Short-term Capital Flows and Currency Crises

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First Version August 2006
This Version November 2007

Abstract

Many economists and practitioners of economic policy have attributed the Asian Crisis in 1997-98 to a sudden outflow of private capital, in particular the "short-term capital flow" represented by short-term loans from foreign banks and portfolio investments by foreign investors. In this paper, I develop a model that explains how the ratio of short-term capital to foreign reserves affects the probability of crisis. I show that this ratio also changes the range of fundamentals that lead to crisis, so that a crisis may occur as a unique equilibrium outcome, even when there is no deterioration of the fundamentals. This result provides a compromise between the "fundamentals" and "panic" views of the Asian Crisis.

*I thank Andy Atkeson and Christian Hellwig for their comments and encouragements. All errors are mine. Comments welcome. E-mail: junichif@ucla.edu

1 Introduction

Many economists and practitioners of economic policy have attributed the Asian Crisis in 1997-98 to a sudden outflow of private capital. In particular, they have emphasized the role of foreign "short-term capital", represented by short-term loans from foreign banks and portfolio investments by foreign investors, which had entered the Asian economies in the 1990s on a large scale.

It is not a straightforward task, however, to provide a formal theoretical link between short-term capital and currency crises under the framework of "first generation currency crisis models", represented by Krugman-Flood-Garber (Krugman (1979) and Flood and Garber (1984), henceforth the KFG model), as well as their modern extensions[1]. It is because in this type of models, in the equilibrium, a "speculative attack" against the local currency amounts to a reduction in the general public's demand for real balances, leaving no role for short-term capital.

In this paper, I develop a model that explains how the ratio of short-term capital to foreign reserves affects the likelihood of a currency crisis. I show that this ratio also changes the range of fundamentals that lead to crisis, so that a crisis may occur as a unique equilibrium outcome, even when there is no deterioration of the fundamentals. This result provides a compromise between the opposing views of the Asian Crisis as well as for a currency crisis in general, namely the "fundamentals" view that attributes crisis to bad economic fundamentals, and the "panic" view that emphasizes the self-fulfilling shift in investors' sentiment.

My modelling approach is to incorporate the global games literature, initiated by Morris and Shin (1998)[2], into a framework similar to Obstfeld (1986). This approach has the following benefits. Firstly, the global games literature provides a clear intuition of why short-term capital matters for the occurrence of a crisis. In this literature, attacks against the currency peg are made by the speculators who choose between the safe foreign asset and the local currency denominated asset, which provides higher nominal returns but is subject to devaluation risk. It turns out that the amount of "hot money" in the economy, captured by the wealth and mass of these speculators, has a critical impact on the devaluation outcome. Since we can closely associate short-term capital with such "hot money", its importance in the occurrence of a crisis is immediate. Secondly, global

[1]This includes Obstfeld (1986), as well as more recent works such as Burnside, Eichenbaum, and Rebelo (2001, 2004) and Lahiri and Vegh (2003).

[2]The global games approach was first proposed by Carlsson and van Damme (1993) in a general 2×2 game. What we refer to as global games models (or literature) in this paper, however, is its applications to the analysis of currency crisis that follow Morris and Shin (1998).

games models are able to deliver a unique equilibrium[3], which enables the computation of probability of crisis. This feature contrasts with that of currency crisis models with multiple equilibria such as Obstfeld (1986, 1996), which will require us to make arbitrary assumptions on the probability of the sunspot variable in order to compute the probability of crisis[4]. Thirdly, incorporating the global games literature, whose models are typically rather abstract, into the more traditional setup of Obstfeld (1986), provides the model with an additional structure. This extension makes clear the model's relation to standard theories of international economics, and enhances our ability to analyze practical problems such as the one I pursue in this paper.

The rest of the paper is organized as follows. In section 2, I discuss the related literature, and in section 3, I review some key empirical facts regarding the Asian Crisis. In section 4, I present my model, and in section 5, I study its equilibrium. In section 6, I examine how the ratio of foreign reserves to short-term capital affects the equilibrium interest rate and crisis probability, and in section 7, I conclude.

2 Related literature

A number of papers (e.g. Rodrik and Velasco (1999), Radelet and Sachs (1998), Chang and Velasco (2002), and in particular Chang and Velasco (2000, 2001)) extend Diamond and Dybvig (1983)'s bank run model to explain how the presence of large short-term debt enables self-fulfilling bank runs, which in turn incurs a balance-of-payment crisis. These models undoubtedly capture one major aspect of the Asian Crisis, namely the feedback from financial fragility to currency crisis. This was especially true for South Korea, where the foreign banks' refusal of rollover of short-term loans directly triggered the government's decision to turn to the IMF in November 1997. I agree with these authors in considering sudden capital outflow to be the major cause of the Asian Crisis. But while these authors emphasize the vulnerability of the financial sector to the self-fulfilling

[3]In global games models, equilibrium can be unique or multiple depending on the information structure. Roughly speaking, equilibrium tends to be unique the more precise the private information is relative to the public information. For details, see Hellwig (2002) and Morris and Shin (2002).

[4]In addition to this drawback related to our goal of computing the crisis probability, I find the presence of multiple equilibria, which hinges on the assumption of common knowledge of the fundamental, less appealing in the context of speculative attacks. For, typical models with multiple equilibria require all speculators to perfectly allign their actions in the equilibrium, which eliminates the possibility of them doing "wrong" actions. In contrast, a global games approach allows speculators to choose actions that turns out to be "wrong" ex-post, although such speculators may have measure zero if the private information is infinitely precise.

expectations under excessive short-term debt, I address the vulnerability of currency peg to short-term capital, which includes short-term debt. Thus, my model is complementary to these authors in explaining the role of capital outflow in currency crisis. Cole and Kehoe (1996, 2000) develop a general equilibrium model which suggests that a short maturity structure of debt enlarges the "crisis zone", or the range of government debt that is prone to self-fulfilling debt crises. While these papers analyze the sovereign-debt crisis, my paper focuses on the currency crisis.

In terms of methodology, this paper is among the recent works that attempt to reconcile a global games approach with conventional equilibrium models. Such works include Hellwig, Mukherji, and Tsyvinski (2005) and Angeletos and Werning (2004), both of which integrate a global games approach into a noisy rational expectation equilibrium model, and consider the role of endogenous information conveyed by prices. While these papers refine and extend the standard global games model, my paper incorporates a global games approach into a KFG type of framework. In that sense, probably the closest to mine in spirit are Guimaraes (2006) and Broner (2005), although neither uses global games. The former incorporates asset market friction into Flood and Garber (1984), and explains how a currency can be overvalued for a long time before devaluation. The latter adds to the KFG model an assumption that only a fraction of agents are informed of the fundamentals, and examines the learning process of the uninformed. My paper also has similarities with Goldstein (2005) in aiming to go beyond the analysis of speculative attack and to examine the deeper cause of crises, while sustaining the global games approach. While his paper analyzes how the twin crises of banking and currency may reinforce each other, mine focuses on the general vulnerability of currency pegs to large mobile capital.

3 Key Facts on the Asian Crisis

In this section, I briefly review several key facts related to the Asian Crisis, which motivate my modelling approach.

Firstly, before the crisis, most East Asian countries, including the five most severely hit by the crisis (Thailand, Indonesia, South Korea, Malaysia, the Philippines), had their currency largely linked to the dollar. While the official exchange rate policies varied, such as hard peg under currency board (Hong Kong), basket peg (Thailand) and crawling peg (Indonesia), these currencies showed very high correlation with the dollar[5].

Secondly, capital flows involved mostly the private rather than the public sector. At

[5] This was true even in the Philippines, whose currency was classified by the IMF as "independent floating".

least before the onset of crisis, the default risk of public external debt was not a major concern[6]. This contrasts with the crisis episodes in Latin America, in which the default risk of public debt had a major role; for example, it was the growing concern for the Mexican government's default of Tesobonos (dollar denominated bond) that triggered the peso crisis in 1994-95.

Thirdly, the external indebtedness of the Asian countries was not at an intolerable level. Table 1 shows two indices of indebtedness of Asian and Latin American countries in 1996. The ratio of total external debt to GNI was relatively high at around 60% in Indonesia and Thailand, but was, overall, comparable in both regions. Moreover, with the exception of Indonesia, the debt-service ratio (ratio of debt-service to export) was much lower in Asia. These figures imply that the external indebtedness in itself was unlikely to be the main problem in Asia.

Country	Total External Debt /GNI (%)	Debt-service /Export (%)
Asia		
Indonesia	58.3	36.64
South Korea	22.3	8.6
Malaysia	41.3	8.9
Philippines	51.0	13.4
Thailand	63.5	12.6
Latin America		
Argentina	41.7	39.4
Brazil	23.8	42.2
Chile	41.7	28.3
Mexico	49.0	35.2
Peru	53.3	34.5

Table 1: External Indebtedness in 1996
(SOURCE: South Korea : Asian Development Bank, Key Indicators 2005
Other Countries : World Bank, Global Development Finance)

Fourthly, the economic fundamentals in the crisis-hit countries were relatively healthy, with the possible reservation of Thailand. Table 2 compares the conventional measures

[6]Moody's downgraded the sovereign credit rating of Thailand from A2 to A3 in April 1997, which precedes the abandonment of the peg in July that year. An A3 rating, however, still implies "low credit risk" according to Moody's definition.

of the economic fundamentals of the 5 Asian countries with those in Latin American countries. Although South Korea and Thailand had some slowdown of growth in 1996, all 5 Asian countries showed solid performance. The inflation rates were in general lower compared to Latin American countries, and all 5 Asian countries had government surpluses rather than deficits. Thailand and Malaysia had relatively large current account deficits in some of the years preceding the crisis, but the figures in Indonesia and South Korea were below 5% of the GDP, which is considered safe by conventional wisdom. In summary, while there are several figures which may be of some concern, it is difficult to explain from these conventional measures of economic fundamentals why Asia, and not other regions such as Latin America, was suddenly hit by the crisis at that particular moment.

	Real GDP Growth			Inflation Rate			Govt. Balance			Current Account		
Country	1994	1995	1996	1994	1995	1996	1994	1995	1996	1994	1995	1996
Asia												
Indonesia	7.5	8.2	7.8	8.5	9.4	7.0	0.9	2.2	1.2	-1.5	-3.0	-2.9
South Korea	8.5	9.2	7.0	6.3	4.5	4.9	0.3	0.3	0.1	-1.0	-1.7	-4.1
Malaysia	9.2	9.8	10.0	3.9	3.5	3.5	2.3	0.8	0.7	-7.6	-9.7	-4.4
Philippines	4.4	4.7	5.8	9.0	8.5	9.1	1.1	0.6	0.3	-4.4	-2.6	-4.6
Thailand	9.0	9.2	5.9	5.1	5.8	5.9	2.8	3.2	0.9	-5.4	-7.9	-7.9
Latin America												
Argentina	5.8	-2.8	5.5	4.2	3.4	0.2	-0.7	-0.6	-1.9	-4.3	-2.0	-2.5
Brazil	5.9	4.2	2.7	2075.8	66.0	16.0	-6.1	NA	NA	-0.3	-2.6	-3.0
Chile	5.7	10.6	7.4	11.4	8.2	7.4	1.5	2.4	2.1	-2.9	-1.9	-4.1
Mexico	4.4	-6.2	5.2	7.0	35.0	34.4	-0.0	-0.5	-0.2	-7.0	-0.5	-0.8
Peru	12.8	8.6	2.5	23.7	11.1	11.6	-3.2	-3.4	-1.4	-5.7	-7.7	-6.1

Table 2: Key Economic Fundamentals before the Asian Crisis
(in %, Government balance and current account are fraction of GDP)
(SOURCE: Government Balance/GDP:IMF International Financial Statistics July 2006 and own computation
Other series: IMF World Economic Outlook Database 2006)

Fifthly, Asian countries saw large capital inflows in the years preceding the crisis, followed by sudden outflows during the crisis. A large part of such capital inflow was from FDI, which is generally considered to be the most stable form of capital inflow. Nonetheless, there were also large inflows of mobile capital represented by bank loans, which tended to have short maturity, and portfolio investment[7]. Table 3 depicts this fact by showing the ratio of short-term debt to reserves and the cumulative inward portfolio investment[8] to reserves. With the exception of Malaysia, these ratios were quite high in the 5 crisis-hit Asian countries. In Indonesia, South Korea and Thailand, the ratio of short-term debt to reserves was above 1 in 1996, which some economists argue for as a symptom of danger, and was considerably higher than in 1993. Moreover, in 1996 this ratio tended to be higher in the Asian countries than in the Latin American countries, especially if we exclude Mexico that had already experienced a crisis in 1994-95[9]. Compared to the ratio of short-term debt to reserves, the ratio of cumulative portfolio investment to reserves has drawn less attention from economists[10]. From our point of view that emphasizes the short-term capital in general, however, this is also an important variable. Table 3 tells us that this ratio was again high in Indonesia and South Korea, and this time also in the Philippines, leaving Malaysia as the only country in this group with low values of both ratios.

Several precautions are in order. First, while we should consider portfolio investment as part of the short-term capital that affects the sustainability of the currency peg, its impact is probably smaller than short-term bank loans of the same face value. This is because the liquidation value of portfolio investment is likely to fall below the original value of investment, when investors rush to pull out of the local financial market. This leaves a smaller amount of local currency in the hands of investors, limiting their ability to sell this currency. Second, while the FDI is usually considered a stable investment and is not included in short-term capital, its stability is a matter of degree. These imply that a good measure of an economy's short-term capital would put a smaller weight on portfolio investment compared to short-term bank loans, and an even smaller yet positive weight on the FDI. Determining the "right" weights, however, is a difficult task which I will not pursue in this paper. Third, such measures may still underestimate the size of mobile capital. For example, in Thailand its "non-resident baht account" is not included in any category of capital flows mentioned above, despite being a major part of capital flows in the 1990s.

[7]Radelet and Sachs (1998) and Ito (1999) provide extensive analysis on the capital flows in Asia.

[8]Computed as the cumulative sum of inward portfolio investment, given in IMF International Financial Statistics, from 1976 (data starts from this year).

[9]Curiously Argentina and Brazil, which had high value in at least one of these two ratios, eventually experienced crisis (Brazil in 1998, Argentina in 2001).

[10]A notable exception is Hsiao and Hsiao (2001).

In either case, Table 3 shows the vulnerability of the Asian economy, which was not present in the conventional measures of fundamentals shown in Table 2.

	Short-term Debt /Reserves				Cumulative Portfolio Investment/Reserves			
Country	1993	1994	1995	1996	1993	1994	1995	1996
Asia								
Indonesia	1.44	1.46	1.74	1.66	0.18	0.46	0.68	0.78
South Korea	0.60	1.23	1.43	1.96	1.12	1.23	1.41	1.99
Malaysia	0.25	0.23	0.29	0.40	0.13	0.08	0.07	0.05
Philippines	0.85	0.80	0.68	0.68	0.80	0.35	0.65	0.87
Thailand	0.89	0.96	1.19	1.23	0.40	0.42	0.45	0.53
Latin America								
Argentina	0.56	0.45	1.34	1.19	2.94	3.54	3.87	3.74
Brazil	0.99	0.84	0.61	0.60	0.73	1.84	1.58	1.71
Chile	0.34	0.28	0.23	0.45	0.18	0.23	0.21	0.28
Mexico	1.43	6.10	2.19	1.53	2.48	11.01	3.59	3.78
Peru	1.46	0.90	1.12	0.59	0.06	0.10	0.11	0.11

Table 3: Short-term Capital and Reserves
(SOURCE: World Bank, Global Development Finance
and IMF, International Financial Statistics)

To summarize, data supports the view represented by Radelet and Sachs (1998), Rodrik and Velasco (1999), and Chang and Velasco (2002), that the Asian crisis was essentially a liquidity crisis rather than a solvency crisis. This led many economists to argue that the crisis was due to a self-fulfilling panic of the international investors, not the deterioration of the fundamentals. While such a story based on multiple equilibria is attractive, it leaves many things unexplained, such as what triggered the shift from "good equilibrium" to "bad equilibrium". In the rest of the paper I provide an alternative account of the crisis, by developing a model that has a taste similar to financial panic models, but whose equilibrium is uniquely determined by the fundamentals.

4 Model

4.1 Basic Environment

The basic environment of my model is similar to Obstfeld (1986), which follows Flood and Garber (1984) but assumes the domestic credit to be stochastic, rather than following a linear growth. My main modifications are the addition of speculative attack phase, as well as that of speculators who perform a central role in that phase.

4.2 Agents

There are two kinds of private agents; continuum of risk-neutral speculators of mass one, who holds local currency denominated bonds and care about returns in foreign currency, and the general public, who issues such bonds and demands money. As will be seen, the general public only has a passive role in the model.

There is also the government, which consists of the central bank and the fiscal authority. The central role is played by the former, which makes the devaluation decision.

4.3 Money, Domestic Credit and the Exchange Rate

The general public's demand for real balances is given by

$$\begin{aligned} \frac{M_t^d}{P_t} &= m, \quad \text{if } t \text{ fixed exchange rate regime} \\ &= \alpha m, \quad \text{if } t \text{ floating regime} \end{aligned} \tag{1}$$

, where M_t^d is the nominal demand for money, P_t is the price level, and $m > 0$ and $\alpha \in (0, 1)$ are some known constants. I assume for simplicity that the demand for real balances M_t^d/P_t is not interest rate elastic, and that it falls after the devaluation, due, for example, to the output cost of crisis.

There are two currencies. The local currency is denoted as the baht, and the foreign currency as the dollar. The baht is pegged to the dollar until there is a successful speculative attack, which I call a "crisis". Let S_t be the baht value of a dollar. I assume that PPP holds and there is no foreign inflation, so that normalizing the foreign price level P_t^* to 1,

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

During the fixed exchange rate regime, $S_t = \bar{S}$ and $M_t^d = M_t^s = \bar{M} = m\bar{S}$ from (1) and (2), where M_t^s is the nominal supply of money and $\bar{S}$ and $\bar{M}$ are some positive constants.

Domestic credit D_t is random during the fixed exchange rate regime, and for simplicity, assumed to be constant once the currency floats. That is,

$$D_t = \min\{\bar{D}\exp(-\theta_{t-1}), \bar{M}\}, \quad \text{if } t \text{ fixed exchange rate regime} \tag{3}$$
$$= D_{t-1} \quad\quad\quad\quad\quad\quad , \quad \text{if } t \text{ floating regime}$$

where θ_t is *i.i.d.* over time with *pdf* $h(\cdot)$, symmetric around zero with support $(-\infty, \infty)$, and with *cdf* $H(\cdot)$. As in standard global games, large values of θ_t imply good fundamentals. While in general domestic credit may consist of the central bank's claim on the fiscal authority (e.g. holdings of government bonds) as well as on the private sector (e.g. holdings of private bonds), I assume that the central bank initially holds only the former. Moreover, for expositional purpose I include the central bank's acquisition of claims on the private sector, which occurs as a result of its sterilization of the speculative attack as discussed below, in a separate entry. Therefore, changes in D_t are driven solely by the fiscal authority's need to have their expenditure financed by the central bank.

R_t denotes the official foreign reserves measured in baht. From the balance sheet of the central bank,

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

must hold during the fixed exchange rate regime. Then, as in the KFG model, when the speculators attack baht and obtain reserves from the government, R_t and M_t fall by the same amount absent offsetting policy by the central bank. If this is the case, (1) will be violated and the general public will have less liquidity than they wish to. I assume, however, that the attack will be "sterilized", so that M_t will remain at $\bar{M}$, and that this is common knowledge. This can be achieved by the central bank's liquidity assistance to domestic banks, or by its purchase of any form of assets from the general public, whose volume equals the drop in R_t. Following such operation an entry "OA_t (other assets)" appears in the asset side of the balance sheet[11], and M_t equals $\bar{M}$ as long as the fixed exchange rate regime continues. In addition, I assume that the central bank keeps R_t and OA_t constant once it moves into the floating regime. These assumptions imply that indeed $M_t = \bar{M}$ for all t. So from (1) and (2), the exchange rate after the crisis is constant at

$$\tilde{S} = \frac{\bar{M}}{\alpha m} = \frac{\bar{S}}{\alpha} > \bar{S} \tag{5}$$

[11]Sterilization is typically done by an open-market purchase of government bonds, but it can also be done by liquidity assistance to private financial institutions, or purchases of any private assets. The claims resulting from some of these operations will be included in "domestic credit" in usual practice, but for expositional purposes we denote them altogether as "other assets".

, implying a discrete devaluation at the time of the crisis.

While some of these assumptions may seem restrictive, they are less so than they may appear to be. The sterilization assumption is made for the sake of tractability, but it is consistent with certain crisis episodes, such as the 1994-95 Tequila crisis in Mexico. Moreover, although sterilization is a realistic policy option, it has been difficult to embed in the standard KFG model[12]. Thus this assumption is not necessarily a weakness of the model. Also, the essential requirement of the model is that the initial exchange rate after the currency floats is known to all. Ignoring technical details, this requires M_t right after moving into the new regime to be known, but does not require it to equal $\bar{M}$. So the assumption can be relaxed in this dimension.

4.4 Timing of Events

Time is discrete and goes to infinity, and during the fixed exchange rate regime a period consists of stages 1 and 2. There is no discounting of payoffs within the same period. Devaluation may occur only in stage 2, and after a devaluation the baht floats and stage 2 will no longer exist.

Stage 1 - "Business as usual" phase

This stage is, as it were, a "business as usual" phase, because during this stage there is no possibility of devaluation. In stage 1 of period t, D_t is observed but there is no information on D_{t+1}, except for the common prior of θ_t. This applies to the government as well, reflecting the reality that there is uncertainty in the next year's government budget due to the complexity of political processes.

In this stage, speculators choose between baht-denominated private bonds and dollar assets by comparing the expected returns from each asset, measured in dollars. Baht bonds yield interest i_t in period t, and are payable on demand; the holder can request the issuer of the bond, which is part of the general public, to redeem this bond for baht currency in stage 2 if he so wishes. In such case, however, the holder will lose the right to receive i_t. On the other hand, the dollar asset yields a safe return, normalized to zero. In equilibrium, i_t adjusts to equalize these expected returns.

Let B_t the total volume of such baht bonds at the end of stage 1 in period t. I assume that B_0 is exogenous, and that under the fixed exchange rate regime, in stage 1 speculators

[12] In the standard KFG model, under the sterlization policy the peg will collapse in the initial period. See Flood, Garber, and Kramer (1996) for a detailed discussion and a model that overcomes this issue by assuming imperfect substitutablity between domestic and foreign bonds.

simply roll over the baht bond they held at the end of stage 2 in the previous period, plus the interest. I only consider the case $B_t < \bar{M}$, and assume that each speculator holds identical amounts of bonds, equal to B_t as speculators have mass one.

B_t is the amount of "hot money" in the model, which in the real world corresponds to the amount of short-term capital subject to sudden outflow. Some readers may argue that while B_t represents the volume of baht denominated bonds, the external debt in Asian countries were mostly denominated in foreign currencies such as dollar and yen. This does not, however, cause a problem for my model. If foreign creditors hold foreign currency denominated claims on domestic agents, they are certainly not exposed to the currency risk. But domestic debtors are, so they have an incentive to sell the local currency when they anticipate devaluation, just like the speculators in my model.

Stage 2 - Speculative attack phase

The second stage is a speculative attack phase, similar to the speculative attack game in standard global games literature. At the beginning of this stage, each speculator receives a noisy private signal of the fundamental $x_{it} = \theta_t + \varepsilon_{it}$, where ε_{it} is *i.i.d.* over time with *pdf* $f(\cdot)$, symmetric around zero with support $(-\infty, \infty)$, and *cdf* $F(\cdot)$. For the sake of tractability, I focus on the case in which the precision of x_{it} approaches ∞. This infinitely precise private signal implies that the prior is ignored once x_{it} is received. It also implies that speculators participating in an unsuccessful attack has measure zero, so that $B_{t+1} = (1 + i_t)B_t$ if the fixed exchange rate regime is maintained at the beginning of period $t + 1$.

Based on this private signal, each speculator decides whether or not to attack the currency, without observing others' actions. "Attack" implies redeeming baht bonds for baht currency with the issuer of the bond, and exchanging baht for dollars with the government. Since there is no short-selling of baht in the model, this is the only form of speculative attack. There is a fixed cost \$$c$ per each $\bar{S}$ baht (=\$1) sold. Unlike in Morris and Shin (1998) this is a pure transaction cost which does not include the interest rate differential, so it should be small under normal circumstances. In particular, I assume

$$1 - \alpha - c < 0 \tag{6}$$

Since the issuer of the bond is part of the general public, such "attack" reduces the general public's holding of real balances and puts equation (1) out of balance. However, (1) is restored as the government sterilizes the attack and offsets the drop in M_t.

4.5 Devaluation rule

In stage 2, the central bank observes the true value of θ_t and the size of the attack A_t, defined as the total amount of baht that speculators attempt to sell. Then, the central bank makes the decision of whether or not to sustain the peg, based on the following decision rule. Note that A_t is bounded above by B_t, as the bondholders are the only agents that may participate in the speculative attack.

Recall from (4) and $M_t = \bar{M}$ that $R_t + D_t = \bar{M}$[13]. In order for the central bank to sustain the peg in period t, it needs to respond to the speculators' entire demand for dollars. Since the central bank sterilizes the attack, as shown in Appendix the balance sheet in the stage 1 of period $t+1$ implies

$$R_{t+1} + D_{t+1} + OA_t = \bar{M} \tag{7}$$

But since $OA_t = A_t$, $R_{t+1} = \bar{M} - D_{t+1} - A_t$. I assume that the central bank devalues if and only if this value is non-positive, that is

$$R_{t+1} = \bar{M} - D_{t+1} - A_t \leq 0 \tag{8}$$

This condition implies that the sum of D_{t+1}, the domestic credit planned for next period, and A_t, the size of the attack, is so large that the official foreign reserves next period R_{t+1} will be non-positive, if the central bank attempts to sustain the currency peg.

5 Equilibrium

5.1 Equilibria with Common Knowledge

Before examining the equilibrium in my main model with private information described above, I present analysis of the common knowledge case for the sake of comparison. To be precise, all assumptions are identical to the private information case, except that in stage 2, θ_t is common knowledge. The equilibrium for each period must satisfy an arbitrage condition in stage 1, and be a Nash equilibrium in the speculative attack game in stage 2. It turns out that multiple equilibria are possible in stage 2, which requires a sunspot variable for a complete definition of equilibria. Since that complicates the analysis without adding much insight, here I focus on the equilibria in stage 2.

[13]Since speculators participating in an unsuccessful attack have measure zero, conditional on peg being sustained in period t, the government has no need to sterilize the attack. Therefore OA_t term does not appear in this equation.

In this section I proceed by taking as given that each speculator is strictly better off attacking if there is a devaluation, and not attacking if there isn't. This will indeed be the case under the assumptions I make. Then, since θ_t is common knowledge, in the equilibrium of stage 2 it must be the case that either all speculators attack and the peg collapses, or none of the speculators attack and the peg is sustained. This feature leads to a partition of the space of fundamentals into three regions, just as in Obstfeld (1996).

Proposition 1 *There exists $\bar{\theta}_t^{ck}$ and $\underline{\theta}_t^{ck}$ such that the equilibrium strategy and the devaluation outcome in stage 2 of period t are,*

1. *If $\theta \leq \underline{\theta}_t^{ck}$, all speculators attack and the peg collapses*
2. *If $\theta > \bar{\theta}_t^{ck}$, no speculator attacks and the peg is sustained*
3. *If $\underline{\theta}_t^{ck} < \theta \leq \bar{\theta}_t^{ck}$, there are multiple equilibria; either all speculators attack and the peg collapses, or no speculator attacks and the peg is sustained*

Proof. Define $\underline{\theta}_t^{ck} \equiv \underline{\theta} \equiv \log \frac{\bar{D}}{M}$ and $\bar{\theta}_t^{ck} \equiv \log(\frac{\bar{D}}{M-B_t})$. First, if $\theta_t \leq \underline{\theta}_t^{ck}$, (3) implies that (8) holds even if $A_t = 0$, so that the peg collapses even if no speculator attacks. Therefore, attacking is a dominant strategy and so all speculators attack, and the peg collapses. Next, if $\theta_t > \underline{\theta}_t^{ck}$, (3) implies that (8) does not hold even if $A_t = B_t$, so that the peg is sustained even if all speculators attack. Thus, not attacking is the dominant strategy and no speculator attacks, and the peg is sustained. Finally, if $\underline{\theta}_t^{ck} < \theta_t \leq \bar{\theta}_t^{ck}$, (3) implies that if all speculators attack, (8) holds so that the peg collapses, and that if no speculators attack, (8) does not hold so that the peg is sustained. ■

5.2 Equilibrium with Private Information

5.2.1 Definition

With private information, the equilibrium for each period must satisfy an arbitrage condition in stage 1, and be a Bayesian Nash equilibrium in stage 2. I show that there exists a unique equilibrium, which starkly contrasts with the common knowledge case, despite the assumption of infinitely precise private signals. While the property of unique equilibrium in stage 2 is directly inherited from Morris and Shin (1998), the proof of existence and uniqueness of equilibrium for each period, which consists of two stages, turns out to be a non-trivial task.

The condition in stage 1 is essentially an uncovered interest rate parity (UIP). However, it differs slightly from the standard UIP in which the interest rate differential compensates for the expected devaluation, because in my model the bondholders (=speculators) may be able to escape devaluation loss by participating in the attack. In stage 2, I focus on monotone strategy equilibria, in which each speculator attacks if and only if the value of his signal is smaller than or equal to some threshold. The threshold turns out to be a function of the variables $\nu_t \equiv \{B_t, R_t, D_t, i_t\}$, so it generally differs across periods. The restriction to monotone strategy equilibria is in fact without loss of generality, because as in Morris and Shin (1998), in my model the unique monotone strategy equilibrium is the unique equilibrium that survives the iterated deletion of strictly dominated strategy[14].

Formally, the equilibrium is defined as follows.

Definition 2 *The equilibrium in period t is the interest rate* i_t*, the speculator's attacking strategy in stage 2,* $a(\nu_t, x_{it})$*, and the aggregate size of the attack in stage 2,* $A(\nu_t, \theta_t)$*, such that under the government's devaluation rule described in (8),*

1. *Given* $\{B_t, R_t, D_t\}$ *and* $a(\nu_t, x_{it})$*,* i_t *equates the expected return, in stage 1, from holding baht bonds and dollar assets*

2. $a(\nu_t, x_{it}) \in \{0, 1\}$ *maximizes the expected return in stage 2 for all speculators, where* $a(\nu_t, x_{it}) = 0$ *implies not attacking and* 1 *implies attacking*

3. $A(\nu_t, \theta_t) = B_t \int_{-\infty}^{\infty} a(\nu_t, x_{it}) f(x_{it} - \theta_t) dx_{it}$

I now analyze the equilibrium conditions in each stage in more detail. For expositional purposes, I start the analysis from stage 2. I let $A_t(\theta_t) \equiv A(\nu_t, \theta_t)$ to simplify notation, and just write A_t except when I emphasize its dependence on θ_t.

5.2.2 Stage 2 Conditions

Payoffs Stage 2 is essentially the speculative attack game in the standard global games literature, and my analysis follows the standard procedure in this literature. However, I

[14] This follows because in our model there exist dominance regions on both sides as in Morris and Shin (1998). The potential complication, arising from the fact that not all speculators manage to sell the local currency when they wish to, is avoided by the assumption that speculators who attempted to buy the dollar but didn't manage to receive the same payoff as those who chose not to attack. Hence there is no extra "cost" from trying to sell the baht and not being able to do so, so that conditional on devaluation one is strictly better off attacking than not. Strategic complementarity between speculators is hence sustained, so that the standard proof based on itereated deletion still applies.

have one important departure from the standard model, which assumes that all speculators who participate in the attack manage to obtain the foreign currency. In my model, in case of a successful attack, R_t may not be large enough to cover all of A_t. I assume that in such case, the government pays out all official reserves R_t but does not respond to demand for dollars exceeding R_t, so that a speculator who attacked receives dollars with probability R_t/A_t, and is stuck with his baht bond otherwise. The computation of payoffs below reflects such considerations.

While each speculator holds bonds worth B_t baht, it suffices to analyze the payoff for $\$1 = \bar{S}$ baht of bond, as speculators are risk neutral. I proceed as such for the sake of convenience.

When the speculator chooses to "attack", his net returns depend on the outcome as follows.

<table>
<tr><th>$Outcome$</th><th>$Payoff$</th><th>$probability$</th><th></th></tr>
<tr><td>$NoDevaluation$</td><td>$-c$</td><td rowspan="2"></td><td rowspan="2">$\}1 - p(x_{it})$</td></tr>
<tr><td>$Devaluation, gets\ to\ buy$ \$</td><td>$-c$</td></tr>
<tr><td>$Devaluation, fails\ to\ buy$ \$</td><td>$\alpha(1 + i_t) - 1$</td><td>$p(x_{it})$</td><td></td></tr>
</table>

When he chooses "not to attack", net returns are as follows;

	$Payoff$	$probability$
$NoDevaluation$	i_t	$1 - q(x_{it})$
$Devaluation$	$\alpha(1 + i_t) - 1$	$q(x_{it})$

Here, $p(x_{it})$ and $q(x_{it})$ are the probabilities of corresponding events, conditional on receiving the private signal x_{it}. To be sure, they depend on ν_t which is predetermined in stage 2, but to simplify notation I suppress such dependence on ν_t.

Threshold conditions As is standard in the literature, I proceed using two conditions. It turns out that the equilibrium in stage 2 game is characterized by the threshold fundamental θ_t^* and threshold signal x_t^*.

The first condition is the threshold fundamental condition. Note that $\theta_t^* \geq \underline{\theta} = \log(\bar{D}/\bar{M})$, because when $\theta_t \leq \underline{\theta}$ the peg will collapse without any attack from the speculators. Now, when $\theta_t = \theta_t^*$ the reserve loss exactly equals the amount required for the peg to collapse, so from (8),

$$\bar{M} = A_t(\theta_t^*) + \bar{D}\exp(-\theta_t^*)$$

which, combined with $A_t(\theta_t^*) = B_t F(x_t^* - \theta_t^*)$, yields

$$F(x_t^* - \theta_t^*) = \frac{\bar{M} - \bar{D}\exp(-\theta_t^*)}{B_t} \tag{9}$$

Observe from (9) that $x_t^* - \theta_t^*$ is increasing in θ_t^*.

The second condition is the threshold signal condition. I will later impose a condition that guarantees

$$1 - \alpha(1 + i_t) - c > 0 \tag{10}$$

to hold, so that conditional on devaluation a speculator is strictly better off attacking. Now, the marginal speculator receiving x_t^* is indifferent between attacking and not, so

$$\underbrace{p(x_t^*)\{\alpha(1+i_t)-1\}+(-c)\{1-p(x_t^*)\}}_{Expected\ Payoff\ from\ Attacking} = \underbrace{\{1-q(x_t^*)\}i_t + q(x_t^*)\{\alpha(1+i_t)-1\}}_{Expected\ Payoff\ from\ Not\ Attacking}$$

This implies

$$\{q(x_t^*) - p(x_t^*)\}\{1 - \alpha(1+i_t)\} - c\{1 - p(x_t^*)\} = \{1 - q(x_t^*)\}i_t \tag{11}$$

5.2.3 Stage 1 Condition

The stage 1 condition is an arbitrage condition which equates the expected returns from baht bonds and the safe dollar asset. Since the speculators' private signals in stage 2 are infinitely precise, in case of devaluation all speculators, except those with measure zero, will correctly attack so that the size of the attack A_t equals B_t. So if $B_t \leq R_t$, even in the case of devaluation they can avoid the devaluation loss and limit their losses to the transaction cost c. However, if $B_t > R_t$, with probability $1 - R_t/B_t$ a speculator who attacked is unable to exchange baht for dollars and suffers a devaluation loss. The arbitrage condition must consider these different possibilities.

Let us define $\gamma_t \equiv R_t/B_t$, and let ρ_t the probability that speculators manage to sell baht for dollars in case there is devaluation in stage 2. The argument above implies that $\rho_t = \min\{1, \gamma_t\}$. Stage 1 condition can then be written as follows.

$$\big[\{\alpha(1+i_t) - 1\}(1 - \rho_t) - c\rho_t\big]H(\theta_t^*) + \{1 - H(\theta_t^*)\}i_t = 0 \tag{12}$$

The LHS of this equation is the expected return from baht bonds, while the RHS corresponds to that from the dollar asset, which equals zero. Recall that θ_t^* is the threshold fundamental in stage 2, so that $H(\theta_t^*) = \Pr(\theta_t \leq \theta_t^*)$ is the ex-ante probability of devaluation. Since the speculators have not received the private signal and they have a common prior on θ_t, in stage 1 all speculators assign this probability to devaluation. So in the event of devaluation, whose ex-ante probability is $H(\theta_t^*)$, each speculator participates in the attack and pays the transaction cost c with probability ρ_t in case he manages to sell baht, and suffers from devaluation loss $\alpha(1 + i_t) - 1$ otherwise. In the event of peg being sustained, whose ex-ante probability is $1 - H(\theta_t^*)$, he will correctly refrain from attacking and receive the interest i_t.

5.2.4 Equilibrium Characterization

Equilibrium in period t is fully characterized by a triple $\{\theta_t^*, x_t^*, i_t\}$ that satisfies the equilibrium conditions (9)-(12). First, I assume that the following condition holds, which guarantees (6).

$$H(\underline{\theta}) < \frac{1 - (\alpha + c)}{(1 - \alpha)(1 - c)} \tag{13}$$

(13) requires that the probability of very weak fundamentals θ_t, such that the peg will collapse without any attack (*i.e.* $\theta_t \leq \underline{\theta}$), is not too high. If c is small, as I argued to be the normal circumstance, the RHS of (13) is close to 1, so it is a rather weak restriction.

The following proposition establishes one of the central results in this paper, the existence and uniqueness of equilibrium.

Proposition 3 *For all $B_t \in [0, \bar{M})$, there exists a unique triple $\{\theta_t^*, x_t^*, i_t\}$ that satisfies (9)-(12).*

Proof. See Appendix. ■

6 Effect of Changes in γ_t

6.1 Analytical Results

Let us now consider our central question of how the ratio of short-term capital to foreign reserves affects the probability of crisis. The experiment here is to fix R_t and vary γ_t, which corresponds to varying the size of B_t, and to see how that affects the ex-ante probability of crisis $H(\theta_t^*)$. Note that since $B_t < \bar{M}$ by assumption, $\gamma_t = R_t/B_t > R_t/\bar{M}$.

As γ_t is the analogue of the ratio of reserves to short-term capital in the real economy, it is inversely related to the ratios shown in section 2, Table 3[15]. So it is natural to expect that the probability of crisis is decreasing in γ_t. This turns out to be true when $\gamma_t \geq 1$.

Proposition 4 *As γ_t falls, i_t always rises. θ_t^* and hence the ex-ante probability of crisis $H(\theta_t^*)$ also rise when $\gamma_t \geq 1$.*

[15] The empirical literature that studies the effect of short-term capital typically considers the ratios as defined in Table 3. I defined γ_t as R_t/B_t, not as its inverse, as it simplifies notations in my computation.

Proof. See Appendix. ■

Proposition 4 implies that the probability of crisis rises monotonically as γ_t falls towards 1. When $\gamma_t \in (R_t/\bar{M}, 1)$, the effect of γ_t on the crisis probability is ambiguous. The intuition is as follows.

When $\gamma_t \geq 1$, $\rho_t = 1$ so that (12) can be rewritten as

$$c\frac{H(\theta_t^*)}{1 - H(\theta_t^*)} = i_t \tag{14}$$

The interpretation of (14) is that a higher probability of devaluation, which forces the speculators to sell baht in stage 2 and incurs them the transaction cost c, must be compensated by a higher interest rate, so that i_t and θ_t^* must move in the same direction. γ_t does not appear in this equation because a speculator can always obtain dollars in stage 2 if he so wishes. Now, in the stage 2 condition, a smaller γ_t (= a larger B_t) makes the speculative attack easier to succeed and hence makes a wider range of fundamentals susceptible to devaluation, leading to a larger θ_t^*. As a result, a smaller γ_t always leads to a larger i_t and θ_t^*.

When $\gamma_t < 1$, $\rho_t = \gamma_t$ so that (12) can be rewritten as

$$\frac{H(\theta_t^*)}{1 - H(\theta_t^*)} = \frac{i_t}{\{1 - \alpha(1 + i_t)\} - \gamma_t\{1 - \alpha(1 + i_t) - c\}} \tag{15}$$

The RHS of (15) is increasing in i_t when $\gamma_t < 1$, so for a given γ_t, i_t and θ_t^* again move in the same direction. But the situation is now more complicated due to the presence of γ_t in this stage 1 condition. As $1 - \alpha(1 + i_t) - c > 0$ from (10), keeping i_t constant, a smaller γ_t requires a smaller θ_t^* in (15). A smaller γ_t implies a higher probability that a speculator is unable to sell baht for dollars in stage 2, even if he so wishes. This reduces the expected return from baht bonds, which needs to be offset by a fall in probability of crisis, or equivalently by a smaller θ_t^*. Conversely, in the stage 2 conditions, a smaller γ_t demands a larger θ_t^* for the same reason as when $\gamma_t \geq 1$. These conflicting effects of γ_t on θ_t^* are reconciled by the rise in i_t, which serves to increase θ_t^* in the stage 1 condition by enabling compensation of higher probability of crisis, and to decrease θ_t^* in the stage 2 conditions by increasing the opportunity cost of speculative attack and making the attack less attractive. Thus a smaller γ_t results in a larger i_t, and as their effects on θ_t^* cancel each other in the stage 1 condition, we are unable to make clear predictions on the movement of θ_t^*.

To summarize, θ_t^* is a function of γ_t, so that whether a given value of fundamentals θ_t is sound ($\theta_t > \theta_t^*$) or not ($\theta_t \leq \theta_t^*$) depends on γ_t. While $\gamma_t \geq 1$, a fall in γ_t yields a rise in θ_t^*, implying a higher probability of crisis. While $\gamma_t < 1$, the effect of γ_t on θ_t^* is ambiguous. A natural question is whether θ_t^* may fall substantially as γ_t falls within this region. If not, the effect that holds for $\gamma_t \geq 1$ should dominate, providing a tendency for θ_t^* to move in the opposite direction of γ_t for all ranges of γ_t. I look at numerical examples to examine this question.

6.2 Numerical Examples

I present below two numerical examples. In both, I use $\bar{M} = 1$, $\bar{D} = 0.5$, $c = 0.01$, $\alpha = 0.8$ and the prior distribution of $\theta \sim N(0, 0.5)$. I let $R = 0.8$ in Figure 1 and $R = 0.4$ in Figure 2, and plot i_t (upper panel) and $H(\theta_t^*)$ (lower panel) against γ_t in the range $\gamma_t > R_t/\bar{M}$.

Figures 1 and 2 show, consistently with my analytical result, that the interest rate i_t and the probability of crisis $H(\theta_t^*)$ rise as γ_t approaches 1 from above. Figure 1 also shows that while $\gamma_t < 1$, $H(\theta_t^*)$ may fall as γ_t falls. But quantitatively this fall is small, and $H(\theta_t^*)$ stays at a high level for $\gamma_t < 1$. Although we should be cautious in generalizing this result, it seems fair to conclude that a small γ_t tends to lead to a high probability of crisis, which is consistent with the empirical findings.

Since the return to dollar assets is normalized to zero and there is no credit risk, i_t corresponds to the difference between the domestic and world interest rate. In my numerical examples, the level of i_t is unrealistically low while $\gamma_t \geq 1$. This is due to the assumption of infinitely precise private signal, which enables all speculators, except for those with measure zero, to correctly attack in the event of devaluation. Thus while $\gamma_t \geq 1$, they don't suffer from devaluation losses and hence i_t only reflects the transaction cost incurred when selling baht. It is only when $\gamma_t < 1$, in which case not all speculators who attacked manage to sell baht, that i_t embeds the devaluation risk and attain non-negligible figures. An obvious remedy to this extremely low interest rate differential is to make the precision of private information finite. This largely complicates the analysis, however, because then the prior of θ, which serves as public information, will not be ignored in stage 2[16]. Extensions in this direction may be interesting, but is unlikely to add extra insight to the main message of the paper that a smaller γ_t tends to increase the probability of crisis.

[16] As discussed e.g. in Hellwig (2002) and Morris and Shin (2002), the introduction of public information will lead to multiple equilibria if the public information is sufficiently more informative than the private information. In such case, we will need to assume a sunspot variable in stage 1, as in the common knowledge case.

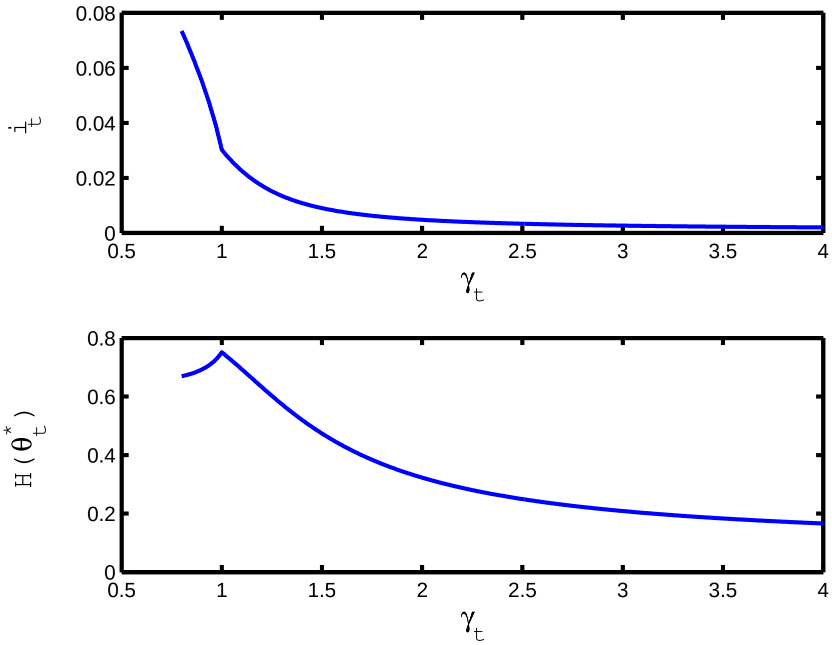

Figure 1: Effect of γ_t on i_t and $H(\theta_t^*)$, when $R_t = 0.8$

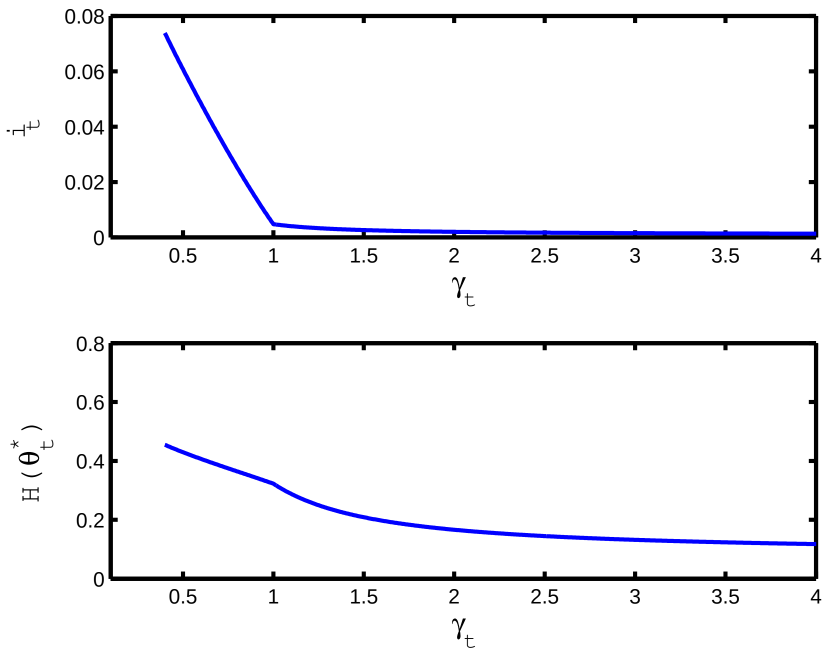

Figure 2: Effect of γ_t on i_t and $H(\theta_t^*)$, when $R_t = 0.4$

7 Conclusion

In this paper, I developed a model that explains how the short-term capital affects the probability of currency crisis. I found both analytically and numerically that the probability of crisis increases when the ratio of reserves to domestic currency denominated bond, which is the analogue of the ratio of reserves to short-term capital in the real economy, falls towards 1. The prediction was less clear-cut when this ratio was below 1, but the numerical analysis suggested that the probability of crisis will remain high in such case. These results are consistent with the existing literature that claims that the ratio of short-term capital to reserves is an important variable in predicting crisis.

In terms of methodology, I incorporated the global games approach into an environment similar to Obstfeld (1986). I endogenized the determination of some of the variables taken as exogenous in the standard global games model, and for other variables provided macroeconomic relations between them. The model illustrates one way of integrating global games models into conventional models of currency crises, which I believe will lead to a further progress in the analysis of currency crisis.

My model has a couple of interesting implications, which do not necessarily agree with the conventional wisdom.

First, contrary to the widely accepted view that blames the foreign-currency denominated short-term external debt as a source of currency crisis, the model suggests that the local-currency denominated short-term external debt, as well as the portfolio investments by foreigners, are no less harmful when they are excessive in size. This is because in order to sustain the fixed exchange rate regime, the government has to respond to sudden reversal of such forms of capital by running down foreign reserves. In my view, currency denomination of debt is not critical in the occurrence of crisis, although once a crisis has occurred foreign currency debt worsens the situation by aggravating the financial condition of local firms and financial institutions through the balance sheet effect. Despite using totally different approaches, this result resembles Chang and Velasco (2000), who claim that when the central bank acts as the lender of last resort under a fixed exchange rate regime, a banking crisis is avoided but is transformed into a balance-of-payment crisis. The policy implication is that under a currency peg, the government should prevent excessive inflows of mobile capital, regardless of the financial instruments used and the currency denomination, and/or increase foreign reserves to keep up with the capital inflows. In this respect, it is reassuring that policymakers now seem to be paying attention to the broad notion of "hot money" rather than just the short-term debt[17].

[17]See Edwards (2004) on the capital control in Chile in 1990s, and Aizenman, Lee, and Rhee (2004)

Second, it may be inappropriate to assess economic fundamentals separately from the ratio of reserves to short-term capital. As the conventional measures of fundamentals suggested that the Asian economies were relatively solid before the crisis, many economists abandoned the explanations of crisis based on fundamentals and shifted to accounts based on multiple equilibria and self-fulfilling expectations. Our analysis in Section 6 suggests, however, that it may have been the criteria with which the fundamentals were evaluated (θ_t^*), not the value of fundamentals per se (θ_t), that had shifted to force the economy into crisis. This tells us that we should not discard too easily the explanation based on fundamentals.

I wish to conclude by discussing the limitations of the paper and possible extensions.

I abstracted from the short-selling of local currency, as well as from the issue of contagion, both of which are important elements in an actual currency crisis. Incorporating these elements into the model may enable us to explain why a country like Malaysia, with relatively solid fundamentals and low ratio of short-term capital to reserves, was unable to escape the crisis.

I took the volume of local currency denominated bond B_t as exogenous. Endogenizing B_t by modelling the preferences of domestic agents (= the general public) and considering their intertemporal optimization problem is a challenging and promising extension, which is left for future research.

on the post-crisis reserve management in South Korea.

<Appendix A: Central Bank's Balance Sheet>

(Period t, before the attack)

R_t	$\bar{M}$
D_t	

(Period t+1, if government sustains the peg)

R_{t+1}	$\bar{M}$
D_{t+1}	
OA_t	

- OA_t refers to "other assets" and is equal to A_t, the size of attack in period t. This appears in the balance sheet as a result of sterilization of the attack. But with infinitely precise private signals, along the equilibrium path $OA_t = A_t = 0$ when the peg is sustained, since only agents with measure zero will participate in the attack in such case.

- Here $R_{t+1} = \bar{M} - D_{t+1} - OA_t = \bar{M} - D_{t+1} - A_t$, $D_{t+1} = \min\{\bar{D}\exp(-\theta_t), \bar{M}\}$ (recall (3)).

(Period t+1, if government abandons the peg)

(Case 1) $R_t > A_t$

R_{t+1}	$\bar{M}$
D_{t+1}	
OA_t	

- Here $R_{t+1} = R_t - A_t$, $OA_t = A_t$, $D_{t+1} = D_t$ (recall (3)).

(Case 2) $R_t \leq A_t$

D_{t+1}	$\bar{M}$
OA_t	

- Here $R_{t+1} = 0$, $OA_t = R_t$, $D_{t+1} = D_t$ (recall (3)).

<Appendix B: Proofs>

Proof of Proposition 3

The first step is to compute the probabilities $p(x_{it})$ and $q(x_{it})$.

Note that

$$q(x_{it}) = \Pr(\theta_t \leq \theta_t^* | x_{it}) = F(\theta_t^* - x_{it}) = 1 - F(x_{it} - \theta_t^*)$$

so

$$q(x_t^*) = F(\theta_t^* - x_t^*) = 1 - F(x_t^* - \theta_t^*) \tag{16}$$

Recall that $p(x_{it})$ is the probability, conditional on receiving x_{it} and attacking, that there will be a devaluation but the speculator does not manage to sell baht for dollars. Recall also that the probability that a speculator who attacked manages to sell baht for dollars equals 1 if $A_t \leq R_t$, and R_t/A_t otherwise. Now, A_t is given by

$$A_t(\theta_t) = B_t \Pr(x_i \leq x_t^* | \theta_t) = B_t F(x_t^* - \theta_t) \tag{17}$$

so $p(x_{it})$ depends critically on the relative size of B_t and R_t. To compute $p(x_t^*)$ and to solve for the equilibrium, I need to consider 3 different cases.

Case 1: $B_t \leq R_t$

In this case $A_t(\theta_t) = B_t F(x_t^* - \theta_t) \leq R_t$ for any θ_t. Thus the government always has sufficient reserves to offer to all speculators who attacked. This implies $p(x_{it}) = 0$ for any x_{it}, and in particular $p(x_t^*) = 0$.

Therefore from (16)

$$q(x_t^*) - p(x_t^*) = q(x_t^*) = 1 - F(x_t^* - \theta_t^*)$$

so that substituting into (11),

$$\{1 - \alpha(1 + i_t)\}\{1 - F(x_t^* - \theta_t^*)\} - c = i_t F(x_t^* - \theta_t^*)$$

which gives

$$F(x_t^* - \theta_t^*) = \frac{1 - \alpha(1 + i_t) - c}{(1 + i_t)(1 - \alpha)} \tag{18}$$

Therefore from (9)

$$\bar{D} \exp(-\theta_t^*) = \bar{M} - B_t F(x_t^* - \theta_t^*) = \bar{M} - B_t \frac{1 - \alpha(1 + i_t) - c}{(1 + i_t)(1 - \alpha)}$$

so using $\gamma_t = R_t/B_t$,

$$\theta_t^* = -\log[\frac{1}{\bar{D}}\{\bar{M} - \frac{R_t}{\gamma_t}\frac{1 - \alpha(1 + i_t) - c}{(1 + i_t)(1 - \alpha)}\}] \tag{19}$$

hence θ_t^* is uniquely determined given ν_t, the set of variables already determined in stage 1.

Now, since $B_t \leq R_t$, $\gamma_t \geq 1$ so that $\rho_t = \min\{1, \gamma_t\} = 1$. By substituting $\rho_t = 1$ into (12), the arbitrage condition in stage 1 is

$$H(\theta_t^*)(-c) + \{1 - H(\theta_t^*)\}i_t = 0$$

where the LHS is the expected return from holding baht bonds and the RHS is that from holding dollar. Thus,

$$c\frac{H(\theta_t^*)}{1 - H(\theta_t^*)} = i_t \tag{14}$$

(14) and (19) implicitly define $\{\theta_t^*, i_t\}$, from which I can compute x_t^* using (9). It is obvious from (14) that there is a one-to-one correspondence between θ_t^* and i_t, but I still need to examine the existence and uniqueness of a pair $\{\theta_t^*, i_t\}$ satisfying (10), (14) and (19). Notice from (19) that θ_t^* is decreasing in i_t. Thus the LHS of (14) is non-negative and decreasing in i_t, while the RHS is increasing in i_t and achieving the minimum of 0 at $i_t = 0$. This implies that there exists at most one i_t that satisfies the equilibrium conditions. To guarantee the existence of i_t that satisfies (10), I need a further assumption. I observe from (10) that the upper bound for i_t is given by $\bar{\imath} = (1-c)/\alpha - 1$, and from (19) that this corresponds to the case $\theta_t^* = \underline{\theta}$. Then, recalling the argument on (14) above, the existence of i_t that satisfies (10), (14) and (19) is guaranteed if the LHS of (14) is strictly less than the RHS as $i_t \to \bar{\imath}$ and $\theta_t^* \to \underline{\theta}$. This is equivalent to

$$H(\underline{\theta}) < \frac{1 - (\alpha + c)}{(1 - \alpha)(1 - c)} \tag{13}$$

that I assumed in the main text. Thus under (13) there exists a unique i_t and a corresponding pair $\{\theta_t^*, x_t^*\}$ satisfying (10), (14) and (19), so that there exists a unique equilibrium.

Case 2: $B_t > R_t > A_t(\theta_t^*)$

This condition implies that while $B_t > R_t$ and hence $A_t(\theta_t) > R_t$ for some θ_t, R_t exceeds A_t at θ_t^*. Inequality $B_t > A_t(\theta_t^*)$ may appear puzzling as it seems to contradict my claim in the text that all speculators attack when there is devaluation. But notice that $A_t(\theta_t^*)$ is the size of attack when $\theta_t = \theta_t^*$, which is a zero probability event. For all $\theta_t < \theta_t^*$, $A_t(\theta_t) = B_t$ and for all $\theta_t > \theta_t^*$, $A_t(\theta_t) = 0$.

Now, as $A_t(\theta_t)$ is decreasing in θ_t,there exists $\tilde{\theta}_t < \theta_t^*$ such that

$$R_t = A_t(\tilde{\theta}_t) = B_t \Pr(x_{it} \leq x_t^* | \tilde{\theta}_t) = B_t F(x_t^* - \tilde{\theta}_t) \tag{20}$$

Then

$$
\begin{aligned}
p(x_t^*) &= \int_{-\infty}^{\tilde{\theta}_t} \frac{A_t(\theta_t) - R_t}{A_t(\theta_t)} f(\theta_t - x_t^*) d\theta_t \\
&= \Pr(\theta_t \leq \tilde{\theta}_t | x_t^*) - \int_{-\infty}^{\tilde{\theta}_t} \frac{R_t}{A_t(\theta_t)} f(\theta_t - x_t^*) d\theta_t \\
&= 1 - F(x_t^* - \tilde{\theta}_t) - \frac{R_t}{B_t} \int_{-\infty}^{\tilde{\theta}_t} \frac{f(\theta_t - x_t^*)}{1 - F(\theta_t - x_t^*)} d\theta_t \\
&= 1 - \frac{R_t}{B_t} + \frac{R_t}{B_t} [\log\{1 - F(\theta_t - x_t^*)\}]_{-\infty}^{\tilde{\theta}_t} \\
&= 1 - \frac{R_t}{B_t} + \frac{R_t}{B_t} \log F(x_t^* - \tilde{\theta}_t) \\
&= 1 - \gamma_t(1 - \log \gamma_t) \qquad (21)
\end{aligned}
$$

where I used the definition of $p(\cdot)$ as well as (17) and (20).

Now, from (11) and (16)

$$
\{1 - \alpha(1 + i_t) - c\} p(x_t^*) + c = \{1 - \alpha(1 + i_t)\} - (1 - \alpha)(1 + i_t) F(x_t^* - \theta_t^*)
$$

so that using (21)

$$
\begin{aligned}
F(x_t^* - \theta_t^*) &= \frac{\{1 - \alpha(1 + i_t) - c\}\{1 - p(x_t^*)\}}{(1 - \alpha)(1 + i_t)} \\
&= \frac{\{1 - \alpha(1 + i_t) - c\} \gamma_t (1 - \log \gamma_t)}{(1 - \alpha)(1 + i_t)} \qquad (22)
\end{aligned}
$$

Therefore from (9),

$$
\bar{D} \exp(-\theta_t^*) = \bar{M} - \frac{R_t}{\gamma_t} \frac{\{1 - \alpha(1 + i_t) - c\} \gamma_t (1 - \log \gamma_t)}{(1 - \alpha)(1 + i_t)}
$$

and so

$$
\theta_t^* = -\log[\frac{1}{\bar{D}} \{\bar{M} - \frac{R_t \{1 - \alpha(1 + i_t) - c\}(1 - \log \gamma_t)}{(1 - \alpha)(1 + i_t)}\}] \qquad (23)
$$

Now, since $B_t > R_t$, $\gamma_t < 1$ so that $\rho_t = \min\{1, \gamma_t\} = \gamma_t$. By substituting $\rho_t = \gamma_t$ into (12), the stage 1 condition becomes

$$
[\{\alpha(1 + i_t) - 1\}(1 - \gamma_t) - c\gamma_t] H(\theta_t^*) + \{1 - H(\theta_t^*)\} i_t = 0
$$

so that

$$
\frac{H(\theta_t^*)}{1 - H(\theta_t^*)} = \frac{i_t}{\{1 - \alpha(1 + i_t)\} - \gamma_t \{1 - \alpha(1 + i_t) - c\}} \qquad (15)
$$

(15) and (23) implicitly define $\{\theta_t^*, i_t\}$. Again, I can prove the existence and uniqueness of such pair, satisfying the additional restriction (10), as follows. From (23), θ_t^* is decreasing in i_t. So in (15), the LHS is non-negative and decreasing in i_t. The denominator of the RHS can be easily confirmed to be decreasing in i_t, so that the RHS is increasing in i_t and that it takes the minimum of 0 at $i_t = 0$. Moreover, at $i_t = \bar{\imath}$ the RHS is equal to $\bar{\imath}/c$, which leads to (14), the same expression as in Case 1. Furthermore, (23) again implies that $\theta_t^* \to \underline{\theta}$ when $i_t \to \bar{\imath}$. Therefore, again under (13) there exists a unique triple $\{\theta_t^*, x_t^*, i_t\}$ that satisfies the equilibrium conditions.

Case 3: $B_t \geq A_t(\theta_t^*) \geq R_t$

This time, $A_t(\theta_t) \geq R_t$ for all $\theta_t \leq \theta_t^*$. Then,

$$
\begin{aligned}
p(x_t^*) &= \int_{-\infty}^{\theta_t^*} \frac{A_t(\theta_t) - R_t}{A_t(\theta_t)} f(\theta_t - x_t^*) d\theta_t \\
&= \Pr(\theta_t \leq \theta_t^* | x_t^*) - \int_{-\infty}^{\theta_t^*} \frac{R_t}{A_t(\theta_t)} f(\theta_t - x_t^*) d\theta_t \\
&= 1 - F(x_t^* - \theta_t^*) - \frac{R_t}{B_t} \int_{-\infty}^{\theta_t^*} \frac{f(\theta_t - x_t^*)}{1 - F(\theta_t - x_t^*)} d\theta_t \\
&= 1 - F(x_t^* - \theta_t^*) + \gamma_t [\log\{1 - F(\theta_t - x_t^*)\}]_{-\infty}^{\theta_t^*} \\
&= 1 - F(x_t^* - \theta_t^*) + \gamma_t \log F(x_t^* - \theta_t^*)
\end{aligned}
$$

so that from (16)

$$q(x_t^*) - p(x_t^*) = -\gamma_t \log F(x_t^* - \theta_t^*)$$

Substituting this into (11),

$$-\{1 - \alpha(1 + i_t)\}\gamma_t \log F(x_t^* - \theta_t^*) = c\{F(x_t^* - \theta_t^*) - \gamma_t \log F(x_t^* - \theta_t^*)\} + i_t F(x_t^* - \theta_t^*)$$

which implies

$$-\{1 - \alpha(1 + i_t) - c\}\gamma_t \log F(x_t^* - \theta_t^*) = (c + i_t) F(x_t^* - \theta_t^*) \tag{24}$$

Now, since $B_t \geq R_t$, $\gamma_t \leq 1$ so that $\rho_t = \min\{1, \gamma_t\} = \gamma_t$. So by substituting $\rho_t = \gamma_t$ into (12), again I find the stage 1 condition to be (15).

(9), (15) and (24) implicitly define $\{\theta_t^*, i_t\}$. Once again, I can prove the existence and uniqueness of such pair, satisfying the restriction (10), as follows. Observe from (9) that θ_t^* is increasing in $x_t^* - \theta_t^*$. (24) then implies that θ_t^* is decreasing in i_t, because the LHS of (24) is decreasing in i_t (as $\log F(x_t^* - \theta_t^*) < 0$) and the RHS is increasing in i_t, so that an increase in i_t requires a fall in $x_t^* - \theta_t^*$, and hence a fall in θ_t^*. Hence in (15), the LHS is decreasing in i_t and the RHS is increasing in i_t as I showed for Case 2. Moreover, when $i_t \to \bar{\imath}$, (24) implies $F(x_t^* - \theta_t^*) \to 0$, and from (9) this implies $\theta_t \to \underline{\theta}$. Therefore a similar argument as in the proof for Case 2 implies that under (13) there exists a unique triple $\{\theta_t^*, x_t^*, i_t\}$ that satisfies the equilibrium conditions.

Proof of Proposition 4

I provide proofs for each of the cases 1-3 described in the proof of proposition 3.

Case 1

Suppose γ_t falls and i_t also falls or remains constant. (19) implies θ_t^* must rise, but (14) implies θ_t^* must either fall or remain constant. This is a contradiction and so i_t must rise, and from (14), θ_t^* must rise as well.

Case 2

Suppose γ_t falls, and i_t also falls or remains constant. (23) implies θ_t^* must rise, but (15) implies θ_t^* must fall since $1 - \alpha(1 + i_t) - c > 0$ from (10). This is a contradiction and so i_t must rise. Since the effect on θ_t^* of a decrease in γ_t and an increase in i_t cancels each other, the overall effect on θ_t^* is ambiguous.

Case 3

Rewriting (9) as

$$F(x_t^* - \theta_t^*) = \frac{\gamma_t\{\bar{M} - \bar{D}\exp(-\theta_t^*)\}}{R_t}$$

, substituting into (24) and cancelling out terms, we obtain

$$-\{1 - \alpha(1 + i_t) - c\} \log \frac{\gamma_t\{\bar{M} - \bar{D}\exp(-\theta_t^*)\}}{R_t} = (c + i_t)\frac{\{\bar{M} - \bar{D}\exp(-\theta_t^*)\}}{R_t} \tag{25}$$

Now, suppose γ_t falls, and i_t also falls or remains constant. Since $1 - \alpha(1 + i_t) - c > 0$ from (10), this increases the LHS of (25) and decreases its RHS, so θ_t^* must rise to restore equality. But (15) implies θ_t^* must fall. This is a contradiction and so i_t must rise. Since the effect on θ_t^* of a decrease in γ_t and an increase in i_t cancel each other, the overall effect on θ_t^* is ambiguous.

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