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Abstract

This paper argues that the recent Asian currency crisis was caused by large *prospective* deficits associated with implicit bailout guarantees to failing banking systems. We articulate this view using a simple dynamic general equilibrium model whose key feature is that a speculative attack is inevitable once the present value of future government deficits rises. This is true regardless of the government's foreign reserve position or the initial level of its debt. While the government cannot prevent a speculative attack, it can affect its timing. The longer the delay, the higher inflation will be under flexible exchange rates. We present empirical evidence in support of the three key assumptions in our model: (i) foreign reserves did not play a special role in the timing of the attack, (ii) large losses in the banking sector were associated with large increases in governments' prospective deficits, and (iii) the public knew that banks were in trouble before the currency crises.

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1. Introduction

Recent events in Asia have renewed interest in the causes and consequences of speculative attacks on fixed exchange rate regimes. The explanation preferred by policy makers in Asia is that the currency crisis was a self fulfilling prophecy: it happened because speculators thought it was going to happen.[1] Not surprisingly, proponents of this view argue that the International Monetary Fund should provide resources to fend off such predatory attacks and help prey countries recover from them. Multiple equilibrium models of currency crises can be used to rationalize this interpretation of recent events in Asia.[2]

The most natural alternative explanation of the Asian currency crisis is that it reflected profligate fiscal policy: ongoing fiscal deficits led to sustained reserve losses and to the eventual abandonment of fixed exchange rates. This is the standard view of speculative attacks in 'first generation' models of currency crises. To articulate this view, the speculative attacks literature focuses on two types of policy experiments: (i) an increase in the fiscal deficit that must eventually be monetized;[3] and (ii) an exchange rate peg that is unsustainable because it reduces the government's seignorage revenues without compensating fiscal adjustments.[4] Both experiments imply that the collapse of a fixed exchange rate is preceded by ongoing deficits and rising debt levels. This has motivated a large body of empirical work aimed at predicting currency crises on the basis of fiscal deficits and other macroeconomic aggregates.[5]

The standard explanation for speculative attacks has an obvious shortcom-

[1] Radelet and Sachs (1998) also take this perspective in addition to arguing that the actions of the IMF exacerbated the crises.

[2] See for example Obstfeld (1986a, 1996), and Sachs, Tornell and Velasco (1996).

[3] See for example Krugman (1979), Flood and Garber (1984), Obstfeld (1986b), and Calvo and Végh (1998).

[4] See for example Calvo (1987) and Wijnbergen (1991).

[5] For a recent example see Kaminsky, Lizondo and Reinhart (1996).

ing when applied to Asia: governments of the crisis countries (Indonesia, Korea, Malaysia, the Philippines, and Thailand) were running either surpluses or small deficits and had substantial foreign exchange reserves. Indeed, when they abandoned fixed exchange rates, all had more than enough reserves to buy back the monetary base, and virtually all of M1 (see Section 6).

This evidence notwithstanding, we argue that the Asian currency crises were caused by fundamentals: large *prospective* deficits associated with implicit bailout guarantees to failing banking systems. The expectation that these future deficits would (at least in part) be financed by seignorage revenues led to a collapse of the fixed exchange rate regimes in Asia.[6] Of course market participants could have believed that governments would fund their obligations by raising taxes or lower expenditures. But is this credible? In our view it is not. The state of the world in which financial intermediaries would suffer grievous losses is exactly the state of the world in which current and prospective real output and tax revenues would fall. While not modeled in this paper, raising distortionary taxes or lowering government purchases under those circumstances could well be politically unacceptable or socially undesirable relative to the alternative: monetizing the prospective deficits and receiving aid from international agencies like the International Monetary Fund. But this alternative is incompatible with maintaining fixed exchange rates. In this sense, our view of recent events in Asia is related to 'second generation' speculative attack models which stress that governments consider the costs and benefits of abandoning fixed exchange rate regimes.[7]

To articulate our view of the Asian currency crisis, sections 2 and 3 of the paper study the dynamics of a speculative attack in a variant of the perfect fore-

[6] Corsetti, Pesenti and Roubini (1998a) also discuss the possible role played by expectations of future seignorage revenues in the Asian currency crises. They do so under the assumption that the affected countries faced a limit on the ratio of total private foreign debt to government reserves.

[7] See Obstfeld (1994) and references therein.

sight small open economy model considered by Calvo (1987). The key difference between our model and Calvo's is the nature of the monetary experiment that we analyze. To capture the effect of a prospective deficit on a fixed exchange rate regime we assume that at time 0 agents receive information that future deficits will be larger than they originally believed. The government's intertemporal budget constraint implies that a speculative attack is inevitable. This is true regardless of the government's initial level of foreign reserves or its initial debt position. Once the government learns that the present value of future deficits has risen, the only choices left to it are when and how to raise the seignorage revenues required to meet its intertemporal budget constraint.

We analyze the date of a speculative attack, i.e. the date at which the economy switches from a fixed to a floating exchange rate regime, under two assumptions. First, we assume that the government follows a threshold rule according to which the fixed exchange rate regime is abandoned in the first period that net government debt reaches some exogenous upper bound. Second, we consider the case in which the only constraint faced by the government is its intertemporal budget constraint. In both cases we depart from the speculative attack literature by distinguishing between the time of the speculative attack and the time at which the government implements the new monetary policy required to balance its intertemporal budget constraint. Disentangling these two events considerably enriches the dynamic implications of the model.

Using versions of the model calibrated to Korean and Thai data, we show in Section 4 that the speculative attack occurs *after* the information about higher future deficits arrives but *before* the new monetary policy is implemented. An econometrician looking at the data would see an exchange rate crisis - but he would not see large deficits, low levels of reserves, high growth rates of money or high rates of inflation prior to the speculative attack. The econometrician could well conclude that the attack was a multiple equilibrium phenomenon. In fact it reflects fundamentals: high prospective deficits.

While the government cannot prevent a speculative attack, it can affect its timing by borrowing. The cost of delaying is higher future inflation once the speculative attack takes place. This raises the issue of what monetary policy the government should pursue. Section 5 shows that in our simple model, the optimal policy is to abandon fixed exchange rates as soon as information about higher prospective deficits arrives. Since this result reflects, in part, the absence of nominal rigidities in our model, it serves primarily to highlight the costs of delaying a speculative attack. In reality, these costs must be counterbalanced against the benefits (if any) of delay.

Section 6 offers empirical evidence in support of the three key assumptions in our model: (i) foreign reserves do not play a special role in the timing of the attack; (ii) large losses in the banking sector are associated with increases in governments' prospective deficits; and (iii) the public knows that banks are in trouble before the exchange rate crisis occurs. To address (i), we examine the behavior of foreign exchange reserves prior to the crises. To address (ii) we use information on pre and post currency crisis loan default rates to generate rough estimates of governments' total implicit liabilities to the financial sector. To address (iii) we construct and analyze stock market based measures of the value of financial and nonfinancial sectors in the crisis countries. We find strong evidence that in Korea, Thailand, and to a lesser extent Malaysia and the Philippines, the value of the financial sector had been declining, in both absolute and relative terms, well before their currency crises. Coupled with the institutional information summarized by Corsetti, Pesenti and Roubini (1998), this constitutes strong evidence in favor of assumption (iii). Finally, Section 7 presents concluding remarks and discusses some shortcomings of our analysis.

2. A Benchmark Model

In this Section we describe a continuous time, perfect foresight endowment economy populated by an infinitely lived representative agent and a government. All agents, including the government, have access to international capital markets. The government faces a standard present value budget constraint and finances expenditures through lump sum taxes, seignorage revenues and borrowing.

There is a single consumption good in the economy and no barriers to trade, so that purchasing power parity holds:

$$P_t = S_t P_t^*. \tag{2.1}$$

Here P_t and P_t^* denote the domestic and foreign price level respectively, while S_t denotes the exchange rate (defined as units of domestic currency per unit of foreign currency). For convenience we assume that $P_t^* = 1$.

2.1. The Representative Agent

The representative agent maximizes lifetime utility, defined as:

$$U = \int_0^\infty \frac{c_t^{1-\sigma} - 1}{1-\sigma} e^{-\rho t} dt. \tag{2.2}$$

Here c_t denotes consumption, ρ is a strictly positive discount factor, and $\sigma > 0$ is the inverse of the elasticity of intertemporal substitution. The representative agent can borrow and lend in international capital markets at a constant real interest rate r. To eliminate trends in the current account we assume that $r = \rho$. The representative agent's flow budget constraint is given by:

$$\begin{array}{lll} \Delta b_t + \Delta d_t = & -\Delta m_t & \text{if } t \in I, \\ \dot{b}_t + \dot{d}_t = & y + r(b_t + d_t) + v - c_t - \tau - \pi_t m_t - \dot{m}_t & \text{if } t \notin I. \end{array} \tag{2.3}$$

Here b_t and d_t denote real domestic government debt and net foreign assets held by the representative agent, respectively, y denotes the constant exogenous endowment of output, v denotes the constant level of lump sum transfers from the government, τ denotes the constant level of lump sum taxes, and π_t is the inflation rate. The variable m_t represents real money balances, defined as $m_t = M_t/P_t$, where M_t denotes nominal money holdings. Throughout the paper $\dot{x}_t$ denotes $\frac{dx}{dt}$. Constraint (2.3) takes into account the possibility of discrete changes in m_t, d_t, and b_t at a finite set of points in time, I. The flow budget constraint, together with the conditions $\lim_{t\to\infty} e^{-rt}b_t = \lim_{t\to\infty} e^{-rt}d_t = 0$, implies the following intertemporal budget constraint for the household:

$$b_0 + d_0 = \int_0^\infty e^{-rt}[c_t + \tau - y - v + \pi_t m_t + \dot{m}_t]dt + \sum_{i\in I} e^{-ri}\Delta m_i. \tag{2.4}$$

According to (2.4), the present value of the representative agent's expenditures, inclusive of taxes and transfers, must equal the present value of endowment income plus initial net assets.

Finally, the agent faces the following continuous time analogue to a cash in advance constraint on consumption purchases:

$$c_t \leq m_t. \tag{2.5}$$

Since the nominal interest rate is positive in all the scenarios that we consider, (2.5) holds with strict equality.

The problem of the representative household is to maximize (2.2) subject to (2.3) and (2.5) by choice of time paths for c_t, m_t, b_t and d_t, subject to a known time path for P_t. In the Appendix we show that the first order conditions for this problem imply:

$$c_t^{-\sigma} = \lambda(1 + r + \pi_t), \tag{2.6}$$

where λ is the current-valued Lagrange multiplier associated with (2.3). Equation (2.6) will play a central role in our derivations.

2.2. The Government

The government purchases goods, g, makes transfer payments, v, levies lump sum taxes, τ, and may borrow at the real interest rate r. In addition, the government can print money. The government's flow budget constraint is given by:

$$\begin{array}{ll} \Delta f_t - \Delta b_t = \Delta m_t & \text{if } t \in I \\ \dot{f}_t - \dot{b}_t = \tau - g - v + r(f_t - b_t) + \dot{m}_t + \pi_t m_t & \text{if } t \notin I. \end{array} \tag{2.7}$$

In this equation f_t represents the government's real net foreign assets.[8] The flow budget constraint together with the conditions $\lim_{t\to\infty} e^{-rt} f_t = \lim_{t\to\infty} e^{-rt} b_t = 0$, imply the following intertemporal budget constraint for the government:

$$b_0 - f_0 = \int_0^\infty e^{-rt}(\tau - g - v + \dot{m}_t + \pi_t m_t)dt + \sum_{i\in I} e^{-ri}\Delta m_i. \tag{2.8}$$

According to this condition, the present value of future surpluses including the value of seignorage revenues must equal the value of the government's net initial debt.

2.3. A Competitive Equilibrium

A competitive perfect foresight equilibrium for this economy is a set of allocations c_t, m_t, $b_t + d_t$, a set of prices P_t and S_t, and a set of paths for the fiscal variables, τ_t, g_t and v_t, such that the following conditions hold: (i) c_t, m_t, $b_t + d_t$ solve the household's problem given the paths for P_t, S_t, τ_t and v_t (ii) the government's

[8]It is common in the literature to divide f_t into two components: $f_t = f_t^r + f_t^{nr}$,where f_t^r and f_t^{nr} denote the government's net foreign exchange reserves and the remaining net foreign assets in the government portfolio, respectively. Note that if f_t and b_t yield the same rate of return, they enter the government's flow budget constraint symmetrically. So given values for τ and g, and a path for m_t the model can only determine the time path of the government's total debt: $b_t - f_t$.

intertemporal budget constraint (2.8) holds; and (iii) $S_t = P_t$ for all t. Note that this definition applies to an economy operating under either a fixed or a flexible exchange rate equilibrium.

2.4. A Sustainable Fixed Exchange Rate Regime

In a sustainable fixed exchange rate regime agents anticipate zero inflation and (2.6) reduces to:

$$c^{-\sigma} = \lambda(1+r), \tag{2.9}$$

implying that consumption is constant over time. The budget constraint (2.4) implies that:

$$c = r(b_0 + d_0) + r\int_0^\infty e^{-rt}(y + v - \tau)dt. \tag{2.10}$$

In this equilibrium, the money supply is endogenous. Purchasing power parity (2.1), and the cash in advance constraint (2.5) imply that the equilibrium level of the money supply is:

$$M = Sc. \tag{2.11}$$

So in a sustainable fixed exchange rate regime, the money supply is constant and the present value of current and future real surpluses equals the initial real net liabilities of the government: no seignorage revenues are available to the government. In our model economy, seignorage revenues can be generated *only* if the country abandons the fixed exchange rate regime.[9] In a fixed exchange rate regime, the government's intertemporal budget constraint (2.8) simplifies to:

$$b_0 - f_0 = \int_0^\infty e^{-rt}(\tau - g - v)dt. \tag{2.12}$$

[9] If there were growth in P^* or in consumption, the government would collect some seignorage revenue under fixed exchange rates.

3. Exchange Rate Crises

Suppose that at time 0 agents learn that there has been an increase, ϕ, in the present value of the deficit due to a rise in future transfer payments. Specifically, we assume that transfers increase permanently after date T':

$$\begin{cases} v_t = v & \text{for } 0 \leq t < T', \\ v_t \geq v & \text{for } t \geq T'. \end{cases}$$

To simplify we suppose that taxes and government purchases remain constant. The increase in the government deficit is then given by:

$$\phi = \int_{T'}^{\infty} e^{-rt}(v_t - v)dt.$$

The government's new budget constraint is:

$$\begin{aligned} b_0 - f_0 &= \int_0^{\infty} e^{-rt}(\tau - g - v)dt \\ &\quad -\phi + \int_0^{\infty} e^{-rt}(\dot{m}_t + \pi_t m_t)dt + \sum_{i \in I} e^{-ri}\Delta m_i. \end{aligned} \tag{3.1}$$

Using equation (2.12) this can be rewritten as:

$$\phi = \int_0^{\infty} e^{-rt}(\dot{m}_t + \pi_t m_t)dt + \sum_{i \in I} e^{-ri}\Delta m_i. \tag{3.2}$$

Since the government must collect seignorage revenues it must, at some point, abandon the fixed exchange regime.[10]

For simplicity we assume that the government will raise the seignorage revenues to balance its intertemporal budget constraint by a combination of a one time

[10] To see this suppose that the economy never reverted to a flexible exchange rate regime. Expected inflation would then be zero and the demand for real balances would remain constant over time. What happens if the government prints money to finance the deficit? Since there is no demand for this money, agents will simply trade it for a different asset. Regardless of whether this asset is domestic bonds, foreign bonds or foreign reserves, the nominal money supply will revert to its initial value. This means that no seignorage revenue has been raised by the government.

increase in the stock of money at time T equal to ΔM_T and growth in the money supply at rate μ from period T on. We denote the time period in which the government abandons the fixed exchange rate regime by t^*. To determine t^*, we must make assumptions regarding the government's rule for abandoning the fixed exchange rate regime.

3.1. A Threshold Rule For Total Debt

In this section we consider a rule that is motivated by standard assumptions in the speculative attack literature. We assume that the government follows a threshold rule: it abandons the fixed exchange rate regime in the first period t^* when $b_t - f_t$ reaches Ψ.

In the literature this threshold rule is typically specialized to apply only to the foreign exchange reserves of the government.[11] This requires the additional assumption that the only component of the government's portfolio that changes over time is the central bank's foreign reserves. Then the threshold rule on net government debt is transformed into a threshold rule for reserves so that the government abandons the fixed exchange rate regime when reserves reach a certain lower bound.

3.2. Timing

To analyze how the economy reacts to the information about higher prospective deficits it is useful to distinguish between four intervals of time.

Time Interval 1: $0 < t < t^*$. This is the time interval after information about the higher future deficits has arrived but before the collapse of the fixed exchange

[11] See for example Krugman (1978) and Obstfeld and Rogoff (1998). Exceptions to this assumption include Drazen and Helpman (1987, 1988) and Wijnbergen (1993).

rate regime. We denote the value of consumption, real balances and nominal money supply in this interval of time by $\bar{c}$, $\bar{m}$, and $\bar{M}$, respectively.

Time Interval 2: $t^* \leq t < T$. This is the time interval between the collapse of the fixed exchange rate regime and the new steady state flexible exchange rate equilibrium. We denote all variables that are time varying during this regime with a subscript t (e.g. c_t is consumption). Variables which are constant during this time interval are denoted with a superscript $*$.

Time Interval 3: $T \leq t < T'$. This is the interval of time after the new monetary policy has been implemented but before the new level of transfers has been adopted. We denote all variables that are constant during this time interval with a lower bar.

Time Interval 4: $t \geq T'$. This is the time interval after which the new transfer policy is implemented. As with time interval 3, we represent all variables that are constant during this interval with a lower bar.

3.3. Computing the Time of the Speculative Attack

In order to solve for the time of the speculative attack, we must compute the model's dynamic, perfect foresight equilibrium. In this section, we describe the key equations that allow us to do this.

At time 0, when information about the new fiscal deficit arrives, the representative agent re-optimizes his consumption plan. The value of the Lagrange multiplier associated with his intertemporal budget constraint jumps from λ to $\tilde{\lambda}$. The consumption optimization condition for time interval 1 is,

$$(\bar{c})^{-\sigma} = \tilde{\lambda}(1+r), \text{ for } 0 < t < t^*. \tag{3.3}$$

Since the government rebates the seignorage revenues in the form of lump sum transfers, the present value of the resources available to the consumer does not change with the arrival of new information at time zero. However, given that the rate of inflation will no longer be constant, consumption at time 0 will, in general, be different from c. The cash in advance constraint is binding, so the time 0 value of real balances must also jump from $m = c$ to $\bar{m} = \bar{c}$. Since $P_t = S$ before t^* the change in real balances is accomplished by a change in the nominal money supply from M to $\bar{M}$, where $\bar{M}$ is given by:

$$\bar{M} = S\bar{c}. \tag{3.4}$$

The change in the money supply occurs as private agents adjust the amount of domestic money, government debt and foreign reserves that they hold. For example if $\bar{M} > M$, agents increase real balances by selling government bonds, b_t, or foreign assets, d_t for domestic money.

In the second time interval, the first order condition for consumption is:

$$c_t^{-\sigma} = \tilde{\lambda}(1 + r + \frac{\dot{P}_t}{P_t}), \text{ for } t^* < t < T. \tag{3.5}$$

Since inflation jumps discretely at t^*, so does consumption. The path for S_t must be continuous, so that $P_{t^*} = S$. Otherwise, given our assumption of perfect foresight, there would be arbitrage opportunities associated with trading the currency just before and after t^*.

By assumption, net government debt at time t^* rises to Ψ:

$$b_{t^*} - f_{t^*} = \Psi = \frac{(\bar{M} - M^*)}{S} + [b_0 - f_0 + \frac{M - \bar{M}}{S}]e^{rt^*} + \int_0^{t^*} (g + v - \tau)e^{rt} dt. \tag{3.6}$$

The last two terms of this equation represent the accumulated government debt up to t^*. The term $(M - \bar{M})/S$ represents the jump in the value of the debt that takes place at time zero. The term $(\bar{M} - M^*)/S$ represents the discrete, positive increase in government debt that takes place at t^*. This increase reflects the fact that agents trade domestic money, at the exchange rate S, for either government bonds or foreign assets.

Equations (3.3) and (3.5) together with the cash in advance constraint imply:

$$\left(\frac{M^*}{P_t}\right)^{-\sigma} = \frac{\bar{c}^{-\sigma}}{1+r}(1+r+\frac{dP_t}{dt}\frac{1}{P_t}). \tag{3.7}$$

This differential equation in P_t can be written as:

$$\begin{aligned}\frac{dP_t}{dt} &= aP_t^{1+\sigma} - bP_t, \\ a &= (M^*)^{-\sigma}(1+r)\bar{c}^{\sigma}, \\ b &= (1+r).\end{aligned} \tag{3.8}$$

The solution to (3.8) is:

$$P_t = \left[\frac{b}{a - e^{(t-\gamma)\sigma b}}\right]^{1/\sigma}. \tag{3.9}$$

Here γ is a constant of integration determined by the condition that P_t must be continuous at t^*. This requires that $P_{t^*} = S$ so (3.9) can be used to express γ as a function of t^*:

$$\gamma = t^* - \frac{1}{\sigma b}\ln(a - bS^{-\sigma}). \tag{3.10}$$

Equation (3.9), the cash in advance constraint at time T, and the continuity of the price level at T (required to prevent arbitrage opportunities) imply that:

$$P_T = M_T/\underline{c} = \left[\frac{b}{a - e^{(T-\gamma)\sigma b}}\right]^{1/\sigma}. \tag{3.11}$$

The level of consumption in the third time interval, which we denote by $\underline{c}$, is determined by the condition:

$$\underline{c}^{-\sigma} = \tilde{\lambda}(1+r+\mu), \text{ for } t \geq T. \tag{3.12}$$

Solving equation (3.11) for γ and using equation (3.10) we find:

$$t^* = T - \frac{1}{\sigma b} \ln \frac{a - bP_T^{-\sigma}}{a - bS^{-\sigma}}. \tag{3.13}$$

The value of t^* depends on the magnitude of the deficit being financed (ϕ), the monetary policy used to finance it, and the debt threshold Ψ. Since the government increases the money supply at time T, P_T will, in general, be greater than S. This suggests that $t^* < T$, that is, the attack takes place before the new monetary policy is implemented. In fact this is the case that arises in the calibrated versions of our model economy. However, there are two other cases to consider: $t^* = 0$, and $t^* > T$.[12]

The first case, $t^* = 0$, arises when M_T is large enough that the rate of inflation at time zero is higher than μ. The relatively high rate of inflation at time 0 induces agents to lower their consumption thus creating a fall in money demand and a rise in government debt. If the rise in debt is large enough to trigger the threshold rule then a speculative attack occurs immediately. The exchange rate will, in general, be discontinuous at time 0. See Subsection 4.3 for further discussion.

The second case, $t^* > T$, occurs for large values of Ψ. The exchange rate is still fixed at T and the endogenous level of the money supply is equal to $\bar{M}$. With a constant money supply no seignorage revenues are collected at T. Even though the government prints money and buys back government bonds, the money supply remains unaffected. This is because private agents reverse the effects of the open market operation by trading money for bonds. The money supply only changes at t^*, at which point it drops to $M^* = \underline{c}S$. Thereafter the growth rate of the money supply and the rate of inflation are both equal to μ. The time of the speculative attack is determined by the requirement that the government's intertemporal budget constraint (2.8) holds.

[12] Equation (3.13) is only valid when $0 < t^* < T$.

The final step in computing t^* is to ensure that $\bar{c}$ is consistent with the household's budget constraint, (2.4) and that monetary policy raises sufficient revenues to balance the government's budget constraint:[13]

$$\begin{aligned} b_0 - f_0 &= \frac{\bar{M} - M}{S} + \int_0^\infty e^{-rt}(\tau - g - v_t)dt + \\ & \frac{M^* - \bar{M}}{S} e^{-rt^*} + \\ & + \int_T^\infty e^{-rt}(\mu \underline{c})dt + (\underline{c} - c_T)e^{-rT}. \end{aligned} \tag{3.14}$$

The term $(\underline{c} - c_T)$ represents the adjustment in real balances that takes place at time T in response to the discontinuous decline in inflation to its new level, μ.

It is evident from (3.14) that there is a continuum of (M_T, μ) combinations that satisfy the government's budget constraint. If we fix M_T we can then solve for the values of $\bar{c}$ and μ that simultaneously solve (2.4) and (3.2). Proceeding analogously we can fix μ and solve for $\bar{c}$ and M_T. Since it is not possible to carry out these steps analytically we now turn to calibrated versions of the model.

4. Numerical Experiments

Here we study the determinants of speculative attacks in versions of our the model that have been calibrated using Korean and Thai data.

4.1. Model Calibration

Table 1 summarizes the parameter values of our benchmark models. Throughout we use 1996 as the baseline period for time series that are sampled at annual

[13] The seignorage collected between time t^* and time T, $\int_{t^*}^T e^{-rt}(\dot{m}_t + \pi_t m_t)dt$ was omitted from this equation because it is equal to zero. This follows from the fact that $\dot{M}_t = 0$ during this interval of time and from the cash in advance constraint, $M^* = S_t c_t$.

frequencies. In addition we normalize both output and the time 0 exchange rate, S, to be one.

Calibrating the Model Using Korea Data

We begin by discussing the debt and threshold rule parameters b_0, f_0, d_0, ϕ, and Ψ. The domestic and foreign debt levels of the public sector in our model were calibrated using the consolidated debt levels of the Korean government and central bank. The Korean Ministry of Finance (MOFE) reports that the level of total government and public sector bonds outstanding at the end of December 1996 was equal to approximately 37.4 trillion won.[14] According to the International Financial Statistics (IFS) of the International Monetary Fund (IMF), the Bank of Korea held claims on the government equal to 2 trillion won as of the end of December 1996. To avoid double counting, we subtracted this number from the reported level of total government and public sector bonds. The IFS also reports that the Bank of Korea had net domestic liabilities (excluding those vis-a-vis the government, official entities and base money) of 4.7 trillion won. Based on this evidence, we conclude that consolidated government domestic liabilities equaled roughly $37.4-2+4.7 = 40.1$ trillion won, or 10.3 percent of 1996 GDP. Accordingly we set $b_0 = 0.103$.

The Korea Institute for International Economic Policy (KIEP) estimated that the foreign debt of the public sector in June 1997 was equal to 2.0 trillion won.[15] According to the IFS, the value of the central bank's net foreign assets was approximately 28.0 trillion won. This suggests that the overall net foreign assets of the consolidated public sector was equal to roughly 26.0 trillion won or 6.7 percent of 1996 GDP. We set $f_0 = 0.067$ and $b_0 - f_0 = 0.036$. According to the Bank of

[14] This data was obtained from MOFE's World Wide Web site, http://www.mofe.go.kr/.

[15] The data are published on the Web at http://kiep.go.kr.

Korea, the value of private sector net foreign debt at the end of 1996 was roughly 13.9 percent of GDP. Accordingly we set $d_0 = -0.139$.

In Section 6 we argue that the value of non-performing loans relative to GDP prior to the crisis was roughly 0.25. Taking this to be an estimate of the governments implicit liabilities to the financial sector we set $\phi = 0.25$. Since there is substantial uncertainty about this number we explore the sensitivity of our results to perturbations in ϕ. The benchmark value of Ψ was chosen to match the increase in consolidated government liabilities that occurred in the period leading up to late October 1997 when the won first lost an unprecedented (by recent standards) fraction of its value. Using data from KIEP and the IFS, we estimate that net liabilities of the consolidated public sector rose to 5.3 percent of GDP as of the end of September 1997. Accordingly we set $\Psi = 0.053$. Later we explore the sensitivity of our results to perturbations in Ψ.

We now discuss how the benchmark value of τ was chosen. According to the IMF World Economic Outlook, the ratio of government revenue to GDP in Korea was roughly 22.0 percent in 1996. Since our model abstracts from investment and from the trade balance, we subtract 27.8 percent from output to ensure that the consumption to output ratio in the model matches the 1996 value in the data, roughly 0.5.

We set the real interest rate, r, to the average ex-post real interest rate in Korea for the period from January 1990 to April 1997, 7.45%. We chose the inverse of the elasticity of intertemporal substitution, σ, to be equal to 1.0. Finally, we assume that the average world rate of inflation, π^*, is 4 percent. This corresponds approximately to the average rate of inflation in the U.S. over the past 10 years. In the theoretical model we assumed that $\pi^* = 0$. Allowing for a positive value of π^* means that the government will collect some revenue during the fixed exchange rate regime. However, this does not change any of our conclusions since those seignorage revenues have already been pledged to financing the old level of the deficit.

Calibrating the Model to Thai Data

According to the Bank of Thailand, total government domestic debt not held by the central bank at the end of December 1996, was roughly 41.7 billion baht or 0.9 percent of GDP. We set $b_0 = 0.009$.[16] The Bank of Thailand estimated that the foreign debt of the public sector in December 1996 was roughly equal to 430.2 billion baht. According to the IFS, net foreign assets of the Thai central bank equaled 988.6 billion baht in December 1996. This suggests that the level of net foreign assets of the consolidated public sector was equal to 558.4 billion baht or 12.1 percent of 1996 GDP. Thus, we set $b_0 - f_0 = -0.112$. Using data from the Bank of Thailand we estimate that net foreign debt of the private sector at the end of 1996 was roughly 38.4 percent of GDP, so we set $d_0 = -0.384$.[17]

In Section 6 we argue that a rough estimate of the fiscal cost of the banking bailout to be 30 percent of GDP, so we set $\phi = 0.3$. The parameter Ψ was chosen to match the decline in consolidated government assets that occurred in the period leading up to the Thai crisis in July 1997. We estimate that during this period (until the end of June 1997), net assets of the consolidated public sector fell to 7.5 percent of GDP. We set $\Psi = -0.075$.

According to the IMF World Economic Outlook, the ratio of government revenue to GDP in Thailand was 18.9 percent in 1996. As in the Korean case, we subtracted an additional 26.5 percent from output to ensure that the consump-

[16] Bank of Thailand data was obtained from their World Wide Web site at http://www.bot.or.th/.

[17] This figure was obtained by taking a standard measure of total gross external debt, subtracting public sector external debt, and then subtracting the foreign assets of the banking system. As in the Korean case, these are the only private sector foreign assets for which information is generally available.

tion to output ratio in the model equaled the 1996 value of that ratio in the data, roughly 0.5.

We set the real interest rate, r, equal to the average ex-post real interest rate in Thailand for the period from January 1990 to April 1997, 4.2%. The remaining parameter values are the same as in the Korean calibration.

Table 1: Parameter Values

Parameter	Korea	Thailand	Description
Y	1	1	Real output
S	1	1	Time 0 exchange rate
b_0	0.103	0.009	Time 0 government domestic debt
$b_0 - f_0$	0.036	-.112	Time 0 net government debt
d_0	-0.139	-0.384	Time 0 private net foreign assets
ϕ	.25	.30	Present value of increase in deficit
Ψ	.053	-.075	Upper limit on net government debt
$r = \rho$	.0745	.0420	Real interest rate
τ	.22	.19	Lump sum taxes
σ	1	1	Inverse elasticity of intertemporal substitution
T	3	3	Time of monetary policy change
π^*	.04	.04	U.S. Inflation Rate
μ	.08	.065	Growth rate of M_t after T
M_T/M	1.10	1.10	Jump in M_t at T

4.2. Results

Since the two calibrated versions of the model display very similar dynamics, we focus our discussion on the Korean case. Figure 1 depicts the dynamic equilibrium paths of c_t (which coincides with m_t), π_t, M_t, $b_t - f_t$ and S_t (which coincides with P_t) for the model calibrated to the Korean data. Two key features of Figure 1 are worth noting. First, the speculative attack occurs at $t^* = 2.27$, before the change in monetary policy which occurs at $T = 3$. For the Thai case, $t^* = 2.42$. Second, inflation begins to increase at t^*, well before the change in monetary policy. This is reminiscent of classic results in Sargent and Wallace (1981) according to which future monetary policy affects current inflation.

We now turn to the behavior of consumption. In the benchmark model consumption increases discretely at time zero (not displayed in Figure 1) to a level that is higher than both the old steady state ($\bar{c} > c$) and the new steady state reached after T ($\bar{c} > \underline{c}$). The fact that $\bar{c} > c$ results from two features of the equilibrium. First, since seignorage revenues are rebated to the household, the present value of resources available to private agents is the same before and after the increase in the government deficit. Second, since inflation is at its lowest value before t^*, the effective price of consuming during time interval 1 is lower than in all other periods. Figure 1 indicates that during time interval 2 consumption declines. This reflects the rise in inflation relative to time interval 1. During time intervals 3 and 4 consumption is constant because inflation is constant. Notice that $\bar{c} > \underline{c}$ because inflation is zero during time interval 1 but positive during time intervals 3 and 4.

Consider next the behavior of the money supply and government debt. In the initial steady state, the level of the money supply is determined by the cash in advance constraint $c = M/S$. At time 0, consumption jumps from c to $\bar{c}$, while the exchange rate remains constant. It follows that the money supply must jump from M to $\bar{M} = S\bar{c}$. Agents obtain the additional money needed for consumption transactions by trading in foreign reserves or government bonds. Consequently, government debt drops discontinuously at time 0 (not displayed in Figure 1). For the remainder of time interval 1 all model variables remain constant except for government debt which evolves according to:

$$b_t - f_t = \left[b_0 - f_0 - \frac{\bar{M} - M}{S} \right] e^{rt} + \int_0^t (g + v - \tau) e^{rt} dt. \tag{4.1}$$

At time t^* there is a discontinuous decrease in consumption which reflects the jump in inflation that occurs at the onset of the floating exchange rate regime. Since the exchange rate is still fixed at t^* the cash in advance constraint implies that the money supply falls discontinuously at the time of the attack. Agents exchange domestic money for foreign reserves or government debt, raising total government liabilities to Ψ. It is this decline in domestic money holdings that is often described as a speculative attack.

At time T, the new monetary policy is implemented so that there is a policy induced jump in M_T after which the money supply grows at rate μ. The government engineers the increase in M_T by retiring government debt. Before the new transfer policy is implemented at T' the government is actually running a surplus, so that government debt is declining. After T' (not displayed) both the government deficit and the debt begin to increase.

4.3. Why Doesn't the Attack Take Place At Time Zero?

A fixed exchange rate regime is a price fixing scheme. As long as the government can borrow enough funds it can support a fixed price for its currency. So the key determinants of t^* are the government's ability to borrow, which is determined by its intertemporal budget constraint, its willingness to borrow, which is determined by Ψ, and agent's demand for domestic money. The latter demand is tied to agents' optimal consumption path. For a speculative attack to occur at time 0 there must be a large enough drop in c_0 to trigger the threshold rule on debt. Since the new monetary policy is only implemented at T, and inflation at time 0 is actually low relative to later periods, consumption does not typically drop at $t = 0$. As noted above in the benchmark model it actually rises.

To provide further intuition about the relation between consumption and exchange rate dynamics, Figure 2 depicts the equilibrium of the model if the government maintains its choice of T, M_T and μ but abandons fixed exchange rates at time 0 while keeping the money supply at some value M_0 until time T. Figure 2 corresponds to the case where $M_0 = M$.[18]

The key feature to note is that here the exchange rate initially *appreciates* at $t = 0$. This is because inflation is lower at time zero than in later time periods. Since the effective price of consumption is low relative to future periods, the initial level of consumption rises relative to the old steady state. Since the money supply is constant, the cash in advance constraint implies that S must fall, i.e. the exchange rate appreciates. This illustrates the importance of the link between consumption and money demand in determining exchange rate dynamics. An attack will happen at time 0 only if consumption and real balances fall enough to drive government debt to a value greater than or equal to Ψ.

4.4. Sensitivity Analysis

Table 2 describes the effect of perturbations to the Korean benchmark parameter values on the timing of a speculative attack and the present value of seignorage revenues. Four key results emerge here. First, if the increase in the deficit reflects a rise in government purchases rather than an increase in transfers, then t^* falls. The reason for this is as follows. In the benchmark model, time 0 consumption rises by 2 percent relative to its initial steady state level. Correspondingly, there is an increase in the demand for money and a reduction in the government's debt. Other things equal, the reduction in $b_0 - f_0$ delays the time at which $b_t - f_t$ reaches its threshold level, Ψ. Because of the rise in future government purchases, the household's wealth declines relative to its initial steady state value. Consequently time 0 consumption does not rise by as much as in the benchmark model. Now $\bar{c}$ is roughly equal to the initial steady state level of consumption, c, and there

[18] We also experimented with setting $M_0 = \bar{M}$, as well as chosing M_0 so that the government's intertemporal budget constraint is satisfied. These perturbations made very little difference to the results.

is no initial improvement in the government's debt position. Other things equal, this implies $b_t - f_t$ will reach Ψ more quickly than in the benchmark case. Note that seignorage revenues also fall relative to the benchmark case. This occurs primarily because the fall in the household's wealth leads to a decline in $\underline{c}$ which reduces the flow of seignorage revenues ($\mu\underline{c}$) after T.

Table 2: Sensitivity Analysis

	t^*	Present Value Seignorage
Baseline	2.27	0.25
Constant transfers	1.60	0.24
$\sigma = 5$	2.82	0.25
$T = 10$	9.44	0.16
$\Psi = 0.10$	2.64	0.25
$M_T/M = 2$	1.10	0.40
$\mu = 0.12$	2.11	0.45

Second, a decrease in the elasticity of intertemporal substitution to 1/5 ($\sigma = 5$) increases t^*. This reflects a greater desire on the part of the household to have a smooth consumption path. There is also a small decline in seignorage revenues which results from a lower level of $\underline{c}$. Third, a rise in T increases t^* and reduces the present value of seignorage revenues. The latter happens because positive seignorage revenues are generated only when the new monetary policy is implemented. Fourth, an increase in Ψ increases t^* and reduces the present value of seignorage revenues. The basic reason for the rise in t^* is that it takes longer for government debt to hit the threshold level associated with abandoning fixed exchange rates. The impact on seignorage revenues is more subtle. Recall that no seignorage revenues are collected between t^* and T, i.e. $\int_{t^*}^{T} e^{-rt}(\dot{m}_t + \pi_t m_t)dt = 0$, so that the increase in t^* has no direct impact on the present value of seignorage revenues. As it turns out, the decline in seignorage is caused by the fall in money demand, $\bar{M} - M^*$, that occurs when the government debt jumps to its threshold level Ψ at t^*. The higher is Ψ, the larger is the decline in money demand and the greater is the loss in seignorage revenue at t^*.[19]

A potential shortcoming of the experiments reported in Table 2 is that they do not hold seignorage revenues constant. We now consider the results of experiments in which monetary policy is adjusted to ensure that the government's intertemporal budget constraint is satisfied. Table 3 reports results when monetary policy is adjusted via changes in M_T, while Table 4 corresponds to the case in which μ is adjusted.

Consider first the results of perturbing the benchmark values of σ and T, as well as assuming that the rise in prospective deficits reflects a rise in future government purchases. Comparing Tables 2, 3 and 4 we see that very small adjustments in monetary policy are necessary to compensate for the changes in seignorage revenues associated with these perturbations of the benchmark model. As a consequence the analogue values of t^* in the three tables are very similar.

Next we consider how uncertainty about ϕ affects the time of the speculative attack. Table 3 presents results for $\phi = 0.1$ and $\phi = 0.4$. Note that the time of the attack is relatively insensitive to ϕ, ranging from 2.08 to 2.39. In contrast μ ranges from 0.05821 to 0.1081. Table 4 presents results for $\phi = .23$ and $\phi = 0.27$. We considered this narrow range of variation for ϕ because, in our model economy, the government cannot raise more than 3 percent of GDP in seignorage through a jump in the money supply at time T. Note that both t^* and M_T/M are relatively sensitive to variations in ϕ. But it is still the case that the attack continues to take place before T in all these experiments: t^* ranges from a low of 2.06 to a high of 2.58.

[19] There are two offsetting effects associated with higher values of Ψ: (i) t^* is increasing in Ψ so that the loss of seignorage revenue at t^* is discounted more heavily, and (ii) a higher value of Ψ is associated with a larger jump in money demand at T. In our benchmark models, these effects are outweighed by the effect discussed in the text.

Table 3: SensitivityAnalysis (μ adjusted to keep seignorage constant)		
$M_T = 1.1$, Seignorage $= 0.25$ for all entries	t^*	μ
Baseline	2.27	.0800
Transfers $= 0$	1.59	.0824
$\sigma = 5$	2.82	.0801
$T = 10$	9.32	.1124
$\phi = .10$	2.08	.0521
$\phi = .40$	2.39	.1081

Table 4: SensitivityAnalysis (M_T adjusted to keep seignorage constant)		
$\mu = .08$, Seignorage $= .25$ for all entries	t^*	M_T/M
Baseline	2.27	1.10
Transfers $= 0$	1.43	1.14
$\sigma = 5$	2.82	1.10
$T = 10$	8.33	2.13
$\phi = 0.23$	2.58	1.04
$\phi = 0.27$	2.06	1.16

We now study the sensitivity of our results to the threshold parameter Ψ. Regardless of the particular threshold rule that the government adopts, its intertemporal budget constraint must hold. As discussed above, an increase in Ψ reduces seignorage revenues. The government must compensate for the loss of these revenues by either raising M_T or μ. Figure 3 depicts the time of the attack and the adjustment in monetary policy as Ψ varies from 0.04 to 0.15. Panel A pertains to the case where M_T is fixed and the adjustment occurs via μ. Panel B refers to the case where μ is held fixed and the adjustment occurs via M_T. The key points to note are as follows. First, regardless of how monetary policy is adjusted, t^* is an increasing function of Ψ. Basically, this reflects the fact that the government can delay the date of the speculative attack by borrowing more resources. Second, both M_T and μ are increasing functions of Ψ. It turns out that as M_T increases, the peak rate of inflation in time interval 2 also increases. Consequently the cost of delaying the attack when monetary policy adjusts via an increase in M_T is higher inflation during the transition to the new steady state of the economy. As μ increases, so too does the steady state rate of inflation. We conclude that the price for delaying a speculative attack is a higher rate of inflation in the future. This suggests that the key issue is not whether governments can borrow to fend off speculative attacks, but whether they should. To examine this issue we proceed in two steps. First, we briefly consider the equilibrium of our model when the only constraint faced by the government is (2.8), its intertemporal budget constraint. In Section 5, we discuss the optimal policy for the government to pursue.

4.5. The Present Value Rule

We now consider the equilibrium of the model when the government operates under a present value rule, i.e. (2.8) is the only constraint that the government faces. We proceed by asking the question: what is the maximal value of Ψ consistent with (2.8)? In one sense we have already answered this question. Given the parameters of monetary policy (M_T and μ), there is a unique Ψ such that (2.8) holds, so that the present value rule can always be described *ex post* as a threshold rule on government debt.

Suppose that we fix one of the monetary policy parameters, say μ. For every value of M_T there exists a value Ψ such that (2.8) holds. We can ask the question: what is the value of M_T that maximizes Ψ? For our benchmark case we obtain roughly $M_T/M = 10$.[20] The associated values Ψ and t^* are 0.48 and 2.91, respectively. Alternatively we could fix M_T and seek the value of μ that maximizes Ψ. We did not pursue this experiment because it yields extreme results in our model: at the cost of hyperinflation the government could delay the attack for a very long (but finite) period of time. This is because the government can seize all private wealth by generating sufficiently high inflation. It's ability to do so is an artifact of two assumptions which we make in our model: the cash in advance constraint applies only to consumption, and output is exogenous.

[20] This is the value of Ψ that satisfies (2.8) when $M_T = 10M$. Further increases in M_T lead to very small changes in Ψ.

We conclude by noting that Figure 3 and the results of this section convey a common message: changes in the threshold rule, Ψ, do not affect the inevitability of the speculative attack, only its timing and how much monetary policy must be adjusted to balance the government's budget. A government can substantially delay the collapse of a fixed exchange rate regime by borrowing but only at the cost of higher future inflation. Because of this, it is not obvious that a government should borrow to delay an attack, even if it can. We now address the question of what monetary policy should the government pursue.

5. Optimal Monetary Policy

This section demonstrates that the optimal monetary policy in our economy is to abandon the fixed exchange rate regime as soon as new information about the deficit arrives. The required seignorage revenues should be raised by an increase in M_0 and/or setting the growth rate of money to a constant, μ. This monetary policy succeeds in balancing the government's intertemporal budget constraint without inducing distortions into the economy.[21] This result follows from three features of our model: output is exogenous, the cash in advance constraint applies only to consumption, and seignorage is rebated to the households.

To demonstrate the optimality of the proposed policy, suppose that the government could finance the increase in the present value of the deficit using lump sum taxes. The equilibrium under this financing strategy cannot be improved upon: the fixed exchange rate could be maintained and inflation would continue to be zero. Note that since tax revenue are rebated lump sum to households, consumption will remain at its initial steady state level, c.

We now prove the optimality of our candidate monetary policy by showing that it supports the same allocation as that which obtains when the government

[21] Rebelo and Xie (1998) prove an analogous result for a continuous time closed economy.

raises to lump sum taxes. Recall that the optimal behavior of consumption is dictated by equation (2.6). It follows that if π_t is constant, consumption will also be constant. Since seignorage revenues are rebated to the household, the intertemporal budget constraint is unaffected and consumption will still equal c. To finance the increase in the present value of the deficit it must be the case that:

$$\frac{c}{M_0}(M_0 - M) + \int_0^{\infty} e^{-rt}(\pi_t m_t + \dot{m}_t)dt = \phi. \tag{5.1}$$

The first term represents seignorage collected from increasing the money supply to M_0 at time 0. The integral term reflects seignorage obtained from the future growth rate of money. Relation (5.1) implies that M_0 and μ must satisfy:

$$\frac{c}{M_0}(M_0 - M) + \mu c/r = \phi.$$

Since this is feasible, the proposed policy supports the optimal equilibrium allocation.

One important caveat to the preceding discussion is that it abstracts from nominal rigidities in prices and wages as well as from non-indexed domestic debt and unhedged loans denominated in foreign currency. These aspects can clearly affect optimal monetary policy and the optimal time to abandon fixed exchange rates. The key point of the preceding discussion is to emphasize that there are clear costs to delaying the adjustment of monetary policy. In our model, the cost is the distortion of consumption decisions induced by the fact that lower inflation now is purchased at the price of higher inflation in the future. The more a government borrows to delay a speculative attack, i.e. the higher is Ψ, the higher are these costs. In this sense, the ability to borrow from abroad to delay a speculative attack actually *reduces* welfare.

6. Empirical Evidence

This section presents evidence to assess the empirical plausibility of our interpretation of the recent Asian currency crisis. Specifically, we offer evidence in support of three key assumptions in our model: (i) foreign reserves do not play a special role in the timing of the attack, (ii) large losses in the banking sector were associated with increases in governments' prospective deficits, and (iii) the public knew that banks were in trouble before the exchange rate crises.

Some Background Information

Figure 4 plots exchange rates of various Asian countries from July 1995 through May 1998. To provide a frame of reference, vertical lines are drawn at what we refer to as the crisis dates. These correspond to the first instance in which there were historically large devaluations or depreciations of the currency in question. Table 5 presents the cumulative depreciation rates of various Asian currencies from the crisis dates to May 1998. It is evident that the experience of the crisis countries was very different from that of the non-crisis countries (Hong Kong, Singapore and Taiwan).

Table 5: Cumulative Depreciation Rates (May 1998)

Indonesia	Malaysia	Thailand	Korea	Philippines	Hong Kong	Singapore	Taiwan
77%*	35%*	36%*	34%**	32%*	0%*	12%***	13%**

* from July 97 ** from Oct. 97 *** from Aug 97

As further background, Table 6 presents the annual growth rate of real GDP, the official CPI inflation rates and the fiscal surpluses for the Asian countries, Japan and the U.S, over the period 1995 - 1997. Note that there are no dramatic differences between the crisis and non-crisis countries. The crises certainly could not have been predicted on the basis of large and/or growing pre crisis fiscal deficits in the crisis countries. We refer the reader to Corsetti, Pesenti and Roubini (1998) for a more comprehensive survey of the pre crisis situation in Asia.

Table 6	Real GDP Growth			CPI Inflation Rates			Fiscal Surplus % of GDP		
	1995	1996	1997	1995	1996	1997	1995	1996	1997
Indonesia	8.2	8.0	5.0	9.0	6.6	11.6	0.8	1.4	1.9
Korea	8.9	7.1	5.9	4.7	4.9	6.6	0.4	0.3	-0.5
Malaysia	9.5	8.6	7.3	3.2	3.3	2.9	3.8	4.2	2.8
Philippines	4.8	5.7	5.1	11.0	5.2	6.1	-1.4	-0.4	-1.0
Thailand	8.7	6.4	0.0	7.5	4.8	7.7	2.6	1.6	-1.1
Hong Kong	3.9	4.9	5.3	7.0	6.6	5.2	-0.3	2.2	3.8
Singapore	8.7	7.0	7.6	0.9	2.0	2.0	2.7	2.8	1.8
Taiwan	6.0	5.7	6.9	4.6	2.5	-0.5	0.4	0.2	0.2
Japan	1.5	3.9	0.9	-0.1	0.1	1.7	-3.6	-1.1	-0.2
USA	2.0	2.8	3.8	2.8	2.9	2.3	-1.9	-1.1	-0.2

Foreign Reserves

Recall that in our model, foreign reserves do not play a special role in the decision to abandon fixed exchange rates. Whether they are high or low is irrelevant because they are already pledged to financing the *old* level of the deficit. An attack is inevitable once prospective deficits rise, regardless of the level of reserves. Moreover, the timing of the attack does not depend on the level of reserves: it depends on the government's threshold rule for overall debt. To help assess how reasonable these implications are, Figure 5 displays the ratio of foreign reserves to the monetary base and M1 in the crisis countries over the period July 1995 - May 1998. Two key facts emerge here. First, all of these countries had more than enough reserves to buy back the monetary base at the time their currencies collapsed. In fact, in all cases, they could have bought back over 90 percent of M1. Thailand's reserves were actually twice as large as M1 at the time of the collapse. Based on this evidence, we conclude that the level of foreign reserves did not play a critical role in the Asian currency crisis.[22]

The Size of the Government's Implicit Liabilities

We now discuss the impact of the banking crises on the governments' potential liabilities. We proceed in two steps. First, we provide evidence based on estimates of loan default rates prior to the crises. Second, we discuss the size of government outlays in Korea, Thailand, Indonesia and Malaysia associated with efforts to reorganize their financial sectors.

Corsetti, Pesenti and Roubini (1998) provide estimates on loan default rates in Asia prior to the crises. These are summarized in the first columns of Tables 7 and 8. Note the sharp difference between default rates in the crisis and non-crisis countries. In the former they range from a low of 14 percent in the Philippines to a high of 19 percent in Thailand. In all of the non-crisis countries the ratio of non-performing loans to total loans is roughly 4 percent. Using these default rates and data on total credit to domestic enterprises and financial institutions, we can generate a rough estimate of the government's total implicit liabilities stemming from guarantees to the financial sector.[23]

Columns 2, 3 and 4 of Table 7 report total non-performing bank loans as a percentage of the monetary base, real output and central government revenue, respectively. Table 8 reports the analogue percentages for the liabilities associated with non-bank foreign borrowing. Note that regardless of which measure we use, Korea and Thailand exhibit high levels of total implicit liabilities. For example, in Korea, the ratio of total non-performing loans to real GDP (obtained by summing

[22] The observation that many countries abandoned fixed exchange rates even though they had enough reserves to cover the Monetary Base (Obstfeld and Rogoff (1998)) is also consistent with multiple equilibrium theories of exchange rate collapses (see Obstfeld (1996)).

[23] Our data on domestic lending are from the IMF International Financial Statistics. We have attempted, as best as possible, to net out lending from one type of financial institution to another (for example, lending by a deposit money bank to some other type of financial intermediary).

the entries in the fifth columns of Table 7 and Table 8) is roughly 25 percent. This is the number we used to calibrate our model. In the case of Thailand, this ratio equals 30 percent.

Table 7: Estimated Total Non-Performing Bank Loans

			Estimate of Non-Performing Credit		
	Non-Perform. Loans (% of all loans)	Credit to Domestic Enterprises and Financial Institutions* (6/97)	% of MB	% of 1997 GDP**	% of 1997 Central Gov. Revenues**
Indonesia	17	343	129.6	9.4	63.0
Korea	16	589	454.1	22.1	103.7
Malaysia	16	403	88.8	23.3	98.3
Philippines	14	1365	84.5	7.8	41.1
Thailand	19	7912	289.6	30.2	176.7
Hong Kong	4	2223	91.6	6.6	33.6
Singapore	4	160	35.0	4.4	11.8
Taiwan	4	12157	26.8	6.0	50.0

*For Indonesia and Korea, expressed in trillions of local currency units.

For the others, in billions of local currency units

**Estimates.

Table 8: Estimated Liabilities from Non-bank Foreign Borrowing					
			Estimate of Non-Performing Credit		
	Non-Perform. Loans (% of all loans)	Non-bank Private Sector Borrowing from Abroad* (6/97)	% of MB	% of 1997 GDP**	% of 1997 Central Gov. Revenues**
Indonesia	17	92	34.6	2.5	16.8
Korea	16	23	18.0	0.9	4.1
Malaysia	16	19	4.1	1.1	4.5
Philippines	14	134	8.3	0.8	4.0
Thailand	19	343	12.6	1.3	7.7
Hong Kong	4	198	8.2	0.6	3.0
Singapore	4	12	2.6	0.3	0.9
Taiwan	4	88	0.2	0.0	0.4
*For Indonesia and Korea, expressed in trillions of local currency units.					
For the others, in billions of local currency units.					
**Estimates.					

The previous two tables summarize information on default rates and implicit liabilities prior to the currency crisis. J.P.Morgan (1998) has estimated non-performing loans as a percentage of total loans and GDP in Indonesia, Korea, Malaysia and Thailand, as of June 1998. In addition they provide estimates of the amount of capital, as a percent of GDP, needed to restore bank capital to the 8% Bank of International Settlement's Capital Adequacy Requirement level. Their estimates assume 60% recovery rates on non-performing loans and no losses to depositors. This information is contained in Table 9.

Table 9: Post-crisis Estimates of Non-Performing Loans and Recapitalization Requirements				
	Indonesia	Korea	Malaysia	Thailand
Non-performing Loans (Percent of Total Loans)	50	30	25	30
Non-performing Loans (Percent of GDP)	37.5	49.5	41.25	30
Recapitalization Need* (Percent of GDP)	30	30	22	30

Comparing Tables 7 and 8 with Table 9, we see a dramatic increase in the magnitude of non-performing loans relative to the pre-crisis estimates. From the perspective of our theory the post crisis estimates are at least as relevant as the pre crisis estimates, since these are tied to the current liabilities of the crisis governments. Notice also that, with the exception of Malaysia, the recapitalization needs as a percentage of GDP all exceed our benchmark value of ϕ.

There are a variety of ways in which the crisis governments could finance their implicit liabilities to the banking sector. For example, they could, in principle, cut government spending or raise taxes. It is important then to consider the actual programs which governments are setting up to deal with their banking crises. To date, these plans do not involve large fiscal adjustments. Indeed as of July 1998, J.P. Morgan (1998, page 12) conclude that the crisis governments have little room left to cut spending or raise taxes.

With this in mind, we now discuss briefly aspects of the financial restructuring programs in a subset of the crisis countries. Our most detailed information pertains to Korea. As of May 1998, Korea announced a program involving a total fiscal outlay of 49 trillion won to achieve three goals: (i) purchase 25 trillion won in bad loans from troubled financial institutions, (ii) recapitalize financial companies by 15 trillion won; and (iii) bolster their deposit-insurance fund by about

9 trillion won.[24] Combined with the 7.5 trillion won already spent by the Korea Asset Management Corporation (KAMC) on bad loans and the 3 trillion won already allocated for the recapitalization of Korea First Bank and Seoul Bank, this represents a total fiscal cost of 60.5 trillion won or about 13 percent of the budget estimate of GDP in 1998. This is a fiscal cost of more than two and a half times the size of the monetary base.[25] To raise funds for these programs the Korea Asset Management Fund and the Deposit Insurance Fund will issue government backed bonds, the interest on which will be paid by the government. Interest costs through 1999 alone are estimated to total just over 20 trillion won.

Details are more sketchy regarding Thailand where the government has launched a process of financial sector recapitalization under the auspices of two newly created agencies, the Radhanasin Bank and the Asset Management Corporation. The cost of this program has been estimated by Standard and Poor's to be roughly 1 trillion baht, or about 21 percent of estimated GDP in 1998.[26]

In Malaysia, the bank restructuring agency, the Pengurusan Danaharta Nasional Berhad, was initially capitalized with roughly 6 billion dollars, which equals 5 percent of 1997 real GDP.[27] Finally, the Indonesian Bank Restructuring Agency, which is supervising the reorganization of the financial sector in Indonesia, has already spent eleven billion dollars which represents over 6 percent of 1997 GDP.[28] Based on this, we conclude that the crisis governments are actively involved in restructuring their financial sectors in ways that involve substantial resource outlays. This is consistent with the conclusion reached by J.P. Morgan (1998, page

[24] *Wall Street Journal*, May 21, 1998.

[25] The bailout program is designed to force existing equityholders to bear a great deal of the losses associated with bad loans, since these loans will be valued at 50 percent of their book value, and not all of them will be purchased by the KAMC. This will force shareholders to write down the value of their capital.

[26] Reported in *The Nation*, 24 April 1998.

[27] *Wall Street Journal*, 12 August, 1998.

[28] *Wall Street Journal*, 12 August, 1998.

12), that "... the burden of absorbing banks' bad loans will increasingly fall on governments. To some extent, this has already happened in countries where the central bank's lender of last resort activities have effectively put the government in control of a large number of banks - notably in Indonesia, Korea and Thailand."

We now present evidence on the role that central banks played in supporting financial institutions after the currency crises. Figure 6 displays central bank credit to deposit money banks, expressed as a ratio of the monetary base, from 1995 on. With the exception of the Philippines, this ratio increased dramatically after the crises. For example, in Korea the ratio climbed from roughly one to 3 and half times the base, while in Thailand it increased from less than 10 percent to roughly 50 percent of the base. We do not have detailed information on how these loans were backed. But presumably, if the quality of the assets of these banks had been high, there would have been no banking crisis to start with and no need for central bank lending. This observation suggests that these loans represent, to a large extent, subsidies to the financial sector.

Were the Banking Crises a Surprise?

We now consider whether private agents anticipated the state of the banking system prior to the currency crises. Corsetti, Pesenti and Roubini (1998) discuss the fragile state of the financial sectors in the crisis countries prior to the recent speculative attacks. In addition they provide several example of bank failures and reorganizations that occurred prior to the crises.

While their discussion is very informative, it leaves open the question of how markets aggregated the information contained in the episodes that Corsetti, Pesenti and Roubini (1998) discuss. To investigate this issue we obtained daily data on stock market indices of the value of the banking or financial sectors and the industrial or commercial sectors in the crisis countries. We then constructed monthly indices of the market value of the financial sectors in these countries as well indices of nonfinancial sectors.[29] These are presented in Figure 7 and summarized in Table 10. Note that in Korea, Thailand and to a lesser extent the Philippines and Malaysia, the value of the financial sectors had been declining well before the currency crises.

Table 10: Changes in Banking Sector Stock Market Values

	Peak	Crisis	% Decline Banking Index	% Decline $\frac{\text{Banking Index}}{\text{Manufacturing Index}}$
Korea	Aug. 3, 1991	Oct. 29, 1997	67%	64%
Thailand	Jan. 4, 1994	July 2, 1997	92%	80%
Philippines	Feb. 17, 1997	July 11, 1997	34%	14%
Malaysia	Feb.25, 1997	July 11, 1997	26%	8%

For Korea the decline in the banking index from its peak (August 3, 1991) to the date of the currency crisis (October 29, 1997) was 67 percent. The analogue decline in the ratio of the banking index to the manufacturing index was 64 percent. In the case of Thailand the decline in the finance index from its peak (January 4, 1994) to the date of the crisis (July 2, 1997) was 92 percent. The analogue decline in the ratio of the finance index to the commerce index was 80 percent. In the Philippines, the peak in the finance index took place on February 17, 1997. This series declined by 34 percent between this date and the date at which their currency crisis began in earnest (July 11, 1997). The peak to trough decline in the ratio of the finance index to the commerce index was 14 percent. Finally for Malaysia the peak in the finance index took place on February 25,

[29] We used the following Bloomberg series to construct our monthly banking/financial sector indices: Indonesia-JAKFIN, Korea-KOSPBANK, Malaysia-KLFIN, Philippines-PFINC, Thailand-SETFIN, Hong Kong-AOF, Singapore-SESFIN, Taiwan Province-TWSEBKI. The Bloomberg series used to construct monthly industrial or commercial sector indices were: Indonesia-JAKMANU, Korea-KOSPMAN, Malaysia-KLPRO, Philippines-PCOM, Thailand-SETCOM, Hong Kong-AON, Singapore-SESIND, Taiwan Province-TWSESTEE.

1997. This series declined 26 percent between this date and the date of the crisis (July 11, 1997). The peak to trough decline in the ratio of the finance index to the industrial index was 8 percent.

Based on this evidence we conclude that private agents in these four countries understood the potentially fragile nature of their banking systems. This also suggests that markets anticipated that the government would bail out only depositors and creditors of the banks. Had they anticipated that the banks would be fully insured by the government, the equity value of banks would not have changed, other things being equal.

Finally we note that examining nominal interest rate movements prior to the crises could be useful for assessing private agent's expectations about the timing of the speculative attack. Our model predicts that nominal yields on bonds of maturity greater than t^* ought to rise once agents receive information about the increase in prospective deficits. In future work, we intend to pursue this avenue of research.[30] In so doing, we face three serious problems: (i) as far as we can tell, the available data pertain primarily to short term loans, typically of duration less than one year, (ii) there was active government intervention in the crisis countries aimed at affecting short term interest rates, and (iii) there were capital controls in some of these countries, e.g. Korea. Finally, it seems important to enrich our model (see below) before formally investigating its detailed implications for nominal interest rates.

[30] Cline and Barnes (1997) analyze trends in spreads on U.S. dollar denominated Eurobonds. They conclude that these spreads fell in emerging markets, including Southeast Asia, between mid-1995 and mid-1997. While useful this information does not bear directly on the issues raised in this paper. Since the bonds in question are dollar denominated, the spreads reflect default risk rather than expected depreciation. Similar comments apply to Park and Rhee's (1998) analysis of the yield spread on Korean Development Bank global bonds.

7. Conclusions

This paper focused on the role played by large prospective deficits in the Asian currency crisis. Our basic argument is simple: absent the political will to raise taxes or cut spending, governments have to resort to seignorage revenues to pay for the bailout of the banking system. In a world of forward looking agents this makes a currency crisis inevitable. In versions of our model calibrated to the Korean and Thai economies, the collapse of the fixed exchange rate happens *after* agents learn that future deficits will rise but *before* the government implements its new monetary policy. Under this scenario standard macroeconomic aggregates such as past inflation and fiscal deficits are not useful in predicting currency crises. In this limited sense our model rationalizes claims that the Asian crises were hard to predict.

Our model suggests that we focus our empirical analysis on information useful for forecasting prospective deficits. This is why we studied the state of the Asian banking system prior to the crisis. We found evidence consistent with the view that agents knew that banks were in trouble before the crisis and that the size of the financial sector bailout would be large. This evidence does not rule out the possibility that the Asian currency crises were multiple equilibrium phenomena. But it does suggest a simple explanation based on fundamentals.

We conclude by highlighting some important shortcomings of our analysis. First, in our model the state of the banking system is costlessly revealed to agents at a particular point in time. In reality, obtaining this information took time and resources. Moreover, information about banking problems in one country may have conveyed information about banking systems in other countries. We suspect that understanding the precise timing and sequencing of currency attacks will require an analysis of these information dynamics. Second, we modeled the decision of when to abandon fixed exchange rates with a simple threshold rule on government debt. In practice this decision is shaped by political considerations. Modeling these political aspects is likely to lead to insights regarding the timing of speculative attacks. Third, to isolate the role of prospective deficits we abstracted from nominal rigidities. These rigidities will almost surely have an impact on the nature of optimal monetary policy. Finally, we did not address the issue of how the collapse of financial intermediaries affects future output and tax revenues. We took as given that in the state of the world where banks collapsed, governments would find it difficult to raise tax revenues. In future work we intend to study in detail the role played by the financial sector in generating the persistent recessions that are often associated with currency collapses.

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8. Appendix

The problem of the representative household is to maximize (2.2) subject to (2.3) - (2.5) by choice of time paths for c_t, m_t, b_t and d_t, given a known time path for π_t. The current-valued Hamiltonian associated with this problem is:

$$\begin{aligned}\mathcal{H} &= \frac{c_t^{1-\sigma}-1}{1-\sigma} + \lambda_t[y + r(b_t + d_t) + v - c_t - \tau - \pi_t m_t - z_t] + \\ &\quad \theta_t z_t + \omega_t(m_t - c_t)\end{aligned}$$

where $z_t = \dot{m}_t$.

The first order conditions to the problem are given by:

$$\begin{aligned} c_t^{-\sigma} &= \lambda_t + \omega_t, \\ \lambda_t &= \theta_t, \\ \dot{\lambda}_t &= (\rho - r)\lambda_t = 0, \\ \dot{\theta}_t &= \theta_t \rho + \lambda_t \pi_t - \omega_t. \end{aligned}$$

These equations imply (2.6) in the main text.

Figure 1: Response to News about an Increase in Prospective Deficits

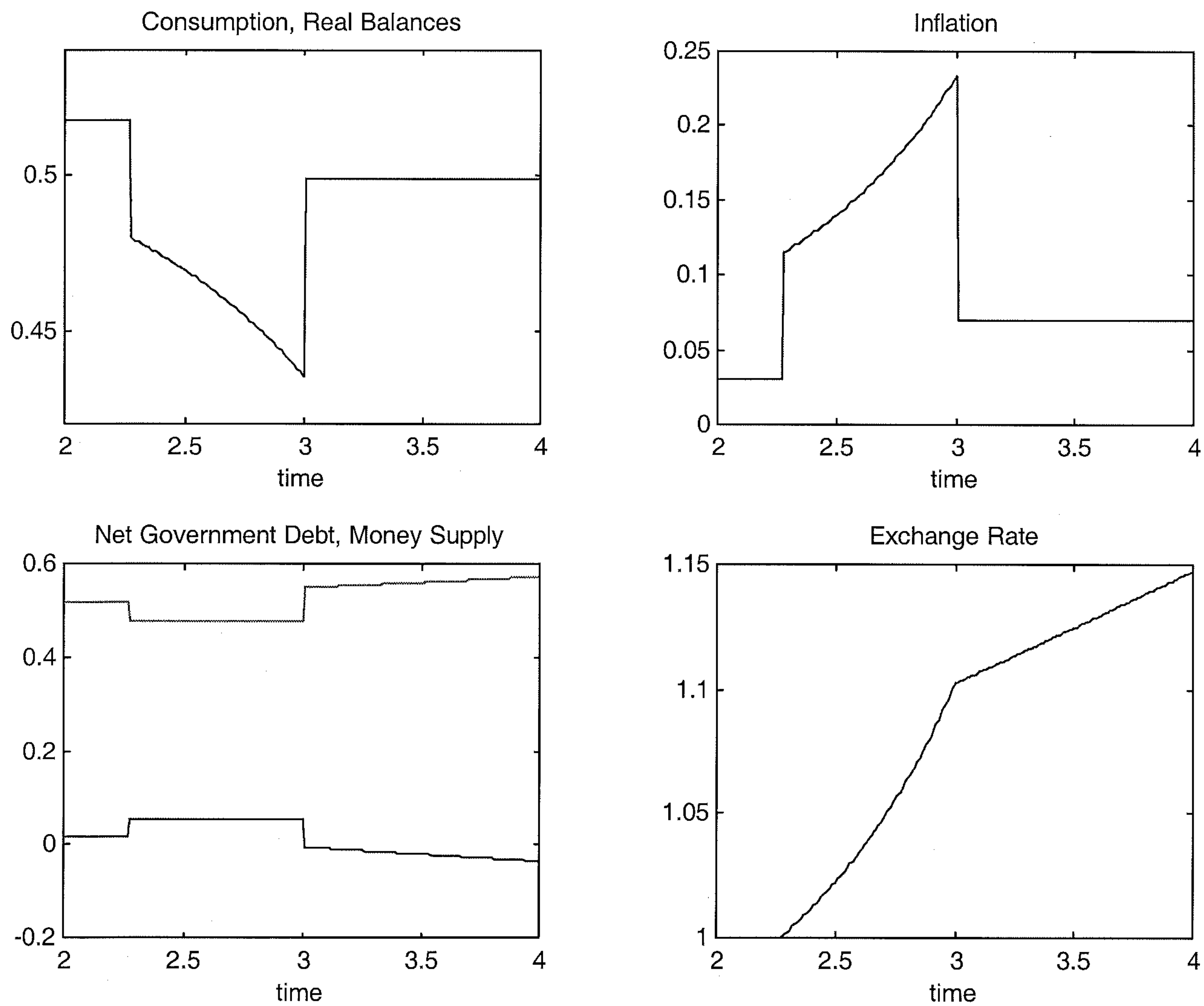


Figure 2: Reverting To Floating Exchange Rates at Time 0

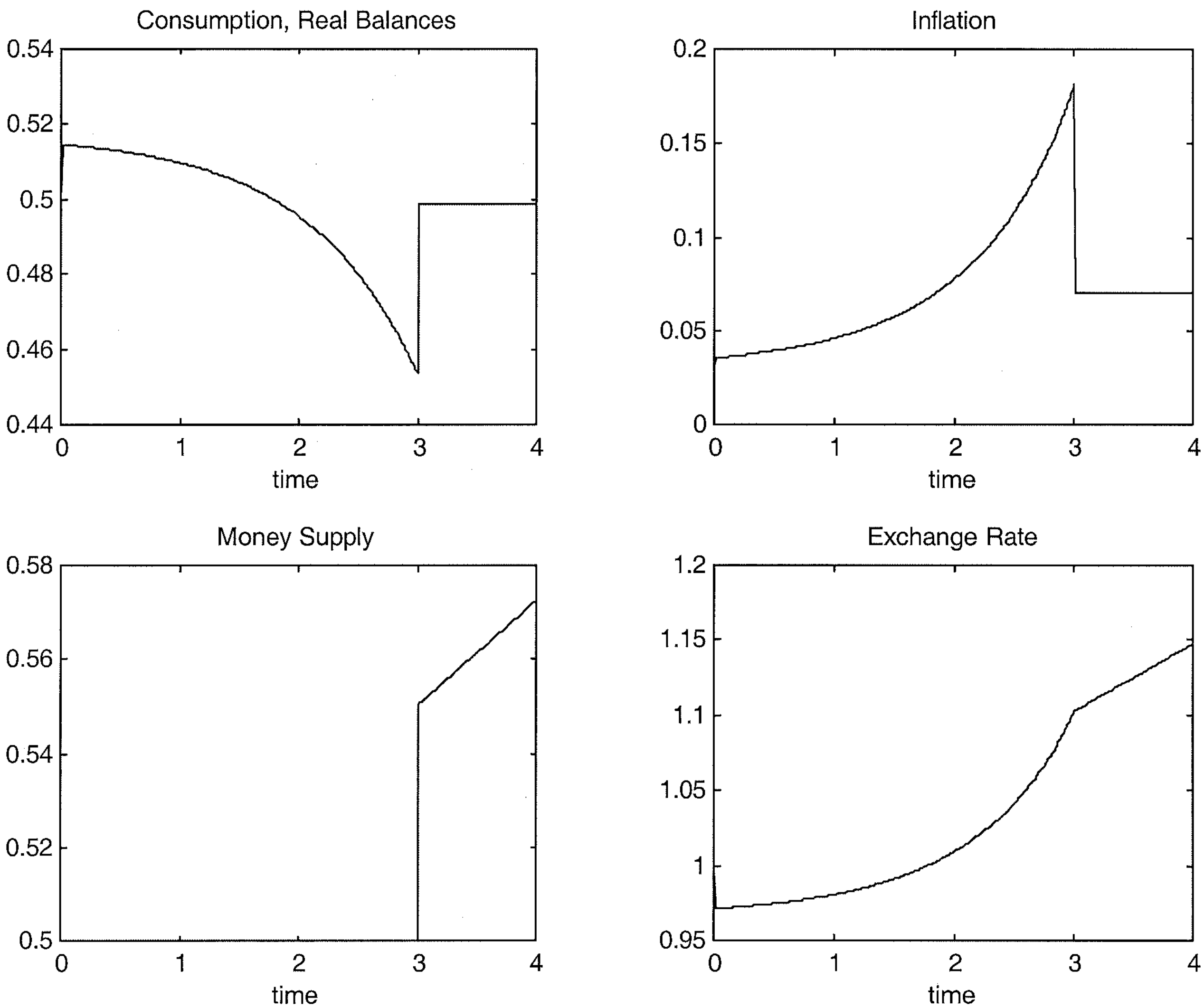


Figure 3a: Effects of Varying Threshold Rule Parameter Ψ on the Time of the Attack

μ Adjusted to Satisfy the Government's Present Value Constraint

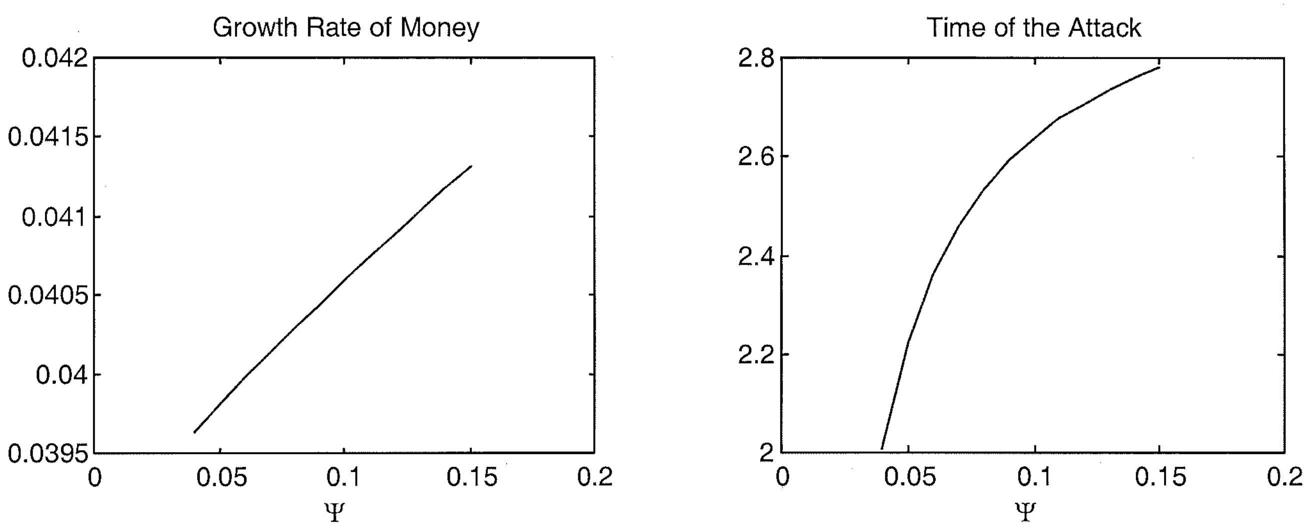


Figure 3b: Effects of Varying Threshold Rule Parameter Ψ on the Time of the Attack

MT Adjusted to Satisfy the Government's Present Value Constraint

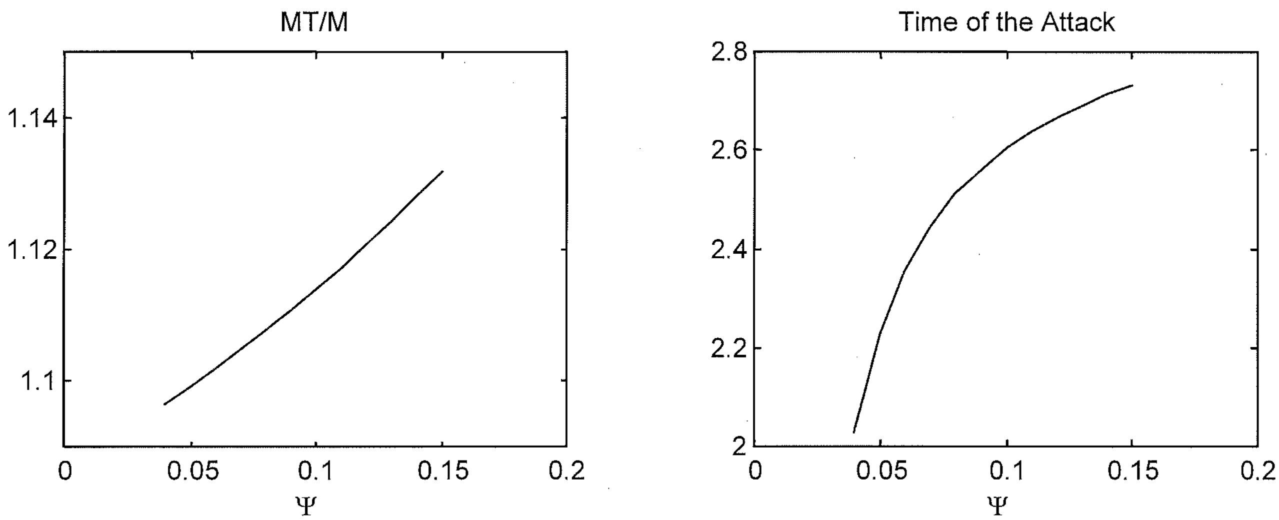
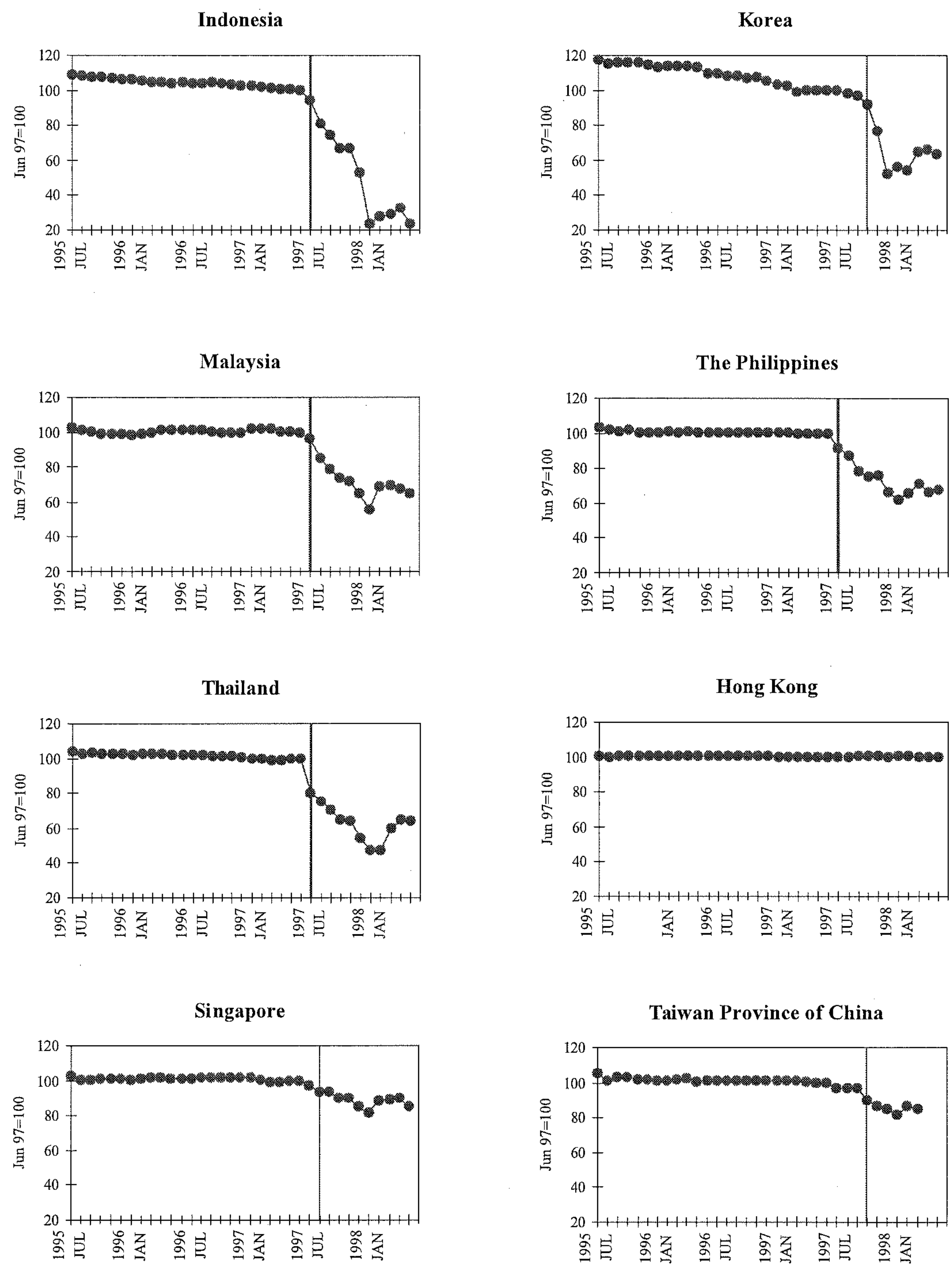
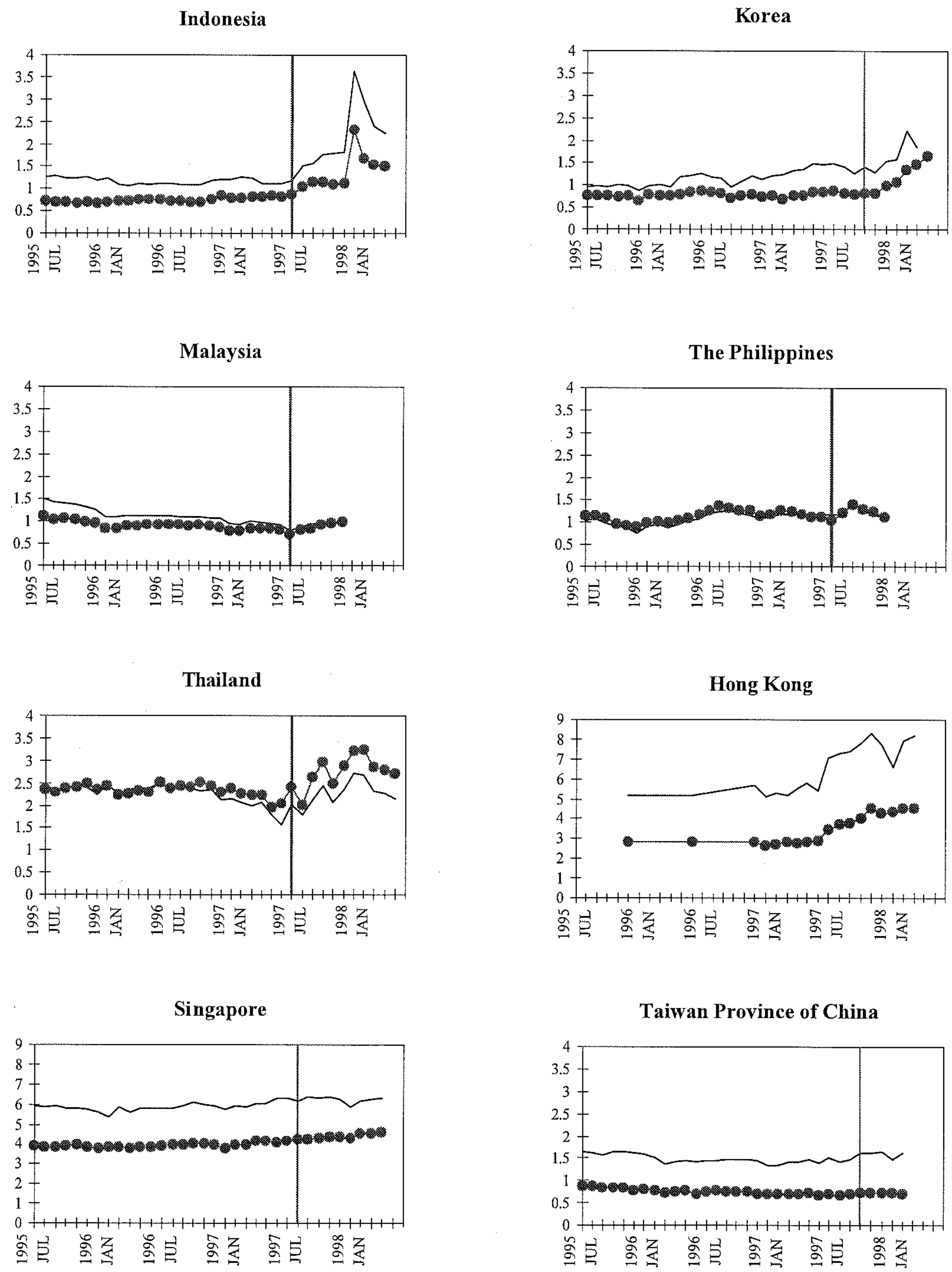


Figure 4
Nominal Exchange Rates Versus the U.S. Dollar



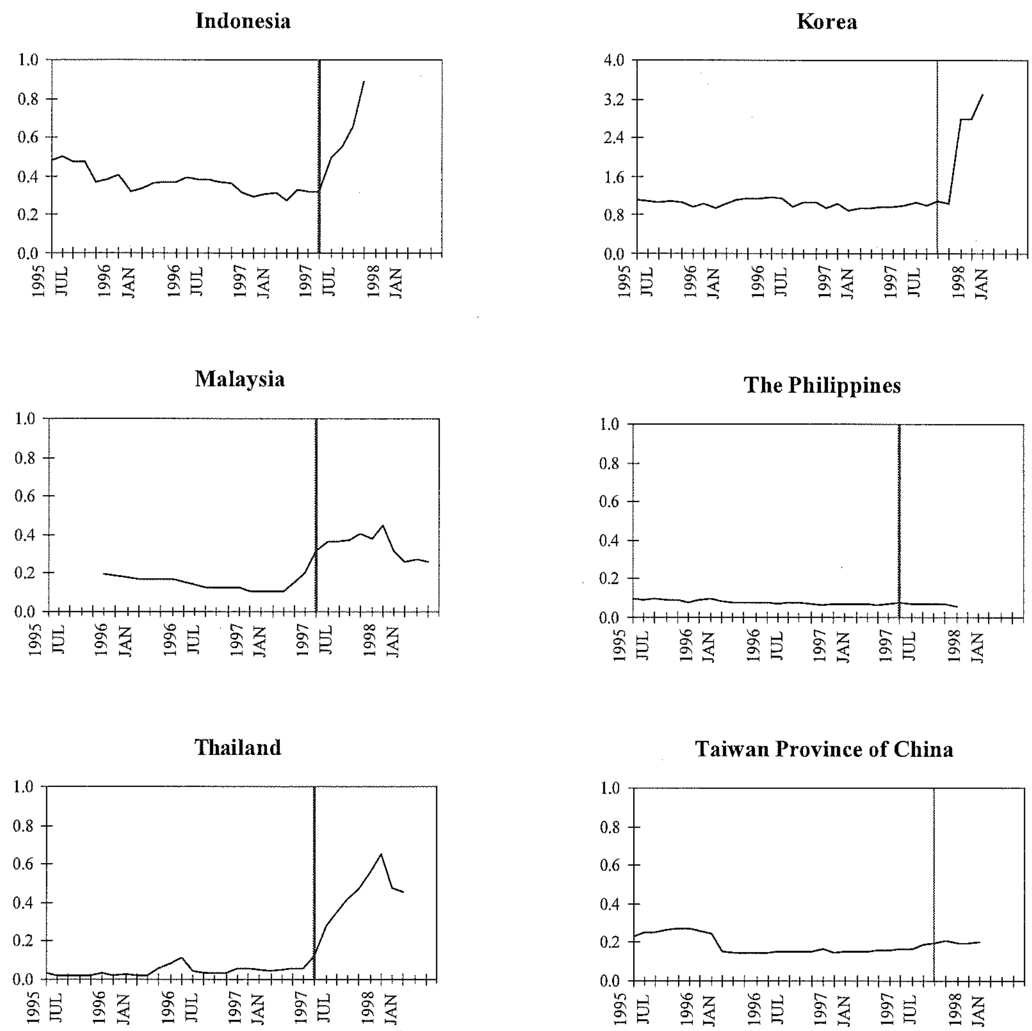
Each point represents a value, at the end of a month, of $100\times S_{6/97}/S_t$ where S_t is the number of local currency units per U.S. dollar at date t. Vertical lines represents crisis dates determined by the first month in which a large depreciation occurred. Source: IFS.

Figure 5
Foreign Reserves Relative to Monetary Aggregates



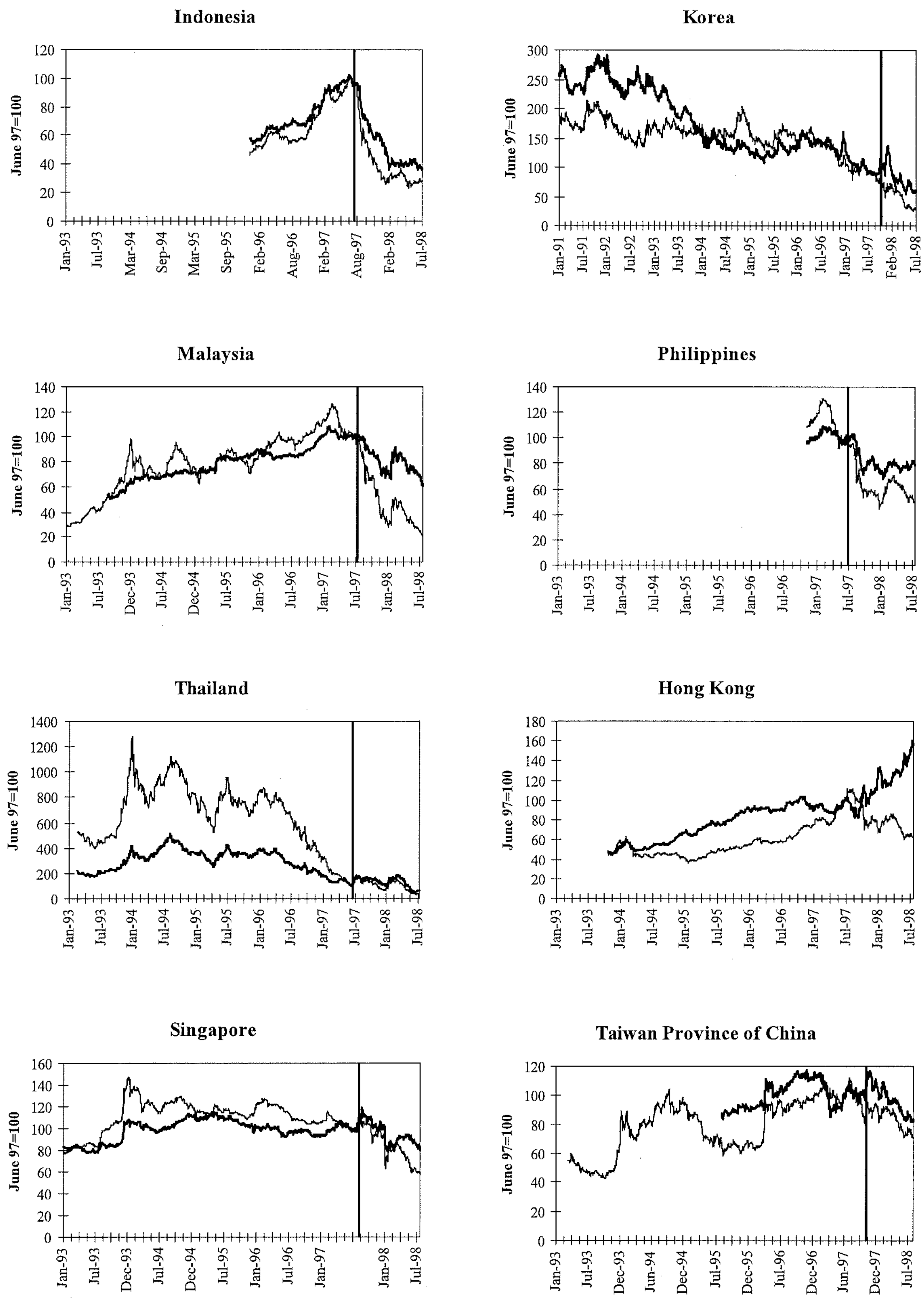
The solid line represents the ratio of foreign reserves to the monetary base. The dotted line represents the ratio of foreign reserves to M1. Note the different vertical scale used for Hong Kong and Singapore for better visibility. Source: IFS.

Figure 6
Central Bank Credit Extended to Banks Relative to Base Money



Each graph plots the value of credit extended by the central bank to commercial banks relative to the monetary base. Source: IFS except for Malaysia, for which the source is Bank Negara Malaysia.

Figure 7
Stock Market Indices and Crisis Dates



The thin line represents the level of the stock market index for the finance sector (banking for Korea). The thick line represents the level of this index relative to a stock market index for the industrial (Hong Kong, Indonesia, Malaysia, Singapore), manufacturing (Korea), commerce (Philippines, Thailand) or steel (Taiwan) sector. The vertical lines represent crisis dates for each country. Source: Bloomberg. Note the different horizontal scale for Korea for illustrative purposes.