

Capital Inflows Problem in Selected Asian Economies in the 1990s Revisited: The Role of Monetary Sterilization*

Tony Cavoli and Ramkishen S. Rajan

Received 12 December 2005; accepted 28 August 2006

This paper develops a simple model to examine the reasons behind the capital inflow surges into selected Asian economies in the 1990s prior to the financial crisis of 1997–98. The analytical model shows that persistent uncovered interest differentials and consequent capital inflows may be a result of complete monetary sterilization, perfect capital mobility, sluggish response of interest rates to domestic monetary disequilibrium, or some combination of all three. Using the model as an organizing framework, the paper undertakes a series of related simple empirical tests of the dynamic links between international capital flows, the extent to which they are sterilized and uncovered interest rate differentials in the five crisis-hit economies (Indonesia, Korea, Malaysia, the Philippines and Thailand) over the period 1990:1–1997:5.

Keywords: capital flows, East Asia, interest rates, monetary sterilization, reserves.

JEL classification codes: F30, F32, F41.

I. Introduction

In a nutshell, the East Asian financial crisis of 1997–98 was due in no small part to an initial surge in international capital flows in the early 1990s (a period in which these countries underwent a significant degree of financial liberalization) that halted abruptly and reversed direction in 1997–98. While the causes and consequences of the ‘sudden stop’ of capital flows have been discussed elsewhere (Rajan and Siregar, 2002), less well understood are the factors motivating the pre-crisis capital inflow boom in the 1990s prior to the bust. In view of the resurgence in capital flows to the region after the crisis (Rajan and Vostroknutova, 2006), it is imperative to understand all dimensions of the causes and consequences of capital inflows surges so as to prevent a repeat of the crisis.

Referring to IMF data in Table 1, it is indicative that the bulk of capital inflows into the region in the years preceding the crisis (1988–1995) was under

* Tony Cavoli (corresponding author): School of Economics and Finance, Queensland University of Technology, Brisbane, Qld 4001, Australia. Email: t.cavoli@qut.edu.au. Rajan: School of Public Policy, George Mason University, 3401 North Fairfax Drive, Arlington, VA 22201, USA. Email: rrajan1@gmu.edu. General discussions on the topic with Alice Ouyang and Tom Willett have been helpful in organizing some of our thoughts in this paper. The authors are also grateful to two anonymous referees of this journal for detailed comments. The usual disclaimer applies.

Table 1 Capital Inflows as a percentage of GDP, 1988–95

	<i>Indonesia</i>	<i>Malaysia</i>	<i>Philippines</i>	<i>Thailand</i>
FDI flows	1.7	7.2	1.8	1.6
Portfolio flows	0.5	0.0	0.2	1.4
Other	3.0	2.9	2.1	8.5
Total	5.1	10.2	4.1	11.5
Δ Reserves ^a	-1.7	-5.1	-1.8	-4.3

Note: ^aA negative sign means an increase in reserves.

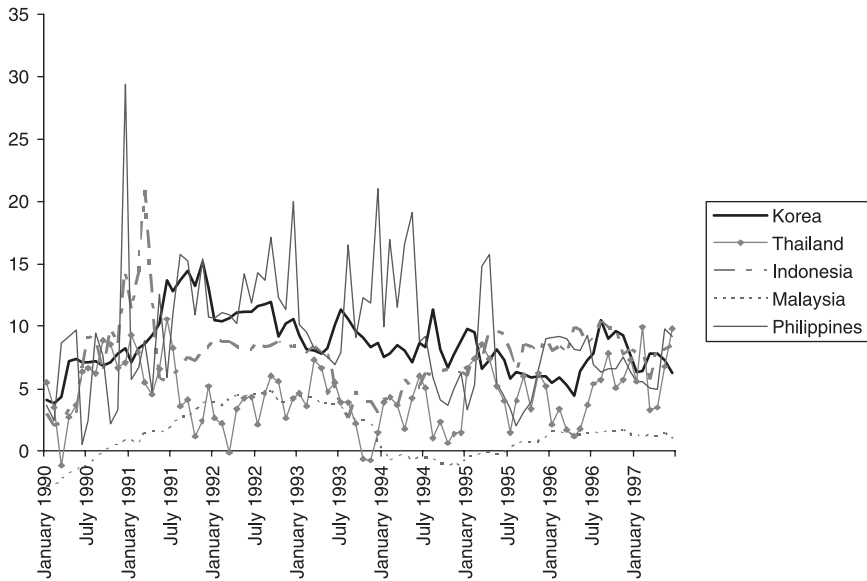
Sources: Rajan and Siregar (2002).

the category of ‘other investments’, comprising a range of short-term and long-term credits (including the use of IMF credit) and currency transactions. This category constituted approximately 75 percent of the private capital inflows on average in the case of Thailand, and it was also the single largest component of capital flows in the cases of Indonesia and the Philippines. Recognizing the interest-sensitive nature of these bank flows, attention can be narrowed to the issue of interest rate differentials between those offered in East Asia before the crisis and comparable international (US) ones. Figure 1 highlights the uncovered exchange rate adjusted interest rate differentials (UIDs) for Korea, Thailand, Malaysia, Indonesia and the Philippines.¹ The data appear to indicate a general non-divergence in the cases of Thailand and Indonesia, while the Philippines and Korea reveal a very gradual convergence. Malaysia’s UID can be broadly split into two sub-samples: there is a higher UID for the first half and a much lower one in the second.

Motivated by the data, this paper attempts to examine the extent to which international capital flows impact on the UIDs in Asia before the crisis and the role of monetary sterilization. In practice, central banks in Indonesia, Korea, Malaysia, the Philippines, and Thailand all sterilized inflows in different ways. For instance, the Bank Indonesia (BI) employed Open Market Operations (OMO) by issuing its own CDs called SBIs. The Indonesian government also managed its budgetary operations in a way that built up large deposits with the Bank Indonesia (McLeod, 1998). Bank of Thailand (BOT) conducted OMO to sterilize its inflows (Warr, 1998). OMO were not used extensively by the Bank of Korea (BOK), which relied on quantitative controls and discounting policies to dampen domestic credit (Kwack, 2003). Bank Negara Malaysia (BNM) historically deployed government and other deposits with the central bank to impact monetary liquidity (Reisen, 1993).

The remainder of the paper is organized as follows. Section II develops a simple analytical model to highlight the links between international capital flows,

1. Measured as the domestic money market rate minus the US Treasury Bond rate and the *ex-post* change in the (log) exchange rate. Expected exchange rate change is given by the actual 3-month change.

Figure 1 Uncovered interest differentials

the extent to which the reserve effects of these flows are sterilized and the ensuing impact on UIDs. Using the model as an organizing framework, Section III undertakes a simple empirical analysis of the dynamic links between international capital flows and UIDs in the five crisis-hit economies under investigation from January 1990 to May 1997. This time period is investigated because it is widely regarded as a period of high and sustained capital inflow for Asian economies that ultimately led to the currency crisis in the region in 1997 (Rajan and Siregar, 2002). The empirics confirm that international capital inflows have not always generated declines in the UIDs, which in turn explains some of the persistence in capital inflows before the crisis. Is complete or near complete sterilization of international capital flows by these countries the reason that the persistence in the positive interest rate spreads? This issue is explored empirically in Section IV. Section V offers a summary and some concluding remarks. Some supplementary empirical tests to support the results in Section III are offered in Appendix I.

II. Interest Rate Determination in a Small and Semi-open Economy

Although many of the East Asian economies have moved to somewhat more flexible exchange rate regimes since the crisis of 1997–98, there is ample evidence to suggest a high degree of exchange rate management by the central banks and resultant sterilization of capital flows (Ouyang et al., 2006; Rajan and Vostroknutova, 2006). There are signs that history is repeating itself. It is

therefore important to understand the causes and consequences of monetary capital flows and monetary sterilization. In particular, the question we are interested in here is: what is the role of international capital flows on UIDs in a small, semi-open economy? To answer this question more formally we use the workhorse model by Edwards and Khan (1985).²

II.1 Basic framework of model

We begin with the following equation:

$$i_t = \psi i_t^* + (1 - \psi)\tau_t, \quad 0 \leq \psi \leq 1. \tag{1}$$

Equation (1) states that the domestic interest rate (i_t) is a weighted average of the international rate (i_t^*) and autarky rate (τ_t). ψ is a parameter representing the degree of de facto capital mobility. High capital mobility implies that the domestic interest rate is determined by i_t^* , which, in turn, is based on the uncovered interest parity (UIP) condition as follows:

$$i_t^* = i_t^f + (e_{t+1}^e - e_t), \tag{2}$$

where i_t^f is a foreign interest rate with which to base UIP; e_t is the log of the current exchange rate (domestic price of foreign currency); and e_{t+1}^e is the expectation at t of the (log) exchange rate at $t + 1$.

Low capital mobility implies that interest rates are explained by τ_t . In the context of the model, τ_t is a ‘shadow’ interest rate capturing conditions of disequilibrium arising from excess demand or supply of money. This shadow rate can be calculated in the following way (Edwards and Khan, 1985):

$$\tau_t = \rho + \pi_{t+1}^e + \gamma(m_t^d - m_t), \tag{3}$$

where ρ is the long-run equilibrium or neutral real interest rate, π_{t+1}^e is the expected inflation rate, and $(m_t^d - m_t)$ captures monetary disequilibrium where m_t^d is the demand for money and m_t is the money supply. γ captures the degree of sluggish adjustment of interest rates to domestic monetary conditions, and is discussed further in Section III.2. Money demand is modeled in the standard way with the addition of Equation (3). This derives the following augmented money demand function:

$$m_t^d - p_t = -\alpha_1(\rho + \pi_{t+1}^e) + \alpha_2 y_t + \alpha_3 m_{t-1}, \tag{4}$$

where y_t is (log) real output and p_t is the (log) price level. Equation (5) is a simple identity stating that the change in the base money (M) is due either to a change in domestic assets (D), a change in foreign assets (F), or both:

$$\Delta M_t = \Delta D_t + \Delta F. \tag{5}$$

2. The Edwards–Khan model has similarly been modified by Haque and Montiel (1991), Dooley and Mathieson (1994) and Willett et al. (2002). The papers used the model to investigate the level of capital mobility in developing countries.

In applying the model, previous authors have normally assumed money supply is exogenously determined. Few have allowed for the possibility of sterilized intervention by the monetary authority and its effect on domestic money supply (Willett et al. (2002) is a notable exception). This is done below. First, express Equation (5) as:

$$\Delta m_t = \Delta d_t + \Delta f_t, \quad (6)$$

where $\Delta m_t = \Delta M_t/M_{t-1}$, $\Delta d_t = \Delta D_t/M_{t-1}$ and $\Delta f_t = \Delta F_t/M_{t-1}$. Complete sterilization implies that $\Delta m_t = 0$ and

$$\Delta d_t = \lambda \Delta f_t, \quad (7)$$

where λ is the degree of sterilization. If there is complete sterilization, $\lambda = -1$. As such, using Equation (7), and using the fact that $m_t = \Delta m_t + m_{t-1}$, the supply of money (monetary base) is given by Equation (8):³

$$m_t = (1 + \lambda)\Delta f_t + m_{t-1}. \quad (8)$$

The domestic interest rate (i_t) can now be calculated by substituting Equations (4) and (8) into Equation (3) to find τ_t , and this and Equation (2) can be substituted into Equation (1) to derive:⁴

$$i_t - i_t^* = (1 - \psi)[(1 - \gamma\alpha_1)\rho - i_t^* - \gamma(1 + \lambda)\Delta f_t - (\gamma - \gamma\alpha_3)m_{t-1} + (1 - \gamma\alpha_1)\pi_{t+1}^e - \gamma p_t + (\gamma\alpha_2)y_t]. \quad (9)$$

II.2 Implications of model

What does the simple model imply about the extent and impact of sterilization? The parameters of interest are those in front of the reserve inflow (Δf_t): $[(1 - \psi)\gamma(1 + \lambda)]$. The degree to which the sterilization of capital inflows is successful in maintaining an upward pressure on UID is driven by three factors: (a) the extent of sterilization undertaken by the central bank (λ); (b) the degree of de facto capital mobility (ψ); and (c) the adjustment parameter that determines the speed with which domestic interest rates adjust to domestic monetary disequilibrium (γ).

The first factor influencing the effect of Δf on the UID is the extent of monetary sterilization. Recall that $\lambda = -1$ implies complete sterilization of capital inflows. If this is the case, international capital flows have no impact on interest rates, because full sterilization offsets any monetary impact of a reserve flow. Alternatively, if the central bank does not engage in sterilization ($\lambda = 0$),

3. We ignore the money multiplier, implicitly assuming it is a constant and normalized to one. See Kwack (2003) for a discussion of sterilization in the context of a varying multiplier. Also see Ouyang et al. (2006).

4. This paper examines similar relationships to the work of Takagi and Esaka (1999). However, this paper differs in that the model provides additional theoretical underpinnings of the relationship between sterilization and interest rates and the UID.

capital inflows and the consequent reserve build-up inevitably puts downward pressure on domestic interest rates.

The second factor affecting the nexus between Δf_t and $(i_t - i_t^*)$ is the degree of de facto capital mobility (ψ). For a given λ (i.e. $-1 < \lambda < 0$), if the level of capital mobility increases, the effect of a capital inflow on the UID diminishes. For levels of capital mobility that are extremely high ($\psi \rightarrow 1$), the effect of capital inflows on the interest rate tends to zero regardless of the extent of sterilization activity. This is consistent with the so-called ‘impossible trilogy’, which states that with perfect capital mobility and a fixed exchange rate a country loses monetary policy autonomy. Note that for the impossible trilogy to hold strictly, and therefore for sterilization to be ineffective, financial assets across countries might be perfectly substitutable. In the context of this (monetary style) model that has no portfolio balance type features, the capital mobility parameter may also capture characteristics more typically associated with imperfect asset substitution (such as a risk premium term). Hence, the capital mobility parameter should be viewed as having a more general interpretation.⁵

The third factor is the adjustment parameter (γ), which denotes the extent to which monetary disequilibrium affects the domestic interest rate. As noted, a higher γ indicates that interest rates are more sensitive to domestic monetary conditions. To be sure, if there are no institutional or other hindrances, and the domestic money market functions effectively, then $\gamma \rightarrow 1$.⁶ As above, its interaction with the other parameters is important. If capital mobility is near perfect, the value of γ is irrelevant because domestic factors have no influence on i_t . Similarly, if $\lambda = -1$, capital inflows have no monetary effects (given our assumption that there are no other independent effects of domestic credit changes); consequently, they ought not to have any impact on domestic interest rates or UIDs.

III. Empirics

III.1 Data and estimation

The data are primarily from the IMF’s *International Financial Statistics* (IFS) CD database and are supplemented by the Asian Development Bank’s Asia Recovery Information Centre (ARIC) databases. Monthly observations are used from January 1990 to May 1997.⁷ The selection of January 1990 as the starting point is dictated primarily by the fact that many of the countries in this sample

5. Hutchison (2003) notes that capital mobility (more strictly interpreted) is a stronger factor in determining the effectiveness of sterilization than imperfect asset substitution. For imperfect asset substitution to have any meaningful effect the relative asset quantities being moved must be enormous.

6. One possible institutional barrier causing the sluggishness in developing countries could be the role played by banks. We touch on this theme in Section V.

7. For the calculation of the sterilization coefficients in Section 4, the sample is curtailed at March 1997 to avoid the rapid depletion of reserves at the onset of the East Asian crisis.

made substantial efforts to deregulate their financial systems during the 1980s. The sample excludes any effects of the financial crisis that began in Thailand in June 1997 (Rajan (2001) and references cited within). Data on exchange rates, net foreign assets and money bases are taken from lines *RF*, (11-16c) and 14, respectively, of the IFS. Interest rates, prices and output are taken from 60b, 64 and 66, respectively, of the IFS. First differences are used for net domestic assets and net foreign assets for the sterilization equation (Equation 10). Δf is measured as $[\Delta \text{FA}/\text{MB}(-1)] * 100$ as defined above. Expected inflation is measured as $[\log(\text{CPI}(12)) - \log(\text{CPI})] * 100$, m_{t-1} is $\log(\text{MB}(-1))$, and output and CPI are both measured in logs.

III.2 Simple UIDs

Table 2 presents unit root tests (Augmented Dickey Fuller (ADF)) of the UIDs of respective money market rates vis-à-vis the US Treasury-Bill for the East Asian countries in question. If a significant UID is present at the start of the sample and the ADF test suggests a rejection of a unit root then we conclude that the UID is maintained over the sample. In other words, stationarity can be broadly interpreted as implying non-convergence in the UID. From Table 2, it can be seen that a unit root can be rejected for all cases (weakly in Korea) except Malaysia, where there is some evidence of a downward trend and additional non-stationarity. This is in line with the tentative conclusion drawn from eyeballing the data in Section I. It is also logically consistent with the fact that, unlike Thailand and the other countries, inflows to Malaysia predominantly took the form of relatively more durable and interest-insensitive direct investment (70 percent of total capital flows on average).

III.3 OLS test

The empirical assessment in this paper centers on the examination of the effects of international capital flows on the domestic interest rate and whether this

Table 2 Augmented Dickey–Fuller Tests for UIDs

	<i>ADF with trend</i>		<i>ADF with no trend</i>	
	<i>Levels</i>	<i>1st differentials</i>	<i>Levels</i>	<i>1st differentials</i>
Korea	-3.26*	-9.76***	-2.86*	-9.71***
Thailand	-4.70***	-10.51***	-4.73***	-10.57***
Indonesia	-3.70**	-7.95***	-3.73***	-7.96***
Malaysia	-2.36	-6.85***	-2.25	-6.55***
Philippines	-4.96***	-14.63***	-4.70***	-14.70***

Note: *, **, ***Significance at the 10%, 5% and 1% level, respectively.

might be responsible for the non-convergence of the UIDs in the crisis-hit economies in Asia. The first step of the empirical analysis is to estimate Equation (9) using OLS.⁸ These results are presented in Table 3. The coefficient of most interest in our study is that for Δf_t . As seen in Table 3, the coefficients are close to zero (two decimal points) for all cases and are statistically significant for Korea and Malaysia, weakly significant (11%) for the case of Indonesia and insignificant for Thailand and the Philippines. This suggests that capital inflows have a negligible effect on the UID. As explained above, this could be due to high sterilization levels or high capital mobility. The estimates provide some evidence that capital mobility is high because the coefficients for i^* (which equates to $(1 - \psi)$ under Equation 9) is, for the most part, quite low. High sterilization levels might also be plausible explanatory factors, as suggested by the analytical model developed previously. (Sterilization coefficients are estimated separately and presented in Section IV below.)

III.4 Granger causality test

While the results for Equation (9) are informative, the major issue with its estimation is the endogeneity of a number of variables (such as capital flows and income). This issue arises from the literature on sterilization (see Ouyang et al. (2006) and references cited within). One way of overcoming the simultaneity bias is by augmenting Equation (9) with expressions for the other variables in the equation for the purposes of conducting Granger causality tests.

The Granger causality tests are conducted to ascertain the lagged effects of capital inflow changes (through foreign reserves, Δf) on UID. Three lag structures are considered; namely 3, 6 and 12 months. Only the null hypothesis that Δf Granger causes the UIDs is considered. The results of the Granger causality tests (Table 4) reveal that, with the exception of Korea, there is evidence to suggest the possibility of reserve changes causing UIDs. For Indonesia and the Philippines, the effect seems to be present over longer lag lengths (12 and 6 months for Indonesia and 12 months for the Philippines). The effect for Thailand is at its strongest for shorter lag lengths (3 and 6 months). The relationship appears to be significant across all reported lag lengths for Malaysia.

Further discussion of the OLS and Granger test would be useful.⁹ For Korea, the contemporaneous relationship between Δf and UID given by the OLS results are quite significant, while the Granger causality results are weak. Given the

8. To supplement the unit root tests for the UIDs in Table 2 and to further inform the reader about the nature of the OLS results of Equation (9), we provide ADF tests for all variables that appear in Equation (9) in Appendix I.

9. A caveat is in order. The OLS and causality results are not directly comparable in that the OLS results yield contemporaneous relationships between reserves and UIDs, while the causality results present lagged relationships. As such, it is our view that although the results are not directly comparable, they complement each other.

Table 3 OLS Estimates, Equation (9)

	Thailand	Korea	Indonesia	Malaysia	Philippines
Constant	-63.43 (-1.25)	18.31 (1.93)*	-9.28 (-0.61)	-3.23 (-0.65)	106.14 (3.06)***
it^*	0.10 (0.42)	0.02 (0.20)	0.09 (0.68)	0.14 (2.50)**	-1.06 (-1.56)
Δf_t	0.05 (0.46)	-0.00 (-1.88)*	0.00 (1.61)	-0.00 (-3.42)***	-0.01 (-0.04)
m_{t-1}	-8.51 (-1.36)	-5.99 (-4.18)***	3.28 (0.96)	-0.34 (-1.31)	4.04 (0.63)
Π_{t+1}^e	0.40 (1.64)	-0.36 (-3.37)***	-7.62 (-3.06)***	0.05 (0.73)	-0.63 (-2.19)**
p_t	24.41 (1.34)	12.28 (2.36)**	-8.19 (-0.96)	1.05 (0.65)	-30.27 (-1.48)
y_t	0.03 (0.00)	-2.28 (-0.92)	3.53 (0.78)	0.24 (0.46)	6.23 (0.67)
UID_{t-1}	0.50 (5.63)***	0.67 (10.33)***	0.66 (5.80)***	1.09 (31.39)***	0.06 (0.40)
Adjusted R^2	0.35	0.80	0.58	0.97	0.23
DW	1.68	1.89	1.94	2.11	2.06
Observations	86	86	86	86	86
Jacque-Bera Test	0.39 (0.82)	1.84 (0.40)	64.12 (0.00)	3.13 (0.21)	199.74 (0.00)
Serial Correlation LM Test	4.41 (0.04)	0.26 (0.61)	0.07 (0.80)	0.33 (0.57)	0.44 (0.50)
ARCH Test	0.22 (0.44)	0.48 (0.49)	25.77 (0.00)	0.58 (0.45)	0.41 (0.52)
Ramsey RESET	0.61 (0.44)	0.11 (0.74)	3.31 (0.07)	0.31 (0.58)	0.06 (0.82)

Notes: Dependent variable: UID_t . Diagnostic tests include p -value in parentheses. Lagged dependent variable included to soak up serial correlation that may bias estimates. F -statistics used for serial correlation test, ARCH test and Ramsey test. *, **, ***Significance at the 10%, 5% and 1% level, respectively.

Table 4 Granger causality tests

	<i>Lags</i>	<i>F</i>	<i>Prob</i>
Korea	12	1.12	0.37
	6	0.74	0.62
	3	0.69	0.56
Thailand	12	1.15	0.34
	6	2.22	0.05
	3	4.34	0.01
Indonesia	12	2.05	0.04
	6	0.72	0.63
	3	0.29	0.83
Malaysia	12	2.90	0.00
	6	5.17	0.00
	3	4.15	0.01
Philippines	12	1.55	0.14
	6	1.12	0.36
	3	0.06	0.98

Note: Null hypothesis: Reserve changes, Δf , do not Granger cause UID. These tests are calculated in a multivariate framework incorporating all the variables in Equation (9).

insignificance of the coefficient for i^* , this suggests that sterilization might have an impact on the UID quite quickly in that country.¹⁰ The opposite is the case for Thailand, implying that sterilization might take 3–6 months to show an effect upon UID. For Malaysia both the OLS and Granger results are strong. This suggests that sterilization has an immediate and persistent effect through to 12 months as tested. The results for Indonesia and the Philippines tend to suggest that the effect is confined to longer lag lengths because the OLS results are either not significant (Philippines) or marginally significant (Indonesia).

IV. Direct Estimation of Monetary Sterilization

The preceding analysis suggests that it is not apparent that persistent international capital inflows led to declines in the UIDs in the Asian region before the crisis. But how much was this due to monetary sterilization? While some indicative estimates of the extent of sterilization have been offered in Section III,

10. Of course, this is assuming that the zero coefficient for Δf is due to sterilization.

this section estimates sterilization coefficients more explicitly. To be sure, the extent of sterilization (λ) can be more formally ascertained from the following equation:

$$\Delta d_t = \theta + \lambda \Delta f_t + \varepsilon_t. \quad (10a)$$

For full sterilization, λ would be expected to be equal to -1 . However, Equation (10a) reveals information only about contemporaneous sterilization. It does not allow for the possibility that the monetary authority may adjust reserve changes more gradually (Glick and Hutchison, 2000). As such, a lagged term for foreign reserves is included into the regression equation. A positive sign might be taken to mean that the central bank is correcting a perceived over-sterilization; a negative sign may imply that the central bank is attempting to gradually sterilize a reserve inflow over two periods. As such we estimate:¹¹

$$\Delta d_t = \lambda_0 + \lambda_1 \Delta f_t + \lambda_2 \Delta f_{t-1} + \varepsilon_t. \quad (10b)$$

The OLS results from estimating Equation (10b) are summarized in Table 5. It is clear that there is a moderate to high degree of sterilization among the countries considered, and that the λ_1 parameter is generally statistically significant. Indonesia's sterilization coefficient is approximately -0.78 over the sample period, while the coefficient for the Philippines is -0.92 . The sterilization coefficient for Korea is less than -1 . This indicates that there may have been 'over-sterilization' throughout the sample period. The Wald (F) test is also used to examine whether $\lambda_1 = -1$. The results are presented in Table 5. Interestingly, Korea is the only case where the null hypothesis of $\lambda_1 = -1$ is not rejected. The others all indicate a rejection of the null despite point estimates of λ_1 being very near -1 for Thailand, Malaysia and the Philippines. The incorporation of a lagged term for foreign reserves reveals evidence of a possible correction to the over-sterilization in the second period. The sterilization coefficient for Thailand is also fairly high at -0.91 . Interestingly, for both Indonesia and Thailand, the lagged effect (λ_2) is also economically and statistically significant (-0.56 and -0.39 , respectively), suggesting a possible scenario of sterilization 'smoothing'.¹²

11. Estimation of single-equation models as in Equation (10a) and (10b) is consistent with most studies attempting to empirically investigate sterilization. For instance, Glick and Hutchison (1994) and Kwack (1994) estimate various versions of Equation (12) for Japan and Korea, respectively. Also see Fane (2000) for a list of sterilization coefficients for a selection of emerging economies for the pre-crisis period. More systematic attempts at estimating sterilization coefficients would require controlling for possible simultaneity between capital flows, reserves and UIDs (for instance, see Ouyang et al. (2006)).

12. The sterilization coefficients reported above are constant over the sample period averages. As part of robustness testing we also conducted rolling regressions *a la* De Koning and Straetmans (1997). For the most part the results show that reserve inflow sterilization was fairly constant for Thailand, the Philippines and Malaysia. Indonesia's sterilization policy seemed to ease and the coefficients for Korea are quite variable. These results are available on request.

Table 5 Extent of monetary sterilization

	<i>Korea</i>	<i>Thailand</i>	<i>Indonesia</i>	<i>Malaysia</i>	<i>Philippines</i>
Constant	9.62 (0.56)	1.05 (3.15)***	35.22 (3.21)***	65.82 (2.25)**	0.61 (2.55)**
<i>Net Foreign Assets (t)</i>	-1.11 (-3.80)***	-0.91 (-8.65)***	-0.77 (-7.19)***	-0.94 (-13.52)***	-0.98 (-11.06)***
<i>Net Foreign Assets (t-1)</i>	0.07 (0.28)	-0.56 (-4.95)***	-0.40 (-2.92)***	-0.06 (-0.43)	-0.33 (-2.52)**
<i>Adjusted R</i> ²	0.25	0.57	0.61	0.38	0.49
DW	2.21	1.98	2.02	1.98	2.00
Observations	86	85	85	86	86
Wald Test for Ho: $\lambda = -1$	0.39 (0.54)	37.46 (0.00)	10.93 (0.00)	5.21 (0.03)	45.17 (0.00)
Jacque-Bera Test	9.36 (0.01)	11.55 (0.003)	25.94 (0.00)	63.65 (0.00)	1.35 (0.51)
Serial Correlation LM Test	8.10 (0.01)	0.001 (0.97)	1.64 (0.20)	0.17 (0.68)	0.32 (0.57)
ARCH Test	0.06 (0.81)	0.18 (0.67)	5.27 (0.02)	0.03 (0.85)	1.10 (0.30)
Ramsey RESET	1.94 (0.17)	1.08 (0.30)	3.92 (0.05)	0.39 (0.53)	0.03 (0.86)

Notes: Dependent variable: change in net domestic assets, ΔNDA . Wald test and diagnostic tests include p -value in parentheses. F statistics used for serial correlation test, ARCH test and Ramsey test. *, **, ***Significance at the 10%, 5% and 1% level, respectively.

V. Concluding Remarks

The first set of empirical results in this paper suggests that the large-scale capital inflows into Korea, Malaysia and the Philippines before the crisis had no discernible impact on domestic interest rates thus leading to persistent UID, which in turn motivated further capital inflows. The simple analytical model presented in this paper clearly emphasizes that the reasons for this may be because of complete sterilization, perfect capital mobility, significantly sluggish response of interest rates to domestic monetary disequilibrium, or some combination of all three. The second set of empirical results in this paper reveals that monetary sterilization was incomplete/partial in Indonesia, this being consistent with the finding that foreign capital flows did have gradual downward pressure on the countries' UIDs. Initial regression results indicate that there may have been complete or almost complete sterilization on average in the other Asian economies (Korea, Malaysia, Thailand and the Philippines).

The foregoing in turn implies that one may need to look elsewhere for the reason behind the seeming lack of impact of capital flows on UIDs in some of these countries. Accordingly, a full explanation of the interest rate premium puzzle probably lies elsewhere. But where? Imperfect capital mobility (including imperfect asset substitutability) is no doubt part of the reason. But there is also the other element of imperfect or rigid adjustment of interest rates to domestic monetary disequilibrium. In their, now prescient, review of capital flows and the domestic financial sectors in East Asia, Folkerts-Landau and Associates (1995) drew the following conclusion:

The ability of banks to accumulate foreign liabilities or domestic liabilities denominated in foreign currency was improved as part of the early deregulation process. Capital inflows were . . . encouraged by the relatively high interest rates that prevailed in the region. Although specific causes differed among countries, high interest rates were a direct result of such factors as monetary tightening, interest rate deregulation, the encouragement of competition among financial institutions, and the relatively high costs of intermediation (p. 41).

Clearly there is a need to pay greater heed to domestic banking structures in emerging economies and the manner in which capital flows is intermediated via the banking system if one is to understand pre-crisis capital inflows surges. While many of these economies have moved to somewhat more flexible exchange rate regimes since the crisis of 1997–1998, there is ample evidence to suggest a high degree of exchange rate management by the central banks and resultant sterilization of capital flows (Ouyang et al., 2006; Rajan and Vostroknutova, 2006). There are signs that history is repeating itself.

Appendix I ADF Test Results for Variables in Equation (9)

	Δf	m	π	y	p	i^*	Residuals
Korea	-9.71***	2.39	-3.32**	-1.57	-3.76**	-1.51	-8.71***
	-7.45***	-12.40***	-6.61***	-4.07***	-7.06***	-5.79***	-8.11***
Thailand	-8.03***	-5.73***	-1.33	-5.45***	-2.39	-2.33	-7.70***
	-7.69***	-7.56***	-8.79***	-7.79***	-8.39***	-5.68***	-13.61***
Indonesia	-5.85***	-1.68	0.68	-3.57***	-3.18***	-1.71	-9.06***
	-9.61***	-11.56***	-3.95**	-16.11***	-2.24**	-5.81***	-7.96***
Malaysia	-6.16***	-2.51	-1.69	-2.50	-2.00	-1.72	-9.78***
	-10.39***	-10.20***	-8.59***	-13.07***	-9.16***	-5.88***	-10.02***
Philippines	-5.55***	-3.73**	-2.34	-5.96***	-0.92	-1.71	-9.32***
	-10.66***	-11.21***	-6.85***	-9.36***	-8.21***	-6.04***	-15.23***

Notes: The first (second) row refers to the ADF test for levels (differences) of each variable. The ADF test for the residuals represents the Engle–Granger Test when the uncovered interest differential (UID) is the dependent variable. *, ** and *** indicate significance at the 10%, 5% and 1% level, respectively.

References

- De Koning, C. and S. Straetmans, 1997, Variation in the slope coefficient of the Fama regression for testing uncovered interest parity: Evidence from fixed and time-varying coefficient approaches. Discussion Paper 97-014, Tinbergen Institute, Amsterdam.
- Dooley, M. and D. Mathieson, 1994, Exchange rate policy, international capital mobility, and monetary policy instruments. In: *Exchange Rate Policy and Interdependence: Perspectives from the Pacific Basin* (eds Glick R. and Hutchison M.), pp. 68–95. Cambridge University Press, New York.
- Edwards, S. and M. Khan, 1985, Interest rate determination in developing countries. *IMF Staff Papers*, **32**, pp. 377–403.
- Fane, G., 2000, *Capital Mobility, Exchange Rates and Economic Crises*. Edward Elgar, Cheltenham.
- Folkerts-Landau, D. and Associates, 1995, Effects of capital flows on the domestic financial sectors in APEC developing countries. In: *Capital Flows in the APEC Region. Occasional Paper No. 122* (eds Khan M. and Reinhart C.), pp. 31–57. International Monetary Fund, Washington, DC.
- Glick, R. and M. Hutchison, 1994, Monetary policy, intervention and exchange rates in Japan. In: *Exchange Rate Policy and Interdependence: Perspectives from the Pacific Basin* (eds Glick R. and Hutchison M.), pp. 255–257. Cambridge University Press, New York.
- Glick, R. and M. Hutchison, 2000, Foreign reserve and money dynamics with asset portfolio adjustment: International evidence. *Journal of International Financial Markets, Institutions and Money*, **10**, pp. 229–47.
- Haque, N. and P. Montiel, 1991, Capital mobility in developing countries: Some empirical tests. *World Development*, **19**, pp. 705–9.
- Hutchison, M., 2003, Intervention and exchange rate stabilization policy in developing countries: The role of sterilized intervention in exchange rate stabilization policy. *International Finance*, **6**, pp. 109–27.
- Kwack, S., 1994, Sterilization of the monetary effects of current account surpluses and its consequences: Korea 1986–1990. In: *Exchange Rate Policy and Interdependence: Perspectives from the Pacific Basin* (eds Glick R. and Hutchison M.), pp. 287–313. Cambridge University Press, New York.

- Kwack, S., 2003, An empirical assessment of monetary policy responses to capital inflows in East Asia before the crisis. *International Economic Journal*, **15**, pp. 95–113.
- McLeod, R., 1998, Indonesia. In: *East Asia in Crisis: From Being a Miracle to Needing One*. (eds McLeod R. and Garnaut R.), pp. 31–48. Routledge, London.
- Ouyang, A., R. Rajan and T. Willett, 2006, Managing the monetary consequences of reserve accumulation in Asia. Mimeo, School of Public Policy, George Mason University, Arlington, VA.
- Rajan, R., 2001, (Ir)relevance of currency-crisis theory to the devaluation and collapse of the Thai baht. *Princeton Studies in International Economics No. 88*, International Economics Section, Princeton University, Princeton.
- Rajan, R. and R. Siregar, 2002, Private capital flows in east Asia: Boom, bust and beyond. In: *Financial Markets and Policies in East Asia*, (ed. de Brouwer G.), pp. 47–81. Routledge, London.
- Rajan, R. and E. Vostroknutova, 2006, Growing and managing risks through capital flows. Mimeo, The World Bank, Washington, DC.
- Reisen, H., 1993, Macroeconomic policies towards capital account convertibility. In: *Financial Opening: Policy Issues and Experiences in Developing Countries*, (eds Reisen, H. and Fischer B.), pp. 43–55. OECD, Paris.
- Takagi, S. and T. Esaka, 1999, Sterilization and the capital inflow problem in East Asia, 1987–8. Discussion Paper No. 86, Economic Planning Agency, Tokyo.
- Warr, P., 1998, Thailand. In: *East Asia in Crisis: From Being a Miracle to Needing One*. (eds McLeod R. and Garnaut R.), pp. 49–65. Routledge, London.
- Willett, T., M. Keil and S. A. Yung, 2002, Capital mobility for developing countries may not be so high. *Journal of Development Economics*, **68**, pp. 421–34.