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Abstract

The huge increase in international reserve holdings by Asian countries since the 1997 crisis has been one of the most important recent developments on the international financial scene. These buildups have contributed substantially to concerns about the creation of excessive global liquidity. How justified these concerns are depends heavily on the extent to which the reserve accumulating countries have been able to sterilize the effects on their domestic monetary aggregates. We use a unified theoretical framework to undertake dynamic estimations of the magnitude of sterilization and offset coefficients (which measure the degree of capital mobility) for a large set of Asian economies. We find that despite substantial capital mobility there has been a high degree of effective sterilization to date.

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1. Introduction

Asia accounted for over half of global international reserve holdings during the period 1999-2005, up from one third in the period 1990-1995 (Kharas et al., 2006).[1] While China and Japan have been the main drivers of the massive stockpiling of reserves in the region, India, the Newly Industrializing Economies or NIEs (Hong Kong, Korea, Singapore and Taiwan), and some middle-income ASEAN economies have also experienced significant swelling of their reserves since the crisis (Figure 1).

For Korea and other regional economies that were hit by the crisis, policy makers appear to have chosen explicitly to amass high levels of reserves for precautionary or self-insurance motives against future financial crises (Aizenman and Marion, 2003 and Bird and Rajan, 2003).[2] Reserve accretion as a financial safeguard is consistent with modern second generation (escape clause-based) currency crisis models *àla* Obstfeld (1986, 1994).[3] However, many Asian countries have continued accumulating reserves well beyond plausible precautionary levels.

Some have argued that the reserve growth in emerging Asia more recently is a by-product of a desire by central banks to smooth exchange rate movements, but smoothing behavior by central banks should, in general, have no net impact on reserves over time. The continued build-up of reserves suggests that intervention is largely asymmetric and that it stems largely from a desire to maintain relatively stable and/or "ultra-competitive" exchange rates.[4] A number of commentators have expressed concerns that such large-scale intervention runs a serious risk of generating increases in inflation in the intervening countries, and some have even suggested that such reserve accumulations have played a major role in the creation of excessive global liquidity. Key to such issues is the extent to which monetary authorities can successfully sterilize the domestic monetary effects of reserve accumulation. Most monetary models of the exchange rate and balance of payments assume no sterilization so that large reserve accumulations would automatically lead to rapid growth in domestic money and credit. Sufficiently high levels of

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1 See Genberg et al. (2005) for more detailed descriptive data of reserve stockpiling in Asia.

2 There has been a growing body of literature exploring various aspects of the precautionary motive for reserve hoarding. See Aizenman et al. (2007), Garcia and Soto (2004), Jeanne and Ranciere (2006), Kim et al. (2005) and Li and Rajan (2006).

3 As noted by the Bank of Thailand (2005):

> "For a while after the 1997 crisis, accumulating foreign exchange reserve was another important consideration for exchange rate management. A strong stock of reserve helps to minimize external vulnerability and increase confidence in the economy, especially among foreign investors (p. 280)."

A similar point has been made regarding Korea:

> "Since adoption of the free floating exchange rate system, the Korean authorities have actively endeavoured to achieve stabilisation of the foreign exchange market. In the process of overcoming the currency crisis, the Korean authorities tried to expand the nation's international reserves (Rhee and Lee, 2005, p. 204)."

The importance of intervention in order to accumulate reserves comes out clearly from the survey of selected central banks by Mihalijek (2005).

4 See, for example, Willett and Kim (2006). Of course, if an economy has been maintaining a fairly stable and rigid exchange rate peg like China and Hong Kong without there being opportunistic devaluations, it may be inappropriate to characterize that as being mercantilist. With regard to the supposed floaters in emerging Asia, there is evidence that they continue to actively manage their currencies vis-à-vis the US dollar even post 1998 (see Cavoli and Rajan, 2006b, Rajan, 2006, Willett et al., 2005, and McKinnon and Schnabl, 2004). In addition, part of the change in reserves in US dollar terms arises from "revaluation gains" due to the depreciation of the US dollar against the major currencies in which reserves might be held, especially the euro.

international capital mobility would make effective sterilization impossible, no matter the intensity of efforts of the domestic monetary authorities. In recent research (Ouyang, Rajan, and Willett, 2007), we analyzed these issues for China and found that they had been able to effectively sterilize a high proportion of their recent reserve increases. China has substantial capital controls, however, so the People's Bank of China's ability to sterilize would not necessarily carry over to the other Asian economies. In this paper we extend our analysis.

The aim of this paper is to investigate the extent of monetary sterilization and the degree of capital mobility to eight Asian economies: ASEAN-4 (Indonesia, Malaysia, Philippines, Thailand), India, Korea, Singapore, and Taiwan.[5] While Indonesia, Korea, Philippines, and Thailand have all implemented open economy inflation targeting regimes (open economy in the sense of there being a role for exchange rate management as well), India, Singapore, and Taiwan operate managed floating regimes, a policy also adopted by Malaysia since July 2005 (Table 1 and Rajan, 2006).[6]

The remainder of the paper is organized as follows. Section 2 offers a brief overview of the evolution of the balance of payments in the eight emerging Asian economies and a first look at the extent of monetary sterilization. Section 3 outlines a set of simultaneous equations to examine the feedback effects between net domestic assets (*NDA*) and net foreign assets (*NFA*) as a means of estimating the extent of *de facto* sterilization (sterilization coefficient) and capital mobility (offset coefficient) concurrently. The theoretical foundations of the equations to be estimated are based on a modified version of a model originally outlined by Brissimis-Gibson-Tsakalotos (2002). Section 4 offers an overview of the data and definitions of variables to be used in the empirics. This section also discusses the empirical results of the sterilization and offset coefficients based on quarterly data for the period 1990:q1 to 2005:q3. We divide the whole sample period into two sub-samples: the pre-crisis period (defined as 1990:q1 to 1997:q1), and the post-crisis period (defined as 1998:q3 to 2005:q3).[7] By comparing the different values of offset and sterilization coefficients in these two sub-samples we are able to ascertain how the extent of sterilization and degree of capital mobility has changed in the two periods for the emerging Asian economies under consideration. We also conduct a recursive estimation to investigate the dynamic change of estimated offset and sterilization coefficients. Given the limited observations for each country our estimations are based on a panel. Section 5 concludes the paper.

2. Balance of Payments Dynamics and Sterilization in Emerging Asia: A First Look

The sharp switch from current account deficit to surplus for emerging Asia as a group has been well documented and is apparent from Table 2. An aggregate current account deficit which averaged $40 billion in 1995-1996 turned into a surplus of over $100 billion in 1998-1999 and more than doubled

[5] Our focus is on emerging Asian economies. Japan was not considered since it stopped large-scale intervention in 2004.

[6] We have excluded Hong Kong from the empirical analysis as the theoretical framework to be used as motivation for the empirics (Section 3) is somewhat more appropriate for quasi-flexible / managed exchange rate regimes. In any event, Hong Kong does not appear to use monetary instruments to sterilize reserve buildup (Mohanty and Turner, 2005 and Pang, 2005).

[7] We exclude the period 1997:q2 - 1998:q2 as this is broadly the period of crisis and acute monetary, exchange rate and financial instability in the region. The dating corresponds to Khalid and Kawai (2003) who identify July 1997 to June 20, 1998 as the currency crisis period in Asia. (Indonesia is the possible exception to this).

by 2005.[8] While this abrupt turnaround in the current account has been the main reason for the reserve accretion in emerging Asia immediately after the 1997-1998 crisis, there has also been a resurgence in net private capital flows to the emerging Asian region.[9] The combination of current account surplus and renewed private capital inflows, along with active exchange rate management by the regional central banks, have contributed to the rapid and significant reserve buildup in emerging Asia in recent years.

What are the monetary consequences of this reserve accretion? Referring to Figure 2, it appears that central banks in the eight emerging Asian economies under consideration have been actively neutralizing the impact of the reserve buildup in the sense that the NDA (which is broadly a proxy for domestic credit), has been moving in the opposite direction of NFA (which is broadly a proxy for foreign reserves).[10] The two most commonly used instruments for monetary sterilization are open market operations (OMOs) and changes in legal reserve requirements (see Mohanty and Turner, 2005 for details). However, the emerging Asian central banks have also employed a number of other tools such as shifting public sector or pension funds from commercial banks to the central banks, adjusting discount rates, setting the restricted lending policy, or capital controls. Table 3 summarizes the main monetary and fiscal instruments used by some of the emerging Asian economies.

Since the foreign exchange and the domestic monetary markets are tightly interrelated, it is important to recognize the contemporaneous relationship between net domestic assets (*NDA*) and net foreign assets (*NFA*), failing which there will be a "simultaneity bias". In other words, both the "sterilization coefficient" (i.e. how much domestic credit changes in response to a change in international reserves) and the "offset coefficient" (i.e. how much the balance of payments changes in response to a change in domestic credit) need to be estimated simultaneously (Argy and Kouri, 1974 and Obstfeld, 1982). The typical model specification for a set of simultaneous equations is:

$$\Delta NFA_t = \alpha_0 + \alpha_1 \Delta NDA_t + X_1'\delta_1 + u_{1t} \quad (3a)$$

$$\Delta NDA_t = \beta_0 + \beta_1 \Delta NFA_t + X_2'\delta_2 + u_{2t} \quad (3b)$$

where: X_1 and X_2 are the vector of controls in the balance of payments function and monetary reaction function, respectively.[11] The coefficient α_1 in eq. 3a is the "offset coefficient", i.e. impact of a change in domestic liquidity conditions on capital flows. The expected value of the offset coefficient is bound by 0 in the event of no capital mobility, and -1 in the event of perfect capital mobility. The coefficient β_1 in eq. 3b is the "sterilization coefficient". The expected value of the sterilization coefficient is -1 if reserve buildup is perfectly sterilized and 0 if the central bank does not sterilize at all. In general, the greater the degree of capital mobility the less effective is monetary sterilization; a small offset coefficient and large sterilization coefficient are usually viewed as the central bank having a fairly high degree of monetary policy independence to neutralize the impact of capital flows effectively on a sustained basis.

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8 Needless to say that aggregates vary between countries. For instance, in ASEAN and the NIEs, the current account switch has largely been due to a collapse in investment rates. While investment rates in China have remained high, the current account surplus in China is primarily fuelled by rising savings rates (especially corporate savings) (see Kharas et al., 2006 and references cited within).

9 See Kharas et al. (2006) and IMF (2006) for recent discussions of capital flows in emerging Asia.

11 For instance, see Celasun et al. (1999), Fry (1993), Kim (1995), Nyatepe and Coo (1995), Sarjito (1996), Rooskareni (1998) and Brissimis, Gibson, and Tsakalotos (2002).

3. Theoretical Basis for the Simultaneous Equations

An obvious concern with estimating eqs. 3a and 3b is the choice of control variables. Most existing empirical studies have chosen control variables based on informal theorizing. One exception is the paper by Brissimis-Gibson-Tsakalotos (BGT) (2002), which develops a formal theoretical model from which the foregoing set of simultaneous equations are derived from explicit minimization of a simple loss function of the monetary authority, subject to a number of constraints that reflect the workings of the economy. We modify the BGT in four important ways.

One, unlike the original BGT model which assumes that the central bank is concerned about the deviation of the exchange rate from a target *level* and therefore incorporates the exchange rate in the loss function directly, we assume instead that the central bank is primarily concerned with exchange rate *volatility*.[12] Undoubtedly most central banks are concerned with both, but it is much less difficult to operationalize exchange-rate volatility than the target exchange rate. Two, unlike the original BGT model we assume that the exchange rate impacts inflation directly via pass through. In other words, the monetary authority is not concerned about the exchange rate for its own sake, but rather because of its impact on inflation and trade. Three, we endogenize the current account by assuming it is affected by both income and price (exchange rate) effects. Four, we also incorporate the role of government spending on cyclical output. These modifications are broadly consistent with the managing floating regimes operated by many emerging Asian economies.[13]

3.1 A Simple Model

In our modified version of the BGT model the loss function of the monetary authority is:

$$L_t = \beta(\Delta p_t)^2 + \gamma(Y_{c,t})^2 + \delta(\sigma_{r,t})^2 + \varepsilon(\sigma_{s,t})^2 \quad (4)$$

12 For instance in the case of Thailand the central bank has noted:

> Since 2 July 1997, Thailand has adopted a managed-float exchange rate regime, replacing the basket-peg regime which had been in operation since 1984. The value of the baht has since then been largely determined by market forces. The Bank of Thailand manages the exchange rate by intervening in the foreign exchange market from time to time in order to prevent excessive volatilities in the markets, while fundamental trends are accommodated. In other words, movements in the exchange rates which are in line with the changes in economic fundamentals and financial development would only be smoothed and not resisted (BOT, 2005, p.276).

A broadly similar point is noted in the case of Korea:

> Considering Korea's thin foreign exchange market as a small open economy, and the vulnerability of the won exchange rate to diverse external shocks and the changing global environment, the Korean authorities' efforts to stabilise the exchange rate could be regarded as inevitable (Rhee and Lee, 2005, p.205).

Also see the survey of selected central banks by Mihaljek (2005).

13 Even in the case of Singapore which is a basket pegger, Cavoli and Rajan (2007) show that the central bank loss function can be modeled in terms of output and inflation, the only difference being that they use the nominal effective exchange rate (NEER) rather than the interest rate as the policy instrument (also see Khor et al., 2004).

The monetary authority's loss function is determined by the change in the logarithm of the price level (i.e. the difference in p_t and p_{t-1}); cyclical income ($Y_{c,t}$); and the volatilities of the interest rate ($\sigma_{r,t}$) and the exchange rate ($\sigma_{s,t}$). All the parameters are assumed to be positive.

The evolution of key variables including inflation and cyclical income is discussed below.

a) Inflation

The evolution of inflation can be written as follows:

$$\Delta p_t = \pi_1[(\Delta NFA_t + \Delta NDA_t)mm_t + MB_t \Delta mm_t] + \pi_2 \Delta p_{t-1} + \pi_3 \Delta s_t \quad \text{[14, 15]} \tag{5}$$

where: $\pi_1 > 0, 0 < \pi_2 < 1, \pi_3 > 0$, MB_t is the monetary base and mm_t is the money multiplier. Eq. 5 states that inflation is a monetary phenomenon with a lagged effect. In addition, depreciation of the nominal exchange rate (rise in s_t) could increase inflationary pressures due to increased prices of tradeable goods.

b) Cyclical income

The evolution of cyclical income can be written as follows:

$$Y_{c,t} = \varphi_1[(\Delta NFA_t + \Delta NDA_t)mm_t + MB_t \Delta mm_t] + \varphi_2 Y_{c,t-1} + \varphi_3 \Delta G_t \tag{6}$$

$$\varphi_1 > 0,\ 0 < \varphi_2 < 1, \varphi_3 > 0$$

where: G_t is the government expenditure.[16] We assume that both expansionary fiscal and monetary policies can boost cyclical output.

c) Balance of Payments

The balance of payments is defined as usual (ignoring errors and omissions):

$$\Delta NFA_t = CA_t + \Delta NK_t \tag{7}$$

[14] While one should ideally use nominal effective exchange rate (NEER), we use bilateral US dollar rates as it substantially eases model solution. In any event, insofar as the bulk of trade in Asia is US dollar denominated, we probably do not lose much in terms of generality by using nominal bilateral rather than effective rates.

[15] It is possible that a change in capital flows will cause a change in the money multiplier (for instance, see Rajan, 2007). More generally one might think about specifying a separate equation endogenizing the money multiplier (Jha and Rath, 2001).

[16] More precisely, one would want to use a measure of broader fiscal stance, viz. full employment primary fiscal balance. As Athukorala and Rajapatirana (2003) note:

> (A) measure widely used to represent a fiscal policy stance in this type of analyses is the budgetary balance (measured as a ratio of GDP). But we believe that government expenditure is a superior indicator because in the context of an economic boom a country could well experience a 'revenue surplus', a reflection of a faster revenue growth compared to expenditure growth. Meaningful deficit comparison across countries should correct for such biases. Another problem with published data on budget deficits is that different definitions of taxation and borrowing can heavily skew the measured deficit.

where: *CA* is the current account balance and ΔNK_t is the net capital inflow in time *t*.[17]

The current account in turn is assumed to depend simply on both cyclical output and the lagged real effective exchange rate (to capture inertial effects) in a linear manner:[18]

$$CA_t = \alpha_0 + \alpha_1 Y_{c,t} + \alpha_2 \Delta REER_{t-1},\ \alpha_1 < 0,\ \alpha_2 < 0 \tag{8}$$

where: *REER* is the real effective exchange rate (rise implies a currency appreciation).

The net capital inflow is assumed to depend imperfectly on the uncovered interest differentials:

$$\Delta NK_t = (1/c)\Delta(s_t - E_t s_{t+1} + r_t - r_t^*) \tag{9}$$

where: s_t is the current exchange rate (logarithm); $E_t s_{t+1}$ is the current expectation of the exchange rate at time $t+1$; r_t is the domestic interest rate; r_t^* is the foreign interest rate; and c represents the degree of substitutability between domestic and foreign assets, i.e. the degree of international capital mobility. This in turn is affected by the extent of capital controls.

The interest rate is determined by the change in money supply:

$$\Delta r_t = -\psi_1[(\Delta NDA_t + \Delta NFA_t)mm_t + MB_t \Delta mm_t] \quad \psi_1 > 0 \tag{10}$$

After substituting eqs. 6 to 10 into 9 we derive:

$$\begin{aligned}\Delta p_t &= (\pi_1 mm_t + c\pi_3 + \pi_3 c\alpha_1\varphi_1 mm_t + \pi_3\psi_1 mm_t)\Delta NFA_t \\ &\quad + (\pi_1 mm_t + \pi_3 c\alpha_1\varphi_1 mm_t + \pi_3\psi_1 mm_t)\Delta NDA_t \\ &\quad + (\pi_1 MB_t + \pi_3 c\alpha_1\varphi_1 MB_t + \pi_3\psi_1 MB_t)\Delta mm_t \\ &\quad + (\pi_3 c\alpha_1\varphi_2)Y_{c,t-1} + (\pi_2)\Delta p_{t-1} + (\pi_3 c\alpha_1\varphi_3)\Delta G_t + (\pi_3 c\alpha_2)\Delta REER_{t-1} \\ &\quad + (\pi_3)\Delta(r_t^* + E_t s_{t+1})\end{aligned} \tag{11}$$

d) Interest rate volatility

Interest rate volatility follows the original BGT model:

$$\sigma_{r,t} = \eta\sigma_{r,t-1} - \theta\,|\,\Delta NDA_t\,| \quad \eta,\theta > 0 \tag{12}$$

---

[17] In reality, the current account and capital account may not be completely independent. However, since the exact links are far from clear – for instance, high capital inflows could lead to trade liberalization to curb the inflationary effects or the domestic boom or does greater trade liberalization lead to intensified capital inflows – the assumption of independence may not be entirely inappropriate.

[18] There are, of course, many other ways one could model the current account (see Edwards, 2002 for a review). Given that our focus is on sterilization as opposed to the current account per se, a parsimonious modeling approach to the current account seems reasonable.

Interest rate volatility is assumed to depend negatively on the absolute amount of intervention undertaken by the central bank in the domestic money market. For estimation purposes eq. 12 is transformed into non-absolute terms. For example, the original BGT model assumes that the central bank injects liquidity ($\Delta NDA_t > 0$) to prevent an interest rate rise while the money market is in deficit. The same logic can be applied to the case when the money market is in surplus. When the money market is in surplus the central bank withdraws money to prevent interest rates from falling so that $\Delta NDA_t < 0$. Therefore, if the money market is in deficit, $\Delta NDA_t > 0$ and eq. 12 can be rewritten as follows:

$$\sigma_{r,t} = \eta\sigma_{r,t-1} - \theta(\Delta NDA_t - d_1\Delta NDA_t) \tag{12a}$$

where: d_1 is the dummy which takes on a value of 0 when the money market is in deficit and a value of 2 when it is in surplus.

e) Exchange rate volatility

Exchange rate volatility follows the original BGT model:

$$\sigma_{s,t} = \eta\sigma_{s,t-1} - \theta\,|\,\Delta NFA_t\,| \quad \eta,\theta > 0 \tag{13}$$

Exchange rate volatility depends negatively on the absolute amount of intervention undertaken by the central bank in the foreign exchange market.[19] Using the same logic as in the case of interest rate volatility we can redefine eq. 13 as follows:

$$\sigma_{s,t} = \kappa\sigma_{s,t-1} - \varsigma(\Delta NFA_t - d_2\Delta NFA_t) \quad \kappa,\varsigma > 0 \tag{13a}$$

where: d_2 is a dummy variable which takes on a value of 2 when there is an excess demand for foreign currency (and the central bank is losing reserves) and a value of 0 when foreign currency is in excess supply (and the central bank is stock-piling reserves).

As is typical of a managed floater we assume that the central bank consciously attempts to alter domestic credit (and thus interest rates) and undertakes foreign exchange rate intervention (i.e. managed float) with the aim of minimizing its loss function (eq. 4). It is important to keep in mind that since we are not attempting to specify a policy rule for the monetary authority it is reasonable to derive an equation for ΔNDA_t as opposed to interest rates (as in Cavoli and Rajan, 2006a for instance) despite most of the regional central banks having adopted the interest rate as the policy instrument. Estimating a set of simultaneous equations with ΔNDA_t and ΔNFA_t as dependent variables is more consistent with the literature.

Given this we can solve for $\partial L_t / \partial\Delta NDA_t$=0 and $\partial L_t / \partial\Delta NFA_t$=0, and after substituting the constraints into the loss function, we derive two reduced-form equations:

---

19 Given that we need daily data to compute a reliable within-the-quarter volatility measure, we use bilateral US dollar rates.

$$
\begin{aligned}
\Delta NFA_t = & -\{[\beta c\pi_3(\pi_1+\pi_3\psi_1+c\alpha_1\varphi_1\pi_3)mm_t+\beta(\pi_1+\pi_3\psi_1+c\alpha_1\varphi_1\pi_3)^2 mm_t^2+r\varphi_1^2 mm_t^2]/u_1\}\Delta NDA_t \\
& -\{[\beta c\pi_3(\pi_1+\pi_3\psi_1+c\alpha_1\varphi_1\pi_3)MB_t+\beta(\pi_1+\pi_3\psi_1+c\alpha_1\varphi_1\pi_3)^2 mm_t MB_t+r\varphi_1^2 mm_t MB_t]/u_1\}\Delta mm_t \\
& -\{[\beta\pi_2(\pi_3 c+(\pi_1+\pi_3\psi_1+c\alpha_1\varphi_1\pi_3)mm_t)]/u_1\}\Delta p_{t-1} \\
& -\{[\beta c\alpha_1\varphi_2\pi_3(\pi_3 c+(\pi_1+\pi_3\psi_1+c\alpha_1\varphi_1\pi_3)mm_t)+r\varphi_1\varphi_2 mm_t]/u_1\}Y_{c,t-1} \\
& -\{[\beta c\alpha_1\varphi_3\pi_3(\pi_3 c+(\pi_1+\pi_3\psi_1+c\alpha_1\varphi_1\pi_3)mm_t)+r\varphi_1\varphi_3 mm_t]/u_1\}\Delta G_t \\
& -\{[\beta c\alpha_2\pi_3(\pi_3 c+(\pi_1+\pi_3\psi_1+c\alpha_1\varphi_1\pi_3)mm_t)]/u_1\}\Delta REER_{t-1} \\
& -\{[\beta\pi_3(\pi_3 c+(\pi_1+\pi_3\psi_1+c\alpha_1\varphi_1\pi_3)mm_t)]/u_1\}\Delta(r_t^*+E_t s_{t+1}) \\
& -\{[\varepsilon\varsigma\kappa(d_2-1)]/u_1\}\sigma_{s,t-1}
\end{aligned} \tag{14a}
$$

where: $u_1=\beta[\pi_3 c+(\pi_1+\pi_3\psi_1+c\alpha_1\varphi_1\pi_3)mm_t]^2+r\varphi_1^2 mm_t^2+\varepsilon\varsigma^2(d_2-1)^2>0.$

$$
\begin{aligned}
\Delta NDA_t = & -\{[\beta c\pi_3(\pi_1+\pi_3\psi_1+c\alpha_1\varphi_1\pi_3)mm_t+\beta(\pi_1+\pi_3\psi_1+c\alpha_1\varphi_1\pi_3)^2 mm_t^2+r\varphi_1^2 mm_t^2]/u_2\}\Delta NFA_t \\
& -\{[\beta(\pi_1+\pi_3\psi_1+c\alpha_1\varphi_1\pi_3)^2 mm_t MB_t+r\varphi_1^2 mm_t MB_t]/u_2\}\Delta mm_t \\
& -\{[\beta\pi_2(\pi_1+\pi_3\psi_1+c\alpha_1\varphi_1\pi_3)mm_t]/u_2\}\Delta p_{t-1} \\
& -\{[\beta c\alpha_1\varphi_2\pi_3(\pi_1+\pi_3\psi_1+c\alpha_1\varphi_1\pi_3)mm_t+r\varphi_1\varphi_2 mm_t]/u_2\}Y_{c,t-1} \\
& -\{[\beta c\alpha_1\varphi_3\pi_3(\pi_1+\pi_3\psi_1+c\alpha_1\varphi_1\pi_3)mm_t+r\varphi_1\varphi_3 mm_t]/u_2\}\Delta G_t \\
& -\{[\beta c\alpha_2\pi_3(\pi_1+\pi_3\psi_1+c\alpha_1\varphi_1\pi_3)mm_t]/u_2\}\Delta REER_{t-1} \\
& -\{[\beta\pi_3(\pi_1+\pi_3\psi_1+c\alpha_1\varphi_1\pi_3)mm_t]/u_2\}\Delta(r_t^*+E_t s_{t+1}) \\
& -\{[\delta\theta\eta(d_1-1)]/u_2\}\sigma_{r,t-1}
\end{aligned} \tag{14b}
$$

where: $u_2=\beta[(\pi_1+\pi_3\psi_1+c\alpha_1\varphi_1\pi_3)mm_t]^2+r\varphi_1^2 mm_t^2+\delta\theta^2(d_1-1)^2>0.$

3.2 Interpreting the Simultaneous Equations

Eqs. 14a and 14b can be generalized as follows:

$$
\begin{aligned}
\Delta NFA_t^* = & \alpha_0-\sum_{i=0}^{n}\alpha_{1i}\Delta NDA_{t-i}^*+\sum_{i=0}^{n}\alpha_{2i}\Delta mm_{t-i}+\sum_{i=1}^{n}\alpha_{3i}(\Delta p_{t-i})+\sum_{i=1}^{n}\alpha_{4i}Y_{c,t-i}+\sum_{i=0}^{n}\alpha_{5i}\Delta G_{t-i} \\
& +\sum_{i=1}^{n}\alpha_{6i}\Delta REER_{t-i}+\sum_{i=0}^{n}\alpha_{7i}\Delta(r_{t-i}^*+E_t s_{t+1-i})+\sum_{i=1}^{n}\alpha_{8i}(d_2-1)\sigma_{s,t-i}+\varepsilon_t
\end{aligned} \tag{15a}
$$

$$
\begin{aligned}
\Delta NDA_t^* = & \beta_0-\sum_{i=0}^{n}\beta_{1i}\Delta NFA_{t-i}^*+\sum_{i=0}^{n}\beta_{2i}\Delta mm_{t-i}+\sum_{i=1}^{n}\beta_{3i}\Delta p_{t-i}+\sum_{i=1}^{n}\beta_{4i}Y_{c,t-i}+\sum_{i=0}^{n}\beta_{5i}\Delta G_{t-i} \\
& +\sum_{i=1}^{n}\beta_{6i}\Delta REER_{t-i}+\sum_{i=0}^{n}\beta_{7i}\Delta(r_{t-i}^*+E_t s_{t+1-i})+\sum_{i=1}^{n}\beta_{8i}(d_1-1)\sigma_{r,t-i}+\nu_t
\end{aligned} \tag{15b}
$$

where:

ΔNFA_t^* = The change in the adjusted net foreign assets scaled by the GDP (adjustments to be discussed in Section 4.2).

ΔNDA_t^* = The change in the adjusted net domestic asset scaled by the GDP.

Δmm_t = The change in money multiplier for M2.[20]

Δp_t = The change in consumer price index.

[20] We also tried the *M1* money multiplier but the results did not change much.

$Y_{c,t}$ = Cyclical income.[21]

ΔG_t = The change in government expenditure scaled by the GDP.

$\Delta REER_t$ = The change in the real effective exchange rate (REER).

$\Delta(r_t^* + s_{t+1}^e)$ = The change in foreign interest rate plus the expected nominal exchange rate (foreign currency per US$).[22]

σ_s = The standard deviation of the within quarter change in the bilateral US$ exchange rate.

σ_r = The standard deviation of the within quarter change in the monthly domestic interest rate (bank rate).

d_1 = A dummy which takes a value of 0 when the domestic money market is in deficit and a value of 2 when it is in surplus.

d_2 = A dummy which takes a value of 2 when there is an excess demand for foreign currency (and the central bank is losing reserves) and a value of 0 when foreign currency is in excess supply (and the central bank is stock-piling reserves).

The balance of payments function (eq. 15a) is essentially a combination of monetary and portfolio balance models and consists of seven control variables. One, a rise in the *M2* money multiplier increases the domestic money supply and pushes interest rates down, thus reducing the extent of capital inflows and reserve build-up. More generally a rising multiplier might also be capturing overall tightening of credit policy, including a more restrictive policy towards capital inflows. The monetary multiplier changed substantially for some of our sample, so its inclusion is important. Two, higher inflation generates concerns about exchange rate depreciation, interest rate hikes and capital losses thereof, hence causing a reduction in reserve accumulation.[23] Three, higher lagged real output could worsen the current account (due to the income effect), reducing foreign reserve accumulation. While not explicitly captured in the model, we should note that this variable is a double-edged sword in the sense that a cyclical upturn may act as a pull factor causing more capital to flow into the economy. As such, the prior expected sign of this variable is ambiguous. Four, an expansionary fiscal policy (higher government expenditure) will raise cyclical income and once again worsen the current account as discussed above. Five, foreign reserves will be decumulated due to a decrease in the current account if the lagged real effective exchange rate rises (price effect). The use of one period lags in REER, cyclical output, and inflation also reduce the possible endogeneity problems.[24] For instance, it could be argued that greater capital inflows and reserve buildup could lead to a domestic economic boom and an exchange rate appreciation (for instance, see Athukorala and Rajapatirana, 2003). Similarly, we use a one period lag of the government expenditure variable to account for the possibility that a contractionary fiscal policy may be a consequence of

21 Cyclical is defined as deviations from trend, where trend is based on the entire sample (i.e. pre- and post-crisis). For a more careful analysis of output gaps in the East Asian economies in our sample (i.e. excluding India) as well as Hong Kong, see Gerlach and Yiu (2004) who discuss various ways of measuring the output gap in emerging Asian economies that are undergoing significant structural changes. They find that various output gap measures, including estimates derived from the HP-filter rule, are quite highly correlated.

22 The exchange rate is in logarithm term.

23 Additionally, higher inflation could in practice engender greater uncertainty, leading to reduced capital flows, though using forward looking inflation and cyclical income in the estimations leads to concerns about causality as discussed above.

24 We tried more than one period lags but they were not significant.

capital inflows (i.e. fiscal tightening as an instrument of indirect sterilization) rather than the other way around.[25] Six, higher exchange rate expectations adjusted foreign interest rates can also lead to capital outflows from the country, hence reducing reserve build-up.[26] Finally, to reduce exchange rate volatility, the central bank tends to buy or sell foreign reserves (i.e. foreign exchange market intervention) when there is an excess supply or demand for foreign currency, respectively. The more volatile the exchange rates the heavier the degree of central bank intervention. Therefore, the expected sign for the interaction term should be negative.

The monetary policy function (eq. 15b) also consists of seven control variables in the monetary reaction function in addition to the change of net foreign assets. These control variables are considered as being important factors influencing monetary policy actions. The monetary authority generally implements a contractionary monetary policy in response to a rise in inflation, an increase in the money multiplier (to curb overall money supply growth) or to an expected exchange rate depreciation (either for its own sake or because of pass-through concerns). Thus, the expected coefficients should be negative. In addition, the monetary authority tends to adopt a tighter monetary policy stance when there is a cyclical rise in income or a more expansionary fiscal deficit, implying negative expected coefficients again.[27] Both a rise in the REER and higher exchange rate expectations adjusted foreign interest rates can lead to a worsening of the balance of payments, causing the monetary authority to implement a contractionary monetary policy to attract capital inflows. Finally, to reduce interest rate volatility the central bank injects or withdraws funds from the market when the domestic money market is in deficit or in surplus, respectively, and the more volatile the domestic interest rate the greater is the extent of central bank intervention.

4. Empirics

4.1 Data and Definitions

The estimation is based on quarterly data over the sample period from 1990:q1 to 2005:q3. We divide the whole sample period into two sub-samples: the pre-crisis period defined as 1990:q1 to 1997:q1, and the post-crisis period defined as 1998:q3 to 2005:q3. By comparing the different values of offset

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25 This said, as highlighted in Table 3, most regional economies did not use fiscal consolidation as a means of curbing the inflationary consequences of capital inflows. The IMF (2005) makes a similar point when it notes of emerging Asia "(f)iscal policy was not used extensively to counter the aggregate demand impact of capital inflows" (p. 61).

26 Three caveats should be noted. One, we use only foreign interest rates rather than interest rate differentials as the domestic interest rates are already captured in the ΔNDA_t term (see eq. 10). Two, the "c" term in eq. 9 is a measure of risk aversion. As discussed in Section 2, declining risk aversion is often cited as a reason for capital inflows to Asia. Since we lack good proxies for this variable, the term is kept constant and embedded within coefficients of the structural model. Three, the other oft-noted push factor, viz. industrial country growth, is likely to be highly correlated with domestic country cyclical growth which is already included in the equation. Dasgupta and Ratha (2000) and Montiel and Reinhart (2000) discuss the determinants of capital flows into developing economies.

27 Of course there are exceptions. For instance, during an economic downturn there could be simultaneous use of expansionary monetary and fiscal policies, and vice versa during an upturn in economic activity.

and sterilization coefficients in these two sub-samples we can ascertain how the extent of sterilization and degree of capital mobility has changed in the two periods for the emerging Asian economies under consideration. We supplemented the country-specific regressions with a set of pooled time series and cross-section regressions (with fixed effects) for both the pre- and post-crisis periods. With regards to the exchange rate expectations, we assume that economic agents have perfect foresight of future exchange rates. So, the actual nominal exchange rate at the next period is used to proxy the expected exchange rate for the next period. In addition, static expectations of future exchange rate are also used to check the robustness. If this is the case, then the current nominal exchange rate is used to proxy the expected exchange rate for the next period.

Table 4 summarizes the definitions and sources of the various data used in the estimating equations. The relevant variables, such as the change in the "adjusted" ΔNFA_t^* and ΔNDA_t (where * denotes adjustments which are discussed in section 4.2) and ΔG_t are scaled by GDP. To check for stationarity we applied the standard unit root test using the Augmented Dickey Fuller (ADF) to each of the variables and found them all to be stationary at the 10 percent level of significance (see Tables 5a and 5b).[28] We used the Hodrick-Prescott (HP) method to measure the trend of real output. In addition we used the standard deviation of the within quarter change in the daily US$ bilateral exchange rate and short-term bank rates to proxy the volatility of exchange rate and volatility of domestic interest rate, respectively.[29] Since we do not have consistent quarterly data on forward rates we assumed that economic agents either had perfect foresight or static expectations to proxy the expected exchange rates for the next period. We also included three quarterly dummies in the model to account for any possible seasonality effects.

4.2 Adjusting the Net Foreign Asset and Net Domestic Asset Figures

Since both the NDA_t and NFA_t are based on the monetary authorities' balance sheet, care must be taken in accounting for non-policy related changes in the variables such as the revaluation effects due to gold value and exchange rate fluctuations.[30] To exclude monetary gold from the foreign assets we use the product of foreign reserves denominated in US dollars and the bilateral exchange rate (domestic currency/US$) to proxy foreign assets. The net foreign assets without the revaluation effect can be stated as follows:

$$NFA_t = (R_t \times s_t) - FL_t \tag{16}$$

where: R_t is the foreign exchange reserves denominated in US$, s_t is the exchange rate against US$, and FL_t refer to the central bank foreign liabilities.

28 Siklos (2000) pointed out a similar problem with the Hungarian-German interest rate differential and has argued that interest rates should not be difference stationary. The ADF results were confirmed by the Kwiatkowski-Phillips-Schmidt-Shin (KPSS) test.

29 Specifically, for Korea, Philippines, Taiwan, and Thailand we use the Money market rate. For Indonesia we use the Call money rate. For Malaysia we use the Interbank overnight money rate. For Singapore we use the 3-month Interbank rate.

30 Another factor includes interest earnings earned from foreign reserves accumulation. We ignore this issue.

We use the ($R_t \times s_t$) rather than FA_t as there are some differences between the two in the case of many of the emerging Asian economies, and from an analytical perspective, monetary sterilization pertains specifically to international reserves.[31] However, the problem with using ($R_t \times s_t$) is that reserve values could change because of currency fluctuations, but these valuation effects will be captured in the bank capital and will not alter the domestic currency value of the banking system's holding of high powered money.[32] As such, we need to exclude these effects before estimation. Ideally if we had the currency composition of reserves we could adjust for the valuation changes. Given that such data are not available, the best we can do is assume that all the reserves are held in US dollars and adjust the reserves for changes in the bilateral US dollar rate.[33] Since the revaluation effect is the change in the net foreign assets due to exchange rate fluctuation, it can be measured as follows:

$$\text{Revaluation effect} = NFA_{t-1}(\frac{s_t}{s_{t-1}} - 1) \qquad (17)$$

Therefore, the revised change of net foreign assets $= \Delta NFA_t^* = NFA_t - NFA_{t-1}(\frac{s_t}{s_{t-1}})$. The adjusted variable excludes the price or valuation effect, which as noted, should have no direct impact on liquidity.

ΔNDA_t^* is defined as $\Delta NDA_t + \Delta NOA_t - \Delta K_t$ + Revaluation effect. Since the revaluation effect is realized in the equity account of balance sheet, the revaluation effect has to be excluded (plus back) from net domestic assets at the same time when we exclude the revaluation effect from ΔNFA_t^*.[34] While the ΔNOA_t usually reflects the increase in inter-bank borrowing and the decline in the capital accounts and other domestic liabilities of the banking system and capital accounts, in some cases it is quite important as central bank bills and notes, which are used to sterilize inflows, are sometimes included under this category.[35] To illustrate the importance of ensuring that the central bank-based variables are appropriately adjusted, Table 6 shows simple correlations between ΔNFA_t and ΔNFA_t^* as well as between ΔNDA_t and ΔNDA_t^*. The correlations regarding the former are positive in all countries and are fairly high (i.e. over 0.8) in India and Malaysia, and moderate in Korea, the Philippines, Singapore, and Taiwan

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31 Loosely speaking, this should correspond to the liquid part of foreign assets of the central bank. Ideally we should also be using only the liquid portion of central bank foreign liabilities. These data are not available.

32 In general, the monetary authority recognizes the end-year revaluation of foreign currency liabilities and assets in the Profit and Loss account of the income statement. Since the end-year income statement balance will be included in the equity (K) account of the balance sheet, the change of net foreign assets due to the revaluation effect can be offset by the change of equity so that the domestic monetary base will be unchanged. In other words, if NFA rises because of an increase in s_t, $M\bar{B} = NFA \uparrow + NDA + NOA - K \uparrow$.

33 Of course, we could assume different scenarios such as Prasad and Wei (2005) do in the case of China. However, we have no basis of making such assumptions and given the number of other issues we deal with in this paper, it seems wise to refrain from making such ad hoc adjustments.

34 Korea, Singapore, and Taiwan do not report data for equity (K) account on International Financial Statistics (IFS), even though the balance sheet is balanced. Therefore, for these three economies, $\Delta NDA_t^* = \Delta NDA_t + \Delta NOA_t$ + revaluation effect.

35 For instance, see Hu (2004) in the case of China.

(0.6 - 0.7), but rather low in the cases of Thailand (0.33) and Indonesia in particular (0.18). In the case of the latter (ΔNDA_t and ΔNDA_t^*) correlations are positive and high in all economies. Overall, the important point is that the correlations between the adjusted and unadjusted figures are not perfect, which suggests that failure to make the appropriate adjustments when estimating the offset and sterilization coefficients can lead to misleading results.

4.3 Empirical Results

We use the two-stage least square (2SLS) method to estimate the simultaneous eqs. 15a and 15b. We ran the regressions based on both perfect foresight and static exchange rate expectations. Since the Hausman test (Table 7) shows that there is no significant difference in the estimations using fixed and random effects, we only report the empirical results estimated by random effects. The empirical results for panel data are reported in Table 8. For ease of interpretation we discuss the absolute values of the sterilization and offset coefficients.

The pre-crisis offset coefficients in both the perfect foresight and static exchange rate expectations models are around 0.8, while the sterilization coefficients are about 1. Post-crisis, while the offset coefficients fell to between 0.5 and 0.6 in both models, it is somewhat harder to draw a conclusion regarding the sterilization coefficient. In the case of the perfect foresight model the coefficient rose to above 1, while in the case of the static expectations model the coefficient declined to around 0.8. So, all that can be said with certainty is that the regional economies as a whole have experienced lower *de facto* capital mobility post-crisis, while the extent of sterilization has remained fairly high after the crisis.

This fall in estimated capital mobility may strike some as surprising in light of all the discussion of growing financial globalization, but we find it quite plausible. One of the major contributing factors to the development of the Asian crisis was the insufficient recognition of exchange risk by many international lenders and borrowers.[36] This resulted in the large unhedged foreign debt positions that made currency depreciation so costly. Recognition of such exchange risk led not only to large initial capital outflows but could also be expected to reduce the interest sensitivity post-crisis capital flows.[37]

The coefficients for the money multiplier terms are statistically significant and negative in both periods in all regressions. Interestingly, while the coefficient has risen in the case of the monetary reaction function, it has declined in the case of the balance of payments function. The lagged inflation and cyclical output terms are generally insignificant across both regressions and have inconsistent signs. These findings of lack of either statistical significance or incorrect signs of the inflation and output coefficients may be due to the fact that while the dependent variables are fairly volatile, the inflation and detrended output series are quite stable. The lagged change in the REER is statistically significant post-crisis with correct sign under the assumption of perfect-foresight expectations, as is the lagged government expenditure variable.

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36 See the analysis and references in Willett et al. (2005).

37 While some countries tightened capital controls during the crisis, average levels of controls are not noticeably after the crisis than before. See Li et al. (2006).

Arguably of most interest when trying to differentiate between the two regressions is the coefficient for the exchange rate expectations adjusted foreign interest rate term. This term is negative and significant for both functions in both regressions pre- and post-crisis under the assumption of perfect foresight. However, it is statistically significant only in the monetary reaction function post-crisis and insignificant in other cases in the case of static expectations. Based on this it appears that the perfect foresight model seems to work somewhat better for the pooled sample.

A simple Chow breakpoint test with a null hypothesis of no structural change between the pre- and post-crisis periods was run for all the regressions (country and pooled). The null hypothesis can be rejected in all cases, suggesting there was a structural break post-crisis (Table 9). We also undertook a number of robustness checks on the pooled regression. Among the more important checks are the following. One, we replaced the lagged cyclical income and lagged change in *REER* with trade balance (akin to the original BGT model). Two, we replaced $\Delta REER_t$ with deviation of *REER* from trend (as ideally one needs to use a measure of real exchange rate misalignment rather than change). Three, to account for the possibility of structural changes affecting the trend output, we replaced $Y_{c,t-1}$ with ΔY_{t-1}. In all the cases the regression results (goodness of fit and statistical significance of key variables) were either unchanged or inferior to the base cases.[38]

4.4 Recursive Estimates

We also applied recursive estimates to investigate the dynamic changes in the offset and sterilization coefficients using the perfect foresight model which appears to be a better fit for reasons discussed above.[39] The estimated recursive offset coefficients indicate that the emerging Asian economies considered here had a relatively high degree of *de facto* capital mobility before the Asian currency crisis (Figure 3). The estimated offset coefficients remained high and constant at around 0.8 to 0.9. However, the degree of capital mobility declined significantly during the crisis period and then remained as low as 0.25 to 0.4 until mid-2003. Since then the degree of *de facto* capital mobility in Asia increased rapidly to 0.7 in 2005. This may reflect the reduced volatility of exchange rates and increasing confidence that large changes are unlikely.

The recursive estimated sterilization coefficients reveal that most monetary authorities in Asian economies sterilized quite heavily in the pre-crisis period (Figure 4). The extent of sterilization remained high after the crisis occurred in mid-1997 but declined to around 0.6 when most Asian economies implemented expansionary monetary policies to stimulate weak economies during the early 2000s. However, the marked increase in the recursively estimated sterilization coefficients after 2003 suggests that the monetary authorities in Asian economies have once again aggressively mopped up excess liquidity as the region experienced new surges in net capital inflows.[40]

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38 Detailed regression results are available on request.

39 The coefficients are initially estimated for the period between 1990:q1 and 1995q1. Then whenever we add one more observation to estimate the following offset and sterilization coefficients we drop the earliest observation at the same time so as to ensure uniform sample size. For example, the second coefficient is estimated by using the sample period from 1990:q2 to 1995:q2. So, each coefficient is estimated by using five year observations. To capture the effect of the currency crisis, we add a crisis dummy (equals 1 between 1997:q2 and 1998:q2) in the model.

40 See Kharas et al. (2006) for a discussion of capital flows in East Asia.

5. Concluding Remarks

This paper has used a unifying framework and common methodology to estimate the degree of *de facto* capital mobility and sterilization in emerging Asian economies (India, Indonesia, Malaysia, Philippines, Thailand, Singapore, Korea, and Taiwan) in the pre-crisis and post-crisis periods. For the eight economies as a group, the estimated offset coefficient decreased from around 0.8-0.9 to 0.5-0.6 post-crisis, indicating the degree of *de facto* capital mobility dropped after the crisis. However, there is evidence that capital mobility has picked up between 2003 and 2005 as the region has seen a resurgence in net capital inflows. There is evidence that the sterilization coefficient remained close to 1 between 1995 and 1999 and between 2003 and 2005, suggesting full sterilization of reserve accumulations. If, however, the reserve build-up persists unabated and the fiscal costs of sterilization begin to escalate (Calvo, 1991) it is unlikely that the regional monetary authorities can persist with aggressive sterilization on such a huge scale.[41] In such a situation domestic macroeconomic stability could be compromised. Our conclusion that past reserve accumulations have not been a major source of excessive liquidity creation should not be taken as suggesting that there is nothing to worry about.[42]

41 The World Bank (2005) and Mohanty and Turner (2005) discuss the latter two costs and Rodrik (2006) discusses the issue of opportunity costs. These costs need to be balanced against the likelihood that higher reserve holdings reduce a country's perceived international credit standing, hence lowering the country's risk premium.

42 Of course there is also the issue that increasing reserve holdings could encourage financial laxity in the reserve-issuing countries such as the United States.

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Table 1. *De facto* IMF Exchange Rate Classifications, 1998-2004

	As of July 1998	As of July 1999	As of July 2000	As of July 2001	As of July 2002	As of July 2003	As of July 2004	As of December 2004
Indonesia	Independently floating	Independently floating	Independently floating	Independently floating	Managed floating with no predetermined path	Managed floating with no predetermined path	Managed floating with no predetermined path	Managed floating with no predetermined path
India	Managed floating with no predetermined path	Managed floating with no predetermined path	Managed floating with no predetermined path	Managed floating with no predetermined path	Managed floating with no predetermined path	Managed floating with no predetermined path	Managed floating with no predetermined path	Managed floating with no predetermined path
Korea	Independently floating	Independently floating	Independently floating	Independently floating	Independently floating	Independently floating	Independently floating	Independently floating
Malaysia	Conventional pegged arrangement	Conventional pegged arrangement	Conventional pegged arrangement	Conventional pegged arrangement	Conventional pegged arrangement	Conventional pegged arrangement	Conventional pegged arrangement	Conventional pegged arrangement
Philippines	Independently floating	Independently floating	Independently floating	Independently floating	Independently floating	Independently floating	Independently floating	Independently floating
Singapore	Managed floating with no predetermined path	Managed floating with no predetermined path	Managed floating with no predetermined path	Managed floating with no predetermined path	Managed floating with no predetermined path	Managed floating with no predetermined path	Managed floating with no predetermined path	Managed floating with no predetermined path
Thailand	Managed floating with no predetermined path	Managed floating with no predetermined path	Managed floating with no predetermined path	Managed floating with no predetermined path	Managed floating with no predetermined path	Managed floating with no predetermined path	Managed floating with no predetermined path	Managed floating with no predetermined path

Note: Taiwan is excluded from IMF reports.

Source: Rajan (2006).

Table 2. Sources of Reserve Accumulation in Emerging Asia, 1995-2005 (US$ Billions)

	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005
Change in Reserves	-42.6	-46.8	-35.8	-53.1	-88.2	-53.7	-90.2	-148.8	-226.5	-340.1	-281.9
Current Account Balance	-40.0	-40.1	14.0	114.0	106.0	85.0	88.4	127.5	166.3	183.5	240.8
Private Capital Flows, net	101.5	121.1	47.6	-53.8	3.1	6.5	19.6	20.8	63.5	120.3	53.8
Official Capital Flows, net	-4.7	-16.1	14.0	19.6	1.8	-11.7	-11.7	4.6	-17.6	1.8	5.0

Notes: Capital flows to "emerging Asia" is dominated by ten economies, viz. the eight economies in this paper (India, Indonesia, Korea, Malaysia, Philippines, Singapore, Taiwan, Thailand), as well as China and Hong Kong. It also includes a number of other countries categorized as "developing Asia" by the IMF.

Source: IMF, World Economic Outlook Database, April 2006.

Table 3. Main Sterilization Instruments Used in Selected Emerging Asian Economies

	Monetary Instruments		Fiscal Policy	
	Market	Non-market	Fiscal stance	Government Cash balance
Indonesia	N.A.	Reserve requirements (not explicitly used for sterilization).	N.A.	N.A.
Korea	Monetary Stabilization bonds.	No.	No.	N.A.
Malaysia	Mainly money market borrowing; Central bank's own securities.	Centralization of government deposits; statutory reserves to a small extent.	No.	Yes (coordination between central bank and banks on a daily basis).
Philippines	Repos, reverse repos and outright transactions in general.	Tiering structure of overnight deposits with the central bank.	No.	Yes (coordination with the government on an infrequent basis).
Thailand	Repos, Forex swaps, central bank securities.	No.	No.	Yes (coordination with the government on a daily basis).

Source: Mohanty and Turner (2005).

Table 4. Definitions and Measurement of the Variables Used in Empirical Study

Variables	Definitions	Measured as	Data (Source)
NFA_t^*	Foreign reserves denominated in domestic currency minus foreign liabilities.	Reserve($) x s_t - Foreign Liabilities	*IFS*
ΔNFA_t^*	The change in NFA_t^* without revaluation effect scaled by the GDP	$[NFA_t - NFA_{t-1}(\frac{s_t}{s_{t-1}})]/GDP_t$	
ΔNDA_t^*	The change in (net domestic assets + net other assets) scaled by the GDP.	$[\Delta NDA_t + \Delta NOA_t - \Delta K_t + NFA_{t-1}^*(\frac{s_t}{s_{t-1}} - 1)]\ / GDP_t$	*IFS*
mm_t	Money Multiplier for M2.	*M2/Reserve Money*	*IFS*
Δmm_t	The change in money multiplier for M2.	ln(mm_t) - ln(mm_{t-1})	
$\Delta REER_t$	The change in Real Effective Exchange Rate.	ln($REER_t$) - ln($REER_{t-1}$)	*IFS*
$Y_{c,t}$	Cyclical Income. The real output deviated from its trend scaled by the trend. The trend is measured by HP filter.	*[ln(Real GDP) - HP filter trend] / HP filter trend*	*IFS and TEJ Great China Database*
Δp_t	Inflation Rate.	ln(cpi_t) -ln(cpi_{t-1})	*IFS*
$\Delta(r_t^* + E_t s_{t+1})$	The change in exchanged adjusted foreign interest rate. The foreign interest rate is the interest rate for US 3-month treasury bill.	$\Delta(r_t^* + \ln s_{t+1})$ *if perfect foresight* $\Delta(r_t^* + \ln s_t)$ *if static expectations*	*IFS*
ΔG_t	The change in government fiscal deficit scaled GDP.	$\Delta G_t / GDP_t$	*IFS*
σ_s	Volatility of exchange rate.	*The standard deviation of the within quarter change in the daily bilateral US$ exchange rate.*	*Bloomberg , Board of Governors of Federal Reserve and Reserve Bank of Australia*
σ_r	Volatility of domestic short-term interest rate.	*The standard deviation of the within quarter change in the monthly domestic interest rate (bank rate).*	*IFS*
D_1	Dummy variable for $\Delta NDA_t < 0$.	*d_1=2 if $\Delta NDA_t < 0$; 0 otherwise.*	
D_2	Dummy variable for $\Delta NFA_t < 0$.	*d_2=2 if $\Delta NFA_t < 0$; 0 otherwise.*	
Q2-Q4	*Seasonal dummies.*	*Q2=1 if the second quarter; Q3=1 if the third quarter; Q4=1 if the forth quarter; otherwise 0.*	

Source: Authors

Table 5a. Unit-Root Test (ADF test): Pre-Crisis Period (1990:q1-1997:q1)

	India	Indonesia	Korea	Malaysia	Philippines	Singapore	Taiwan	Thailand
ΔNFA_t^*	-2.980**	-3.493**	-3.046**	-3.562**	-3.909***	-5.220***	-4.006***	-3.521**
ΔNDA_t^*	-4.936***	-3.188**	-7.033***	-3.265**	-4.273***	-4.613***	-4.452***	-5.284***
Δmm_t	-5.000***	-7.101***	-6.316***	-3.046**	-5.182***	-3.712***	-3.332**	-6.542***
Δp_t	-7.454***	-5.704***	-4.361***	-4.958***	-3.173**	-3.594**	-5.846***	-4.198***
$Y_{c,t}$	-5.808***	-3.232**	-4.916***	-4.718***	-6.007***	-4.357***	-3.627**	-2.711*
ΔG_t	-3.904***	-8.091***	-6.999***	-6.662***	-6.577***	-7.038***	-5.499***	-8.538***
$\Delta(r_t^* + E_t s_{t+1})$	-3.714***	-3.476**	-3.268**	-4.649***	-2.639*	-2.809*	-2.648*	-5.195***
$\Delta REER_t$	-4.331***	-5.659***	-4.375***	-3.897***	-3.896***	-5.592***	-4.977***	-3.575**
$(d_2 - 1)\sigma_{s,t}$	-4.233***	-5.606***	-1.885*	-3.689**	-4.861***	-4.341***	-4.167***	-1.656*
$(d_1 - 1)\sigma_{r,t}$	-4.606***	-4.273***	-4.967***	-2.308**	-3.553**	-4.633***	-7.284***	-4.029***

Note: (*) Significant at more than 10 percent; (**) Significant at more than 5 percent; (***) Significant at more than 1 percent

Table 5b. Unit-Root Test (ADF test): Post-Crisis Period (1998:q3-2005:q3)

	India	Indonesia	Korea	Malaysia	Philippines	Singapore	Taiwan	Thailand
ΔNFA_t^*	-3.690**	-6.022***	-4.517***	-2.667*	-3.765***	-3.784***	-2.968*	-3.282**
ΔNDA_t^*	-2.831*	-6.191***	-4.082***	-2.898*	-6.754***	-3.362**	-3.338**	-3.045**
Δmm_t	-5.466***	-6.056***	-4.333***	-3.011**	-3.724***	-4.064***	-3.431**	-5.576***
Δp_t	-4.854***	-4.032***	-5.089***	-5.381***	-2.672*	-2.945*	-3.601**	-3.426**
$Y_{c,t}$	-6.611***	-3.256**	-2.753*	-4.045***	-8.266***	-2.896*	-4.064***	-3.597**
ΔG_t	-4.132***	-3.729***	-4.664***	-5.483***	-5.807***	-10.80***	-6.973***	-8.095***
$\Delta(r_t^* + E_t s_{t+1})$	-4.050***	-4.715***	-2.799*	-5.330***	-4.264***	-4.493***	-4.033***	-2.637*
$\Delta REER_t$	-3.416**	-3.725**	-4.111***	-3.079**	-4.010***	-3.103**	-3.219**	-4.179***
$(d_2 - 1)\sigma_{s,t}$	-3.560**	-4.728***	-3.424**	-26.76***	-3.941***	-5.260***	-3.494**	-3.784***
$(d_1 - 1)\sigma_{r,t}$	-5.672***	-2.630*	-4.792***	-2.779*	-2.944*	-4.726***	-3.948***	-4.478***

Notes: (*) Significant at more than 10 percent; (**) Significant at more than 5 percent; (***) Significant at more than 1 percent.

Table 6. Simple Correlations between Actual and Adjusted ΔNFA and ΔNDA

	Corr (ΔNFA_t^*, ΔNFA_t)	Corr (ΔNDA_t^*, ΔNDA_t)
India	0.949	0.968
Indonesia	0.189	0.907
Korea	0.632	0.933
Malaysia	0.913	0.969
Philippines	0.791	0.964
Singapore	0.636	0.775
Taiwan	0.771	0.925
Thailand	0.309	0.820

Note: Actual change in NDAs can be measured by deducting actual change in NFAs from change in monetary base. Therefore, $\Delta NDA_t = \Delta MB - \Delta NFA_t$. The definition of adjust ΔNFA and ΔNDA can be found in sec. 4.2.

Table 7. Hausman Test

Perfect Foresight	**Balance of Payments Function**	**Monetary Reaction Function**
Pre-crisis period	5.53 (0.903)	-6.82
Post-crisis period	4.10 (0.943)	2.34 (0.997)
Static Expectation	**Balance of Payments Function**	**Monetary Reaction Function**
Pre-crisis period	6.82 (0.814)	-6.87
Post-crisis period	6.21 (0.797)	-6.03

Note: 1) The number in parenthesis is the P-value. All tests failed to reject the null hypothesis that the coefficients estimated by the efficient random effects estimator are the same as the ones estimated by the consistent fixed effects estimator.

2) Monetary Reaction Function fitted on data fails to meet the asymptotic assumption of Hausman test during post-crisis period.

Table 8. Panel Data with Random Effects Estimation, 1990:q1-1997:q1 and 1998:q3-2005:q3

Random Effects model	**Perfect Foresight**				**Static Expectation**			
	1990:Q1-1997:Q1		**1998Q3-2005:Q3**		**1990:Q1-1997:Q1**		**1998Q3-2005:Q3**	
	ΔNFA_t^*	ΔNDA_t^*	ΔNFA_t^*	ΔNDA_t^*	ΔNFA_t^*	ΔNDA_t^*	ΔNFA_t^*	ΔNDA_t^*
Intercept	**0.015*** (0.007)	0.008 (0.008)	**0.018**** (0.007)	0.007 (0.010)	**0.013*** (0.008)	0.006 (0.008)	**0.019**** (0.009)	**-0.015*** (0.009)
ΔNDA_t^*	**-0.796***** (0.074)	-	**-0.601***** (0.065)	-	**-0.838***** (0.080)	-	**-0.514***** (0.090)	-
ΔNFA_t^*	-	**-1.046***** (0.083)	-	**-1.265***** (0.118)	-	**-0.966***** (0.079)	-	**-0.846***** (0.130)
Δmm_t	**-0.338***** (0.057)	**-0.419***** (0.044)	**-0.289***** (0.053)	**-0.519***** (0.043)	**-0.364***** (0.060)	**-0.428***** (0.042)	**-0.230***** (0.067)	**-0.545***** (0.041)
Δp_{t-1}	-0.035 (0.263)	0.092 (0.268)	-0.312 (0.201)	0.058 (0.216)	-0.087 (0.267)	0.032 (0.257)	-0.176 (0.262)	**0.606**** (0.237)
$Y_{c,t-1}$	0.006 (0.093)	-0.038 (0.091)	0.025 (0.016)	0.021 (0.020)	-0.032 (0.093)	-0.067 (0.086)	0.027 (0.018)	0.001 (0.019)
ΔG_{t-1}	0.083 (0.064)	**0.106*** (0.063)	**-0.173***** (0.055)	**-0.168**** (0.075)	0.095 (0.065)	**0.105*** (0.060)	**-0.165***** (0.062)	-0.056 (0.070)
$\Delta(r_t^* + E_t s_{t+1})$	**-0.352***** (0.119)	**-0.310**** (0.133)	**-0.440***** (0.082)	**-0.640***** (0.098)	-0.052 (0.130)	0.078 (0.129)	-0.159 (0.185)	**0.618***** (0.181)
$\Delta REER_{t-1}$	0.163 (0.110)	0.147 (0.116)	**-0.117*** (0.068)	**-0.247***** (0.091)	0.148 (0.114)	0.138 (0.112)	-0.247 (0.192)	**0.355*** (0.196)
$(d_2 - 1)\sigma_{s,t-1}$	0.001 (0.001)	-	0.00003 (0.00002)	-	0.001 (0.001)	-	**0.0001***** (0.00002)	-
$(d_1 - 1)\sigma_{r,t-1}$	-	0.0001 (0.001)	-	**0.005**** (0.002)	-	0.001 (0.001)	-	0.003 (0.002)
Q1	**0.020**** (0.010)	**0.023**** (0.010)	0.012 (0.009)	**0.022**** (0.011)	**0.020**** (0.010)	**0.022**** (0.010)	0.014 (0.010)	**0.019*** (0.011)
Q2	**0.016*** (0.009)	**0.016*** (0.009)	-0.007 (0.009)	-0.001 (0.012)	**0.016*** (0.009)	0.014 (0.009)	-0.004 (0.010)	0.005 (0.011)
Q3	0.004 (0.009)	0.005 (0.009)	**0.020**** (0.009)	**0.021*** (0.012)	0.002 (0.009)	0.003 (0.009)	**0.022**** (0.011)	0.019* (0.011)
Adj. R-square	0.699	0.741	0.700	0.774	0.687	0.746	0.638	0.769

Notes: (*) Significant at more than 10 percent; (**) Significant at more than 5 percent; (***) Significant at more than 1 percent.

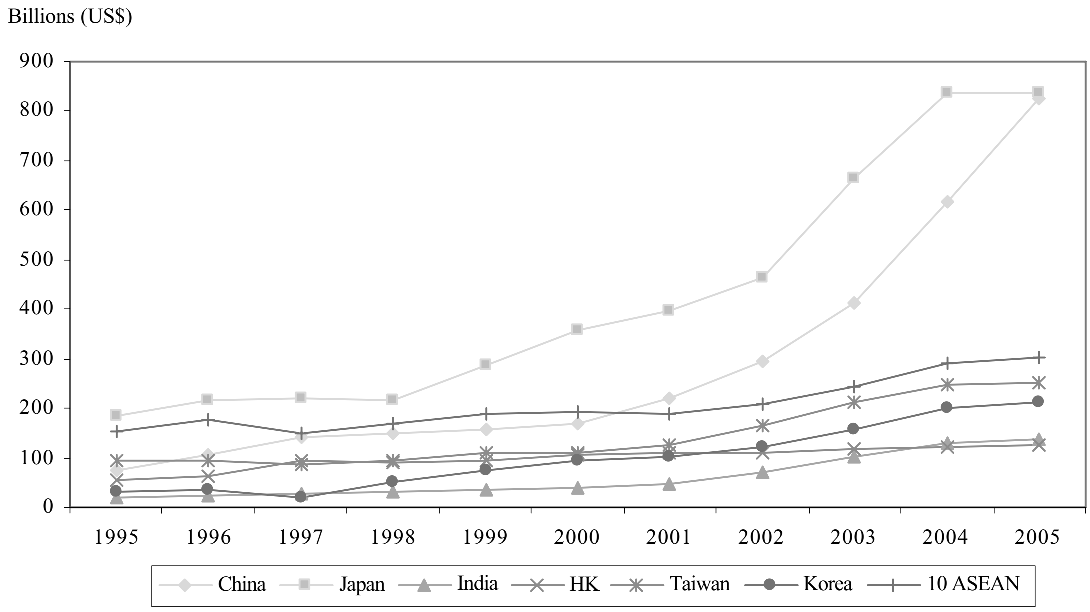
There are 232 observations for each sub-period.

Table 9. Chow Breakpoint Test
(H_0: No Structural change), Pre- and Post-crisis Periods

	Balance of Payment function		Monetary Reaction function	
	Perfect Foresight	Static Expectations	Perfect Foresight	Static Expectations
Pooled sample	2.335*	2.551*	59.217***	24.925***

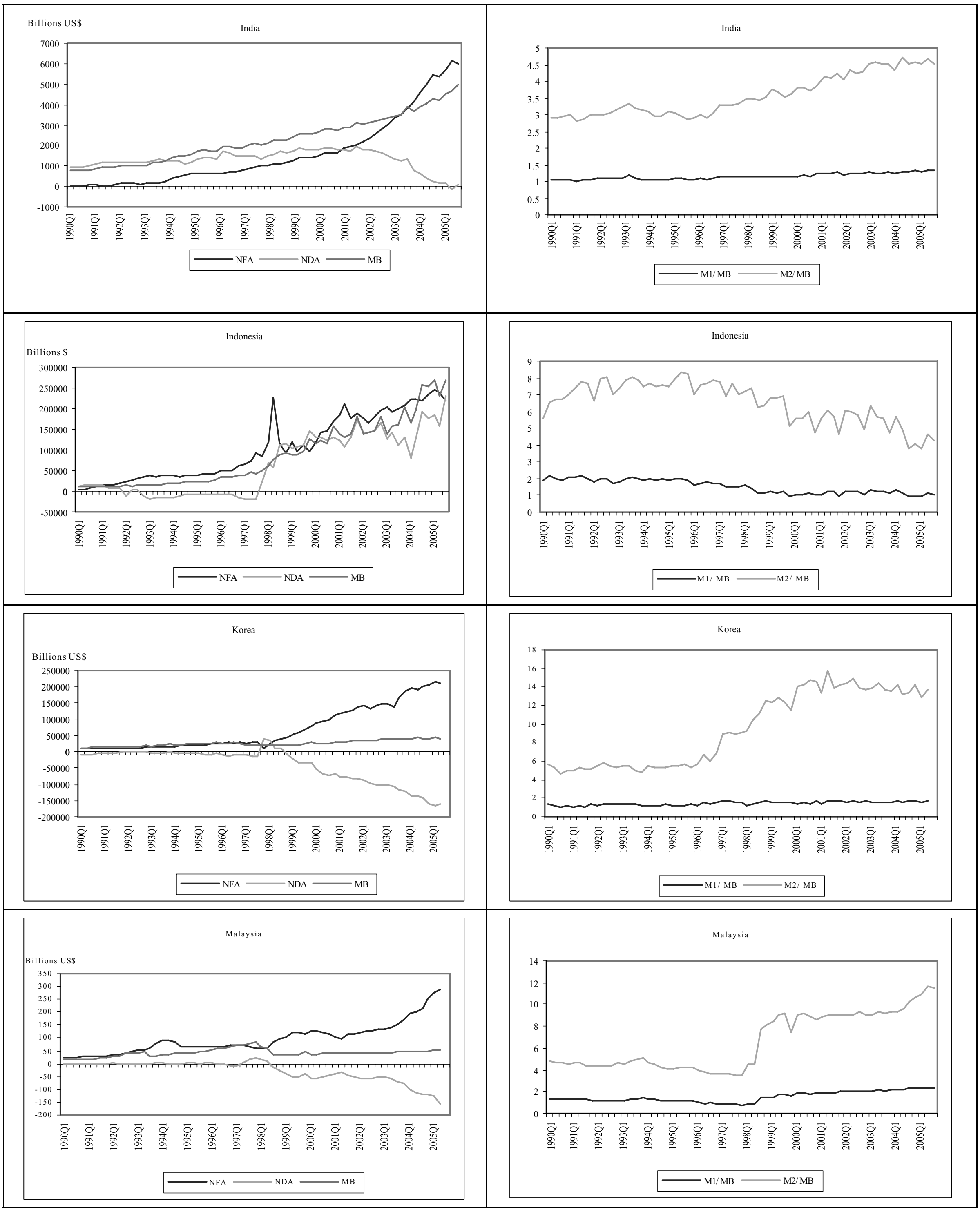
Note: (*) Significant at more than 10 percent; (**) Significant at more than 5 percent; (***) Significant at more than 1 percent.

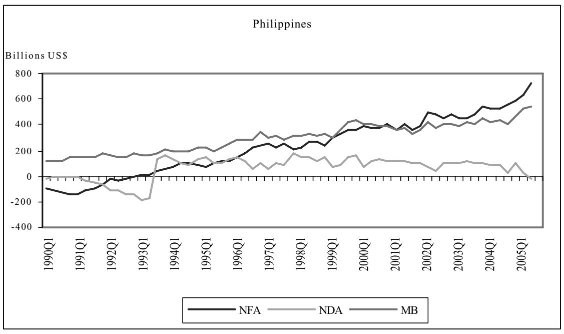
Figure 1. International Reserve Holdings in Emerging Asia (including gold), 1990-2005 (US$ Billions)

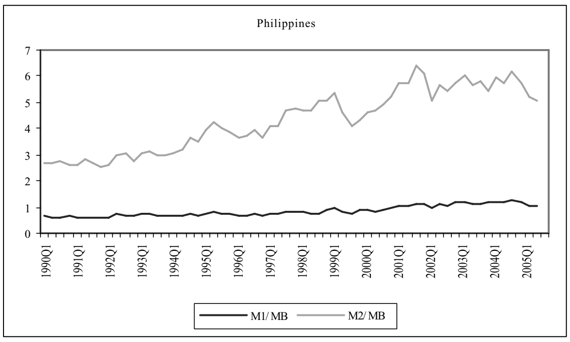


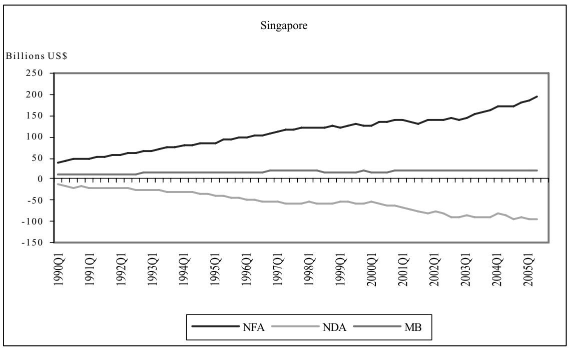
Source: All data are from IFS, except Taiwan. The data from 1995-2004 for Taiwan is from AREMOS dataset which is published by Taiwan Economic Data Center. The 2005 data for Taiwan is updated from Taiwan's central bank website.

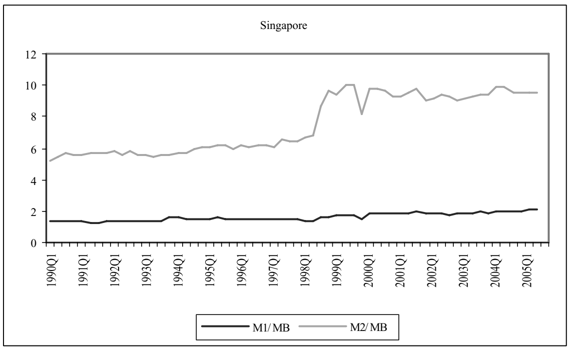
Figure 2. NDA, NFA, Monetary Base and Money Multipliers in Emerging Asia, 1990:q1-2005:q1 (US$ Billions)

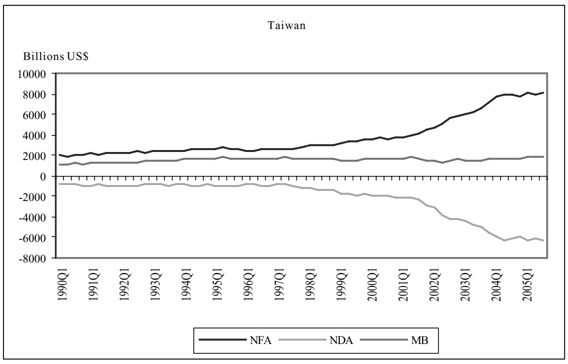


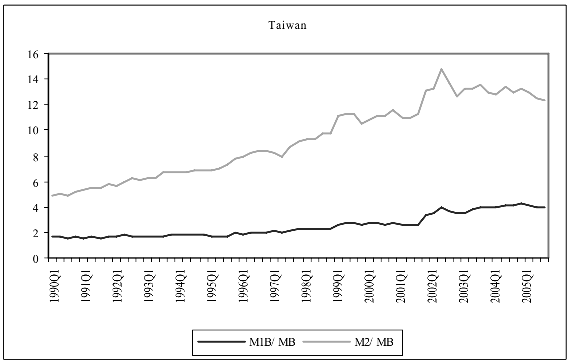


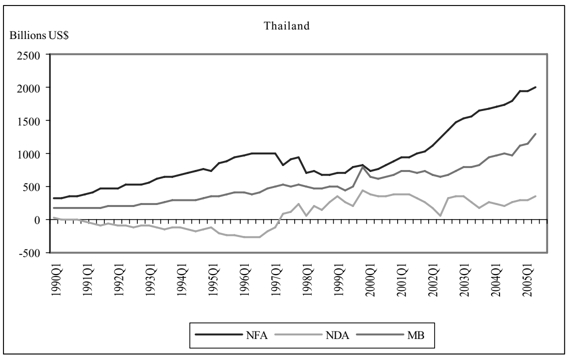


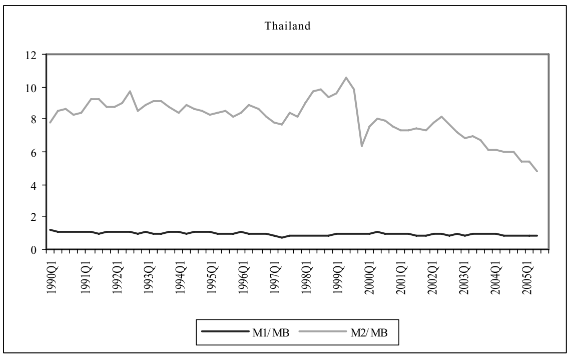












Source: All data from IFS except for Taiwan which is from AREMOS database.

Figure 3. Recursive Estimated Offset Coefficients (Based on Perfect Foresight Model with Random Effects)

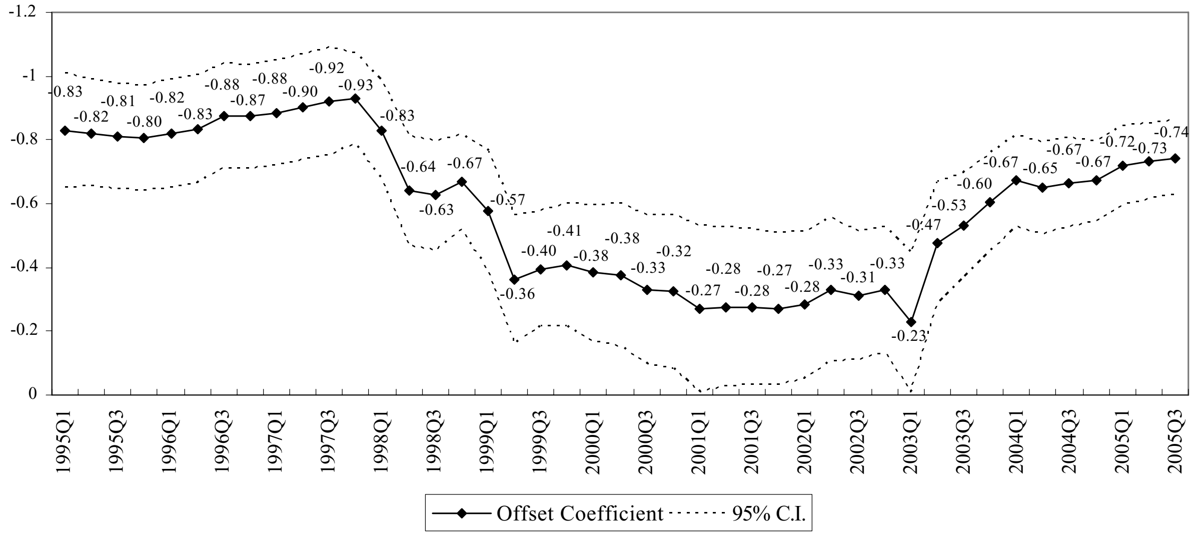


Figure 4. Recursive Estimated Sterilization Coefficients (Based on Perfect Foresight Model with Random Effects)