crises**

	Number of crises
Currency crises, 1980-2001	
- 1,5 * st.dev.	263
- 2 * st.dev.	139
- 3 * st.dev.	72
Currency crisis periods	
- entire sample, 1980-2001	78
- before liberalization	42
- after liberalization	36
Banking crises periods	
- entire sample, 1980-2001	40

Table A4 **Probit model 1980:1–2001:12, currency crises**

Random-effects probit					Number of obs = 6828			Y = Pr (X=median)	
Group variable (i) : i					Number of groups = 31			0.039	
								Y = Pr (X=weak)	
Random effects u_i ~ Gaussian					Pseudo R2 = 0.164			0.238	
					Wald chi2(25) = 754.41				
Log likelihood = -2496.8887					Prob > chi2 = 0.000				
bop	Coef.	Std. Err.	z	P>|z|	[95% Conf. Interval]		dy/dx X	X (weak)	
budgetbal	-.0031717	.0033316	-0.95	0.341	-.0097014	0.0033581	0.0058	-5.9	
publicdebt	.0022502	.0006724	3.35	0.001	.0009323	.0035681	0.0449	64.5	***
M2toR	.0099695	.0013993	7.12	0.000	.0072269	.0127121	0.0256	8.3	***
industprod	-.0010737	.0025993	-0.41	0.680	-.0061682	.0040207	0.0005	-1.6	
inflation	.0592954	.005083	11.67	0.000	.0493328	.069258	0.0550	3	***
unempl	.0318399	.0082605	3.85	0.000	.0156496	.0480302	0.0985	10	***
domcred	.0028668	.0013055	2.2	0.028	.000308	.0054257	0.0039	4.4	**
exports	.002004	.0009134	2.19	0.028	.0002137	.0037943	-0.0053	-8.6	**
currentacc	-.0221354	.0045858	-4.83	0.000	-.0311235	-.0131473	0.0377	-5.5	***
RER	-.0272922	.0018561	-14.70	0.000	-.0309301	-.0236544	0.0388	-4.6	***
bankdepo	-.002963	.0031795	-0.93	0.351	-.0091946	.0032687	-0.0002	0.2	
claimspriv	.0081795	.001375	5.95	0.000	.0054845	.0108745	0.1298	51.3	***
banksforliab	.0163276	.0021469	7.61	0.000	.0121197	.0205356	0.0566	11.2	***
lenddeporate	-.080989	.0405752	-2.00	0.046	-.160515	-.0014631	-0.0301	1.2	**
brestoasset	.3005097	.2179622	1.38	0.168	-.1266885	.7277078	0.0037	0.04	
bc	.8415151	.0600343	14.02	0.000	.72385	.9591801	0.3132		***
stcinflow	-.0126551	.0065	-1.95	0.052	-.025395	.0000847	0.0012	-0.3	*
FDI	-.042059	.01132	-3.72	0.000	-.0642458	-.0198723	-0.0026	0.2	***
ratediff	-1.53e-07	7.43e-08	-2.06	0.039	-2.99e-07	-7.58e-09	0.0000	0.7	**
usrate	.0380136	.007109	5.35	0.000	.0240802	.0519469	0.1053	8.95	***
EMindex	-.0074362	.0033403	-2.23	0.026	-.013983	-.0008894	0.0087	-3.8	**
fixedexr	-.0748642	.0669238	-1.12	0.263	-.2060324	.0563041	-0.0225		
intermexr	-.296749	.0533191	-5.57	0.000	-.4012525	-.1922456	-0.1007		***
libinternal	-.1306011	.1107051	-1.18	0.238	-.3475791	.0863768	-0.0385		
libexternal	-.4124916	.1393167	-2.96	0.003	-.6855473	-.139436	-0.1077		***
_cons	-2.284031	.1599066	-14.28	0.000	-2.597442	-1.97062			
/lnsig2u	-1.50285	.1291191				-1.7559	1.249781		
sigma_u	.4716939	.0304524				.4156302	.53532		
rho	.1820009	.0192228				.1473022	.222738		
Likelihood ratio test of rho = 0:			chibar2(01) = 274.24		Prob >= chibar2 = 0.000				

One, two and three asterisks denote significance at the 10, 5, and 1 percent levels, respectively. For dummy variables (dy/dx)X is the discrete change from 0 to 1. The values in column X are the weakest quintiles of the variables.

Goodness-of-fit, 1980:1–2001:12, in sample

	tranquil	crisis
cut-off prob. 50%		
predicts tranquil	98.0 %	67.9 %
predicts crisis	2.0 %	32.1 %
observations correctly called		87.0 %
cut-off prob. 25%		
predicts tranquil	91.6 %	43.6 %
predicts crisis	8.4 %	56.4 %
observations correctly called		85.7 %
cut-off prob. 15%		
predicts tranquil	79.7 %	25.6 %
predicts crisis	20.3 %	74.4 %
observations correctly called		78.8 %

Note: A pre-crisis period is correctly called when the estimated probability of crisis is above the cut-off during the 12 months window and currency crisis occurs.

Table A5 **Probit model 1980:1–2001:12, banking crises**

Random-effects probit					Number of obs = 6828			Y = Pr (X=median)	
Group variable (i) : i					Number of groups = 31			0.0796	
								Y = Pr (X=weak)	
Random effects u_i ~ Gaussian					Pseudo R2 = 0.137			0.203	
					Wald chi2(25) = 538.27				
Log likelihood = -1763.5199					Prob > chi2 = 0.000				
bc	Coef.	Std. Err.	z	P>|z|	[95% Conf. Interval]		dy/dx X	X (weak)	
budgetbal	0.007724	0.004169	1.85	0.064	-0.000448	0.015895	-0.0129	-5.9	*
publicdebt	0.014633	0.000977	14.98	0.000	0.012718	0.016548	0.2663	64.5	***
M2toR	0.016116	0.001979	8.14	0.000	0.012237	0.019995	0.0377	8.3	***
industprod	-0.005670	0.002628	-2.16	0.031	-0.010820	-0.000520	0.0026	-1.6	**
inflation	-0.013586	0.005693	-2.39	0.017	-0.024744	-0.002427	-0.0115	3	**
unempl	-0.013757	0.008952	-1.54	0.124	-0.031302	0.003789	-0.0388	10	
domcred	-0.001661	0.000439	-3.78	0.000	-0.002521	-0.000800	-0.0021	4.4	***
exports	0.000493	0.001144	0.43	0.666	-0.001748	0.002735	-0.0012	-8.6	
currentacc	0.023817	0.005709	4.17	0.000	0.012628	0.035006	-0.0370	-5.5	***
RER	0.011992	0.001962	6.11	0.000	0.008147	0.015838	-0.0156	-4.6	***
bankdepo	-0.020820	0.004554	-4.57	0.000	-0.029745	-0.011896	-0.0012	0.2	***
claimspriv	0.009847	0.001592	6.19	0.000	0.006726	0.012967	0.1425	51.3	***
banksforliab	-0.021233	0.003126	-6.79	0.000	-0.027360	-0.015106	-0.0671	11.2	***
lenddeporate	-0.468875	0.052998	-8.85	0.000	-0.572750	-0.365000	-0.1587	1.2	***
brestoasset	-0.825377	0.242834	-3.4	0.001	-1.301323	-0.349432	-0.0093	0.04	***
bop	0.868008	0.060531	14.34	0.000	0.749369	0.986647	0.3116		***
stcinflow	-0.004567	0.008220	-0.56	0.578	-0.020677	0.011543	0.0004	-0.3	
FDI	-0.045597	0.013947	-3.27	0.001	-0.072933	-0.018260	-0.0026	0.2	***
ratediff	0.000002	0.000001	2.36	0.018	0.000000	0.000003	0.0000	0.7	**
usrate	-0.003836	0.008983	-0.43	0.669	-0.021442	0.013770	-0.0097	8.95	
EMindex	-0.001288	0.003997	-0.32	0.747	-0.009121	0.006546	0.0014	-3.8	
fixedexr	-0.068328	0.069316	-0.99	0.324	-0.204185	0.067530	-0.0187		
intermexr	0.214466	0.060923	3.52	0.000	0.095059	0.333874	0.0550		***
libinternal	-0.557856	0.155991	-3.58	0.000	-0.863592	-0.252120	-0.1204		***
libexternal	-0.253828	0.128048	-1.98	0.047	-0.504798	-0.002859	-0.0639		**
_cons	-1.342176	0.160723	-8.35	0.000	-1.657187	-1.027164			
/lnsig2u	-0.4010946	0.1066715			-0.6101669	-0.1920223			
sigma_u	0.8182828	0.0436437			0.7370619	0.9084539			
rho	0.4010494	0.0256234			0.3520211	0.4521414			
Likelihood ratio test of rho = 0:			chibar2(01) =504.53		Prob >= chibar2 = 0.000				

One, two and three asterisks denote significance at the 10, 5, and 1 percent levels, respectively. For dummy variables (dy/dx)X is the discrete change from 0 to 1. The values in column X are the weakest quintiles of the variables.

Table A6 **Probit model, periods before the liberalisations, currency crises**

Random-effects probit					Number of obs = 2671			Y = Pr (X=median)	
Group variable (i) : i					Number of groups = 24			0.2086	
Random effects u_i ~ Gaussian					Pseudo R2 = 0.1831			Y = Pr (X=weak)	
					Wald chi2(25) = 411.32			0.37	
Log likelihood = -1116.5438					Prob > chi2 = 0.000				
bop	Coef.	Std. Err.	z	P>|z|	[95% Conf. Interval]		dy/dx X	X (weak)	
budgetbal	0.01275	0.00513	2.49	0.013	0.002698	0.022798	-0.0284	-5.9	**
publicdebt	0.00129	0.00131	0.98	0.326	-0.001278	0.003848	0.0313	64.5	
M2toR	0.00886	0.00170	5.22	0.000	0.005533	0.012179	0.0278	8.3	***
industprod	0.00703	0.00695	1.01	0.312	-0.006591	0.020646	-0.0042	-1.6	
inflation	0.05763	0.00696	8.28	0.000	0.043997	0.071271	0.0653	3	***
unempl	0.13222	0.01897	6.97	0.000	0.095051	0.169392	0.4993	10	***
domcred	0.00388	0.00255	1.52	0.128	-0.001120	0.008880	0.0064	4.4	
exports	0.00074	0.00184	0.4	0.686	-0.002858	0.004346	-0.0024	-8.6	
currentacc	-0.08133	0.00980	-8.3	0.000	-0.100532	-0.062130	0.1689	-5.5	***
RER	-0.02632	0.00250	-10.53	0.000	-0.031222	-0.021426	0.0457	-4.6	***
bankdepo	-0.00015	0.00402	-0.04	0.970	-0.008023	0.007724	0.0000	0.2	
claimspriv	-0.02098	0.00437	-4.81	0.000	-0.029531	-0.012420	-0.4064	51.3	***
banksforliab	0.02344	0.00989	2.37	0.018	0.004050	0.042833	0.0991	11.2	**
lenddeporate	-0.00366	0.08656	-0.04	0.966	-0.173315	0.165995	-0.0017	1.2	
brestoasset	-0.66103	0.29398	-2.25	0.025	-1.237221	-0.084848	-0.0100	0.04	**
bc	0.67350	0.09925	6.79	0.000	0.478971	0.868036	0.2637		***
stcinflow	0.07734	0.02629	2.94	0.003	0.025821	0.128861	-0.0088	-0.3	***
FDI	-0.18978	0.03604	-5.27	0.000	-0.260423	-0.119130	-0.0143	0.2	***
ratediff	-1.54E-07	7.44E-08	-2.07	0.038	-3.00E-07	-8.21E-09	0.0000	0.7	**
usrate	0.03202	0.01105	2.9	0.004	0.010370	0.053672	0.1082	8.95	
EMindex	-0.00168	0.00547	-0.31	0.759	-0.012395	0.009034	0.0024	-3.8	
fixedexr	0.13171	0.10528	1.25	0.211	-0.074637	0.338050	0.0507		
intermexr	-0.46744	0.09098	-5.14	0.000	-0.645765	-0.289115	-0.1580		***
_cons	-1.88376	0.28386	-6.64	0.000	-2.440117	-1.327393			
/lnsig2u	-0.6772258	0.1559094				-0.9828026	-0.371649		
sigma_u	0.7127583	0.0555629				0.6117685	0.8304193		
rho	0.3368808	0.0348289				0.2723361	0.4081426		
Likelihood ratio test of rho = 0:		chibar2(01) = 168.60			Prob >= chibar2 = 0.000				

One, two and three asterisks denote significance at the 10, 5, and 1 percent levels, respectively. For dummy variables (dy/dx)X is the discrete change from 0 to 1. The values in column X are the weakest quintiles of the variables.

Table A7 **Probit model, periods after liberalisations, currency crises**

Random-effects probit					Number of obs =4157			Y = Pr (X=median)	
Group variable (i) : i					Number of groups = 31			0.0088	
								Y = Pr (X=weak)	
Random effects u_i ~ Gaussian					Pseudo R2 = 0.201			0.3334	
					Wald chi2(25) = 484.00			Y = Pr (X=medianB)	
Log likelihood = -1126.0823					Prob > chi2 = 0.000			0.0137	
bop	Coef.	Std. Err.	z	P>|z|	[95% Conf. Interval]		dy/dx X	X (weak)	
budgetbal	-0.007037	0.005008	-1.41	0.160	-0.0168534	0.002779	0.0151	-5.9	
publicdebt	0.005671	0.001487	3.81	0.000	0.0027557	0.0085859	0.1330	64.5	***
M2toR	0.032898	0.005794	5.68	0.000	0.0215425	0.0442544	0.0993	8.3	***
industprod	0.007339	0.003040	2.41	0.016	0.0013799	0.0132979	-0.0043	-1.6	**
inflation	0.058770	0.011376	5.17	0.000	0.0364737	0.0810654	0.0641	3	***
unempl	0.033431	0.012250	2.73	0.006	0.009421	0.0574403	0.1216	10	***
domcred	0.003059	0.001658	1.84	0.065	-0.0001909	0.0063094	0.0049	4.4	*
exports	0.002188	0.001120	1.95	0.051	-0.00000792	0.004384	-0.0068	-8.6	*
currentacc	-0.000627	0.005921	-0.11	0.916	-0.0122311	0.0109773	0.0013	-5.5	
RER	-0.030433	0.003105	-9.8	0.000	-0.0365191	-0.0243478	0.0509	-4.6	***
bankdepo	0.001642	0.008571	0.19	0.848	-0.0151578	0.0184411	0.0001	0.2	
claimspriv	0.032345	0.002387	13.55	0.000	0.0276667	0.0370225	0.6022	51.3	***
banksforliab	0.021282	0.002305	9.23	0.000	0.0167639	0.0257998	0.0867	11.2	***
lenddeporate	-0.032354	0.047982	-0.67	0.500	-0.1263964	0.0616891	-0.0141	1.2	
brestoasset	2.486667	0.528445	4.71	0.000	1.450934	3.522399	0.0362	0.04	***
bc	0.867673	0.088097	9.85	0.000	0.6950052	1.04034	0.3356		***
stcinflow	-0.018400	0.007122	-2.58	0.010	-0.0323587	-0.0044404	0.0002	-0.3	**
FDI	-0.020130	0.012746	-1.58	0.114	-0.0451117	0.0048526	-0.0015	0.2	
ratediff	-0.000015	0.000014	-1.08	0.280	-0.0000434	0.0000126	0.0000	0.7	
usrate	0.131947	0.015109	8.73	0.000	0.1023333	0.1615597	0.4294	8.95	***
EMindex	-0.011663	0.004809	-2.43	0.015	-0.0210887	-0.0022377	0.0161	-3.8	**
fixedexr	-0.443972	0.117946	-3.76	0.000	-0.6751419	-0.2128014	-0.1425		***
intermexr	0.219100	0.079271	2.76	0.006	0.0637314	0.3744676	0.0754		***
_cons	-5.144122	0.303335	-16.96	0.000	-5.738648	-4.549596			
/lnsig2u	-0.0024231	0.138254			-0.2733959	0.2685497			
sigma_u	0.9987892	0.0690433			0.8722336	1.143707			
rho	0.4993942	0.0345634			0.4320736	0.5667368			
Likelihood ratio test of rho = 0:			chibar2(01) =356.29		Prob >= chibar2 = 0.000				

One, two and three asterisks denote significance at the 10, 5, and 1 percent levels, respectively. For dummy variables (dy/dx)X is the discrete change from 0 to 1. The values in column X are the weakest quintiles of the variables.

Table A8 **Probit model 1980:1–2001:12, currency crises, liberalisation lagged**

Random-effects probit					Number of obs = 6828			Y = Pr (X=median)	
Group variable (i) : i					Number of groups = 31			0.041	
								Y = Pr (X=weak)	
Random effects u_i ~ Gaussian					Pseudo R2 = 0.1653			0.252	
					Wald chi2(25) = 754.43				
Log likelihood = -2493.4654					Prob > chi2 = 0.000				
bop	Coef.	Std. Err.	z	P>|z|	[95% Conf. Interval]		dy/dx X	X (weak)	
budgetbal	-0.004011	0.003368	-1.19	0.234	-0.010612	0.002591	0.0076	-5.9	
publicdebt	0.001469	0.000707	2.08	0.038	0.000084	0.002854	0.0303	64.5	**
M2toR	0.009087	0.001387	6.55	0.000	0.006368	0.011806	0.0241	8.3	***
industprod	-0.001298	0.002691	-0.48	0.630	-0.006571	0.003976	0.0007	-1.6	
inflation	0.064154	0.005536	11.59	0.000	0.053304	0.075005	0.0615	3	***
unempl	0.035777	0.008261	4.33	0.000	0.019586	0.051969	0.1143	10	***
domcred	0.002842	0.001304	2.18	0.029	0.000286	0.005398	0.0040	4.4	**
exports	0.001869	0.000916	2.04	0.041	0.000074	0.003663	-0.0051	-8.6	**
currentacc	-0.020248	0.004961	-4.08	0.000	-0.029971	-0.010525	0.0356	-5.5	***
RER	-0.027826	0.001916	-14.52	0.000	-0.031580	-0.024071	0.0409	-4.6	***
bankdepo	-0.001983	0.002973	-0.67	0.505	-0.007811	0.003845	-0.0001	0.2	
claimspriv	0.007880	0.001639	4.81	0.000	0.004668	0.011091	0.1291	51.3	***
banksforliab	0.016228	0.002081	7.8	0.000	0.012150	0.020306	0.0580	11.2	***
lenddeporate	-0.076783	0.040278	-1.91	0.057	-0.155727	0.002162	-0.0294	1.2	*
brestoasset	0.115676	0.226067	0.51	0.609	-0.327407	0.558759	0.0015	0.04	
bc	0.862344	0.067064	12.86	0.000	0.730901	0.993787	0.3251		***
stcinflow	-0.013382	0.006401	-2.09	0.037	-0.025928	-0.000837	0.0013	-0.3	**
FDI	-0.039854	0.011279	-3.53	0.000	-0.061961	-0.017748	-0.0025	0.2	***
ratediff	0.000000	0.000000	-1.77	0.076	0.000000	0.000000	0.0000	0.7	*
usrate	0.044422	0.007154	6.21	0.000	0.030401	0.058442	0.1270	8.95	***
EMindex	-0.007416	0.003335	-2.22	0.026	-0.013953	-0.000880	0.0090	-3.8	**
fixedexr	-0.111467	0.070114	-1.59	0.112	-0.248889	0.025954	-0.0342		
intermexr	-0.303795	0.054229	-5.6	0.000	-0.410083	-0.197508	-0.1058		***
libinternal (+2yr.)	0.213167	0.098266	2.17	0.030	0.020570	0.405765	0.0726		**
libexternal (+4,5 yr.)	0.373103	0.099417	3.75	0.000	0.178248	0.567957	0.1320		***
_cons	-2.265001	0.152578	-14.84	0.000	-2.564049	-1.965954			
/lnsig2u	-1.677301	0.1703182			-2.011119	-1.343484			
sigma_u	0.4322935	0.0368137			0.3658399	0.510818			
rho	0.1574532	0.0225947			0.1180405	0.2069377			
Likelihood ratio test of rho = 0:			chibar2(01) = 283.00		Prob >= chibar2 = 0.000				

One, two and three asterisks denote significance at the 10, 5, and 1 percent levels, respectively. For dummy variables (dy/dx)X is the discrete change from 0 to 1. The values in column X are the weakest quintiles of the variables.

The internal liberalisation is lagged by two years and the external liberalisation is lagged by four and half years.

Figure A1 **The medians of indicators**

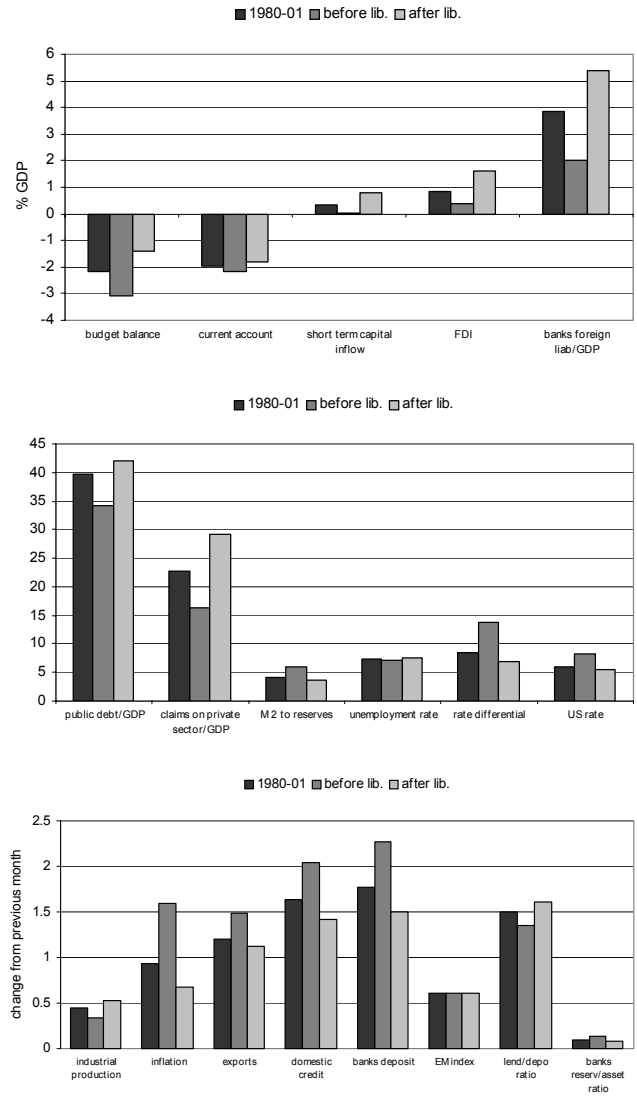
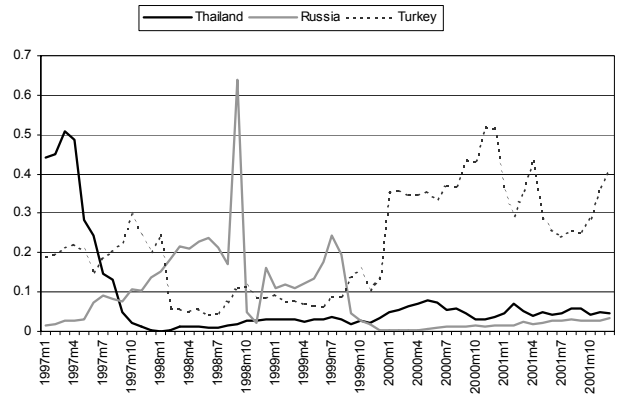


Figure A2 **Probability of crisis, out-of-sample forecasts 1997:1–2001:12**



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