Monetary Sterilization in China Since the 1990s: How Much and How Effective?

by

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Ongoing discussions on the topic with James Dean, Jie Li and Tom Willett helped formalize some of the ideas in this paper. The usual disclaimer applies.

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Abstract

China is the largest reserve holder among developing countries, having amassed over US$ 600 billion of reserves by end 2004. Given the potential liquidity overhang concerns in China due to the rapid reserve buildup, the People's Bank of China (PBOC) has actively attempted to sterilize these inflows using a combination of market-based and administrative measures to mop up the excess liquidity. This paper focuses on the magnitude and sources of reserve buildup in China as well as their monetary consequences since the 1990s. It undertakes an econometric investigation to assess the *de facto* extent of monetary sterilization by estimating a set of simultaneous equations explicitly derived from an optimizing framework to examine the relationship between net domestic assets and net foreign assets.

Keywords: *China, Capital Inflow Function, Monetary Reaction Function, Monetary Sterilization, Reserves*

1. Introduction

Despite the seeming frailty of pegged regimes, there appears to be a continued fixation with US dollar pegs, especially in Asia. For instance, China, Hong Kong and Malaysia all maintain firm US dollar pegs (unlike the other two, the Hong Kong dollar is backed by a currency board arrangement). Many supposed floaters also seem to heavily manage their currencies vis-à-vis the US dollar (Cavoli and Rajan, 2005 and McKinnon and Schnabl, 2004). While the nominal anchor rationale for a peg may have some validity in general, it can be taken too far, and is probably less of a concern for many Asian developing countries which have generally maintained relatively low inflation rates.[1] And while there is a widespread belief that a pegged regime induces greater policy discipline, the effects of unsound macro policies become evident immediately under flexible rates through exchange rate and price level movements (i.e. depreciation-inflation spiral). As such, it could be argued that flexible exchange rates instill relatively greater fiscal restraint/discipline as the costs of macroeconomic policy transgressions have to be paid upfront (Tornell and Velsaco, 2000).[2]

Nonetheless, an oft-noted virtue of a US dollar peg appears to be its transparency, and the simplicity of operating such a regime (in normal circumstances). Thus, it is well known that the Malaysian ringgit is fixed at 3.80 to the US dollar, the Chinese renminbi is pegged at 8.28 per US dollar, and the Hong Kong dollar is set at 7.80 per US dollar.[3] There is no ambiguity about any of this, and private agents -- exporters, importers, financial

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[1] See Willett (1998) for a detailed exploration of the nominal anchor debate. Moreno (2002) questions the relevance of a pegged regime for East Asia in keeping inflation rates low.

[2] Similarly, the endogeneity argument of a fixed exchange rate seems to have been largely discredited – one need look no further than the Argentine crisis of the late 1990s.

[3] The Hong Kong has recently moved away from a rigid peg, having effectively introduced a degree of flexibility – 7.75 to 7.85 per US dollar (so-called "convertibility zone").

market participants and foreign direct investors -- can go about their respective activities accordingly. The need for stability to promote international trade and foreign direct investment (FDI) is something that has been repeatedly emphasized by Asian policy makers.[4] Concerns about the potential vulnerability of the domestic financial systems to variations in exchange rates have also been expressed in defense of a US dollar pegged system, particularly in China.[5]

The fixed -- or heavily managed -- exchange rate regimes operated by many Asian developing countries even post 1997-98 has in turn contributed to a notable global macroeconomic development, viz. the rapid buildup of reserves in Asia (for instance, see Kim et al., 2005 and references cited within). The largest reserve holder among developing countries is China; it amassed over US$ 600 billion of reserves by end of 2004 (Figure 1), equivalent to about two-fifth of the country's gross domestic product (GDP).[6] Given the potential liquidity overhang concerns in China due to a massive and rapid reserve buildup, the People's Bank of China (PBOC) has actively used a combination of market-based and administrative measures to mop up the excess liquidity. However, the extent and success of sterilization remains in doubt.

[4] See Rajan (2002) for references on the impact of exchange rate fluctuations on trade and FDI flows. Also see Clark et al. (2004). Of course, a single currency peg leaves a country vulnerable to fluctuations in a third currency, a problem faced by Asia pre 1997 following the appreciation of the US dollar vis-à-vis the Japanese yen (Bird and Rajan, 2002 and McKinnon and Schnabl, 2003).

[5] While official figures place China's non-performing loans (NPLs) at about 15 to 20 percent of the total, most other estimates place them at over 40 percent (Holland and Lague, 2004 and Lin, 2003). It is partly because of concerns about banks and inefficient state-owned enterprises that the PBOC has been reluctant to raise interest rates, having increased them marginally once in October 2004. In addition, interest rate hikes could precipitate capital inflows.

[6] Japan is, of course, the world's largest holder (about US$ 830 billion as of December 2004). The other top reserve holders are all Asian as well – Taiwan, Korea, India, Singapore and Hong Kong – each hold over US$ 100 billion in reserves.

The next section explores the evolution of the balance of payments flows in China since the 1990s, focusing on the magnitude and sources of reserve buildup as well as their monetary consequences. Section 3 undertakes an econometric investigation to assess the *de facto* extent of sterilization by estimating a set of simultaneous equations to examine the relationship between net domestic assets and net foreign assets. In particular, we simultaneously estimate the "sterilization coefficient", i.e. how much domestic credit changes in response to a change in international reserves, as well as the "offset coefficient", i.e. how much private capital changes in response to a change in domestic credit. The analysis uses quarterly data between 1995: q1 and 2004: q4. The vectors of controls in the simultaneous equations are derived from an explicitly optimizing framework based on Brissimis-Gibson-Tsakalotos or BGT (2002). The final section concludes with a brief discussion of the macroeconomic policy implications and tradeoffs facing China going forward.

2. Dynamics of Reserves and Monetary Growth in China Since the 1990s

2.1 Evolution of China's Balance of Payment Account

An examination of trends in the growth of China's reserves suggests that one can identify various sub-periods since 1990 (Figure 1).

China's reserves remained stagnant in 1990 and 1991 and actually declined in 1992, as small surpluses on the current and capital accounts were more than offset by capital flight, as witnessed by the negative balance in the errors and omissions category. However, things changed once the Chinese Renminbi (RMB) was officially devalued from 5.8 RMB per US dollar to 8.45 in January 1994. Between 1992 and 1996 the surplus in the capital account exceeded the current account deficit, and "illegal" capital flight (as proxied by the errors and omissions balance), such that reserves rose briskly during this period. The country's current account shifted to a surplus from 1997 onwards, though the capital account surplus diminished, while capital flight continued unabated. In aggregate, between 1997 and 2000, China's reserves remained more or less stagnant. Since 2001, China has experienced large and growing surpluses on both the capital and current accounts, while even the errors and omissions balance turned positive. Thus, reserves increased markedly during this period -- almost threefold.

An interesting dynamic appears to have taken hold in China in recent years (as well as many other Asian economies). Large reserves are viewed as a sign that the domestic currency has to eventually appreciate. They also tend to be taken as an indication of "strong fundamentals", hence leading to an upgrading of the country's credit ratings. This expectation of future capital gains and lower risk perceptions had motivated large-scale capital inflows (so-called "capital inflows problem"). This in turn has added to the country's stock of reserves as central banks have mopped up excess US dollars to keep the bilateral exchange rate stable in nominal terms (Dean and Rajan, 2004).[7] Thus, referring to Figure 2, it is apparent that the swelling of China's capital account surplus was because of a surge in portfolio capital flows as well "other investments" (i.e. short term debt flows), possibly a reflection of mounting market expectations of an impending revaluation of the Chinese currency (i.e. speculation on the RMB as a one-way trade).[8]

[7] Also see Hu (2004). Two caveats should be noted. One, part of the rise in reserves is also because of a valuation effect as a portion of reserves that was invested in non-US dollars (gold, euros, etc) has appreciated in US dollar terms (while most central banks including the PBOC do not disclose the composition of assets in which reserves are being invested, it is generally suggested that a large part has been invested into dollar-denominated assets like Treasury securities). Two, there was a one-off fall in reserves in China in 2004. This was because in February 2004 the government transferred US$ 45 billion to four state-owned banks, Bank of China, China Construction Bank, Agricultural Bank of China and Industrial and Commercial Bank of China, to aid in their recapitalization (Holland and Lague, 2004).

2.2 Monetary Growth and Sterilization in China

What are the monetary consequences of this reserve buildup in China? To help fix ideas, it is useful to recall that:

$$M2 = MB * mm .$$

So, $\Delta M2 = \Delta MB \times mm + MB \times \Delta mm = (\Delta NFA + \Delta NDA) \times mm + MB \times \Delta mm$,

where *MB* = monetary base; *NFA* = net foreign assets; *NDA* = net domestic assets; and *mm* = M2 multiplier.

Referring to Figure 3, by and large since 2002: q4, domestic credit (NDA) growth remained rather low if not negative. This helped moderate the increase in the domestic Monetary Base (MB), suggesting that the PBOC was actively neutralizing the impact of the reserves buildup. Since the early-to-mid 1990s, the PBOC has been relying increasingly on open market operations (OMOs) involving government securities to influence domestic money supply. As with many of its other Asian counterparts, sustained contractionary OMOs to curb liquidity growth has depleted the PBOC's stock of government bonds. In response to this problem, the PBOC started floating its own securities (central bank bills) which have since been used in its OMOs (Figure 4).[9] The

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[8] Indeed, a large number of so-called "qualified foreign investment institutions" or QFIIs received approval by the China Securities Regulatory Commission to increase their investments to China which in turn has fuelled large-scale portfolio capital inflows (Hu, 2004 elaborates on the QFIIs and their impact on capital inflows into China).

[9] Unlike the PBOC, the Reserve Bank of India (RBI), which operates a managed float and has been faced with a similar problem (of depleting stock of government bonds), decided against issuing its own bonds for two reasons. One, if the central bank issues its own bonds, it would have to bear the costs of sterilization (hence decreasing central bank capital). Two, issuance of central bank bonds may raise the risk premium demanded on government bonds (which tend to be perceived as riskier

PBOC has also made fairly frequent use of changes in legal requirements to impact domestic liquidity (see Table 1), and in particular, to keep M2 stable (Figure 5).

3. Estimation of China's Sterilization and Offset Coefficients

The previous section has provided a brief overview of the extent of reserve and monetary buildup in China in recent years, as well as offered preliminary evidence of the presence of monetary sterilization. This section undertakes a more formal empirical investigation of the magnitude of sterilization in China by estimating the nexus between net domestic assets and net foreign assets using a set of simultaneous equations. The need for the use of simultaneous equations is straightforward. As discussed, domestic monetary conditions are impacted by a change of international capital flows and foreign reserves. Concurrently, international capital flows respond to a change in domestic monetary conditions (e.g. higher domestic interest rates could, *ceteris paribus*, lead to capital inflow surges).[10]

3.1 Overview of the Analytical Framework

The theoretical model used here takes as a starting point -- but modifies -- the innovative model developed by Brissimis-Gibson-Tsakalotos or BGT (2002) which derives

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than those issued by the central bank), hence exacerbating the costs of raising much-needed finances by the government. Instead, the RBI recently launched so-called market stabilization bonds (MSBs), which are to be issued by the Government of India with the specific aim of absorbing the liquidity created in the financial system due to foreign exchange intervention. The proceeds of the MSBs will not add to the fiscal deficit as they are held in a separate noninterest bearing account called the Market Stabilization Scheme (MSS) account which is to be maintained and operated by the RBI. The government cannot spend the money available in the MSS account except to pay back maturing debt. The MSS account should help improve the transparency of the RBI's sterilization operations.

[10] Indeed, this is the basic dilemma involved in sterilization (Calvo, 1991), a point we return to in Section 4.

both the capital inflow and the monetary reaction functions 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.

The loss function is:

$$L_t = \beta(\Delta p_t)^2 + \gamma(Y_{c,t})^2 + \delta(\sigma_{r,t})^2 + \varepsilon(\sigma_{s,t})^2 \qquad (1)$$

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_{ct}); and the volatilities of the interest rate ($\sigma_{r,t}$) and the exchange rate ($\sigma_{s,t}$).[11] All the parameters are assumed to be positive.

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

a) Inflation

$$\Delta p_t = \pi_1[(\Delta NFA_t + \Delta NDA_t)mm_t + MB_t \Delta mm_t] + \pi_2 \Delta p_{t-1} + \pi_3 \Delta s_t \qquad (2)$$

where $\pi_1 > 0, 0 < \pi_2 < 1, \pi_3 > 0$. Eq. (2) 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 price of imports.

[11] We have simplified the original BGT model by including actual changes in inflation and cyclical output in the loss function rather than changes of actual (inflation and output) from their respective target levels. Other changes include incorporation of the role of government spending on cyclical output and endogenization of the current account.

b) Cyclical income

$$Y_{c,t} = \varphi_1[(\Delta NFA_t + \Delta NDA_t)mm_t + MB_t\Delta mm_t] + \varphi_2 Y_{c,t-1} + \varphi_3 G_{c,t} \quad (3)$$

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

where: $G_{c,t}$ is the cyclical government expenditure.[12] We assume that both expansionary fiscal and monetary policies can boost cyclical output.

c) Balance of Payments

$$\Delta NFA_t = CA_t + \Delta NK_t \quad (4)$$

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

The current account mainly depends on output and lagged real effective exchange rate (to account for inertial effects of real exchange rate change on the trade balance), while the net capital inflow depends imperfectly on the uncovered interest differentials:

$$CA_t = -\alpha_1 Y_{c,t} - \alpha_2 REER_{t-1} \quad \alpha_1 > 0, \alpha_2 > 0 \quad (5)$$

$$\Delta NK_t = (1/c)\Delta(s_t - E_t s_{t+1} + r_t - r_t^*) \quad (6)$$

[12] More precisely, one would want to use a measure of broader fiscal stance, viz. full employment fiscal balance.

where: $REER$ is the real effective exchange rate;[13] 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 relative risk aversion between domestic and foreign assets and the extent of capital controls.

In addition, the interest rate is determined by the change in money supply:

$$\Delta r_t = -\psi_1[(\Delta NDA_t + \Delta NFA_t)mm_t + MB_t \Delta mm_t] \quad \psi_1 > 0 \tag{7}$$

From (6), we get:

$$\Delta s_t = c\Delta NK_t + \Delta E_t s_{t+1} - \Delta r_t + \Delta r_t^* \tag{8}$$

After Substituting (3), (4), (5), (7) and (8) into (2) we derive:

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

(9)[14]

[13] A rise implies a currency appreciation.

[14] Note, with a fixed exchange rate, only the first three terms in eq. 9 will be relevant. Referring to Figure 1, one notices that there have been a few – albeit infrequent -- variations in the Chinese exchange rate over the last decade and a half. Rather than add dummies to capture the periods of exchange rate changes, in the empirical analysis (Section 3) we use the more general form as shown by eq. (9).

d) Interest rate volatility

$$\sigma_{r,t} = \eta\sigma_{r,t-1} - \theta(\Delta NDA_t - d_1\Delta NDA_t) \quad \eta,\theta > 0 \tag{10}$$

Interest rate volatility depends negatively on the absolute amount of intervention undertaken by the central bank in the domestic money market. 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

$$\sigma_{s,t} = \kappa\sigma_{s,t-1} - \varsigma(\Delta NFA_t - d_2\Delta NFA_t) \quad \kappa,\varsigma > 0 \tag{11}$$

Exchange rate volatility depends negatively on the absolute amount of intervention undertaken by the central bank in the foreign exchange market. d_2 is a dummy 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).

Solving for $\partial L_t / \partial \Delta NDA_t = 0$ and $\partial L_t / \partial \Delta NFA_t = 0$ and substituting the constraints into the loss function derives the semi-reduced-form equations.

$$
\begin{aligned}
\Delta NFA_t = & -\{[\beta c\pi_3(\pi_1+\pi_3\psi_1+c\alpha_1\varphi_1\pi_3)mm_t+(\pi_1+\pi_3\psi_1+c\alpha_1\varphi_1\pi_3)^2 mm_t^2+r\varphi_1^2 mm_t^2]/u_1\}\Delta NDA_t \\
& -\{[\beta c\pi_3(\pi_1+\pi_3\psi_1+c\alpha_1\varphi_1\pi_3)mm_t+(\pi_1+\pi_3\psi_1+c\alpha_1\varphi_1\pi_3)^2 mm_t^2+r\varphi_1^2 mm_t MB_t]/u_1\}\Delta mm_t \\
& -\{[\beta\pi_2(\pi_3 c+(\pi_1+\pi_3\psi_1+c\alpha_1\varphi_1\pi_3)mm_t)]/u_1\}\Delta p_{t-1} \\
& -\{[\beta c\alpha_1\varphi_2\pi_3(\pi_3 c+(\pi_1+\pi_3\psi_1+c\alpha_1\varphi_1\pi_3)mm_t)+r\varphi_1\varphi_2 mm_t]/u_1\}Y_{c,t-1} \qquad (12) \\
& -\{[\beta c\alpha_1\varphi_3\pi_3(\pi_3 c+(\pi_1+\pi_3\psi_1+c\alpha_1\varphi_1\pi_3)mm_t)+r\varphi_1\varphi_3 mm_t]/u_1\}G_{c,t} \\
& -\{[\beta\pi_3(\pi_3 c+(\pi_1+\pi_3\psi_1+c\alpha_1\varphi_1\pi_3)mm_t)]/u_1\}REER_{t-1} \\
& -\{[\beta\pi_3(\pi_3 c+(\pi_1+\pi_3\psi_1+c\alpha_1\varphi_1\pi_3)mm_t)]/u_1\}\Delta(r_t^*+E_t S_{t+1}) \\
& -\{[\varepsilon\varsigma\kappa(d_2-1)]/u_1\}\sigma_{s,t-1}
\end{aligned}
$$

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

$$
\begin{aligned}
\Delta NDA_t = & -\{[\beta c\pi_3(\pi_1+\pi_3\psi_1+c\alpha_1\varphi_1\pi_3)mm_t+\beta(\pi_1+\pi_3\psi_1+c\alpha_1\varphi_1\pi_3)^2 mm_t^2+r\varphi_1^2 mm_t^2]/u_2\}\Delta NFA_t \\
& -\{[\beta(\pi_1+\pi_3\psi_1+c\alpha_1\varphi_1\pi_3)^2 mm_t MB_t+r\varphi_1^2 mm_t MB_t]/u_2\}\Delta mm_t \\
& -\{[\beta\pi_2(\pi_1+\pi_3\psi_1+c\alpha_1\varphi_1\pi_3)mm_t]/u_2\}\Delta p_{t-1} \\
& -\{[\beta c\alpha_1\varphi_2\pi_3(\pi_1+\pi_3\psi_1+c\alpha_1\varphi_1\pi_3)mm_t+r\varphi_1\varphi_2 mm_t]/u_2\}Y_{c,t-1} \qquad (13) \\
& -\{[\beta c\alpha_1\varphi_1\pi_3(\pi_1+\pi_3\psi_1+c\alpha_1\varphi_1\pi_3)mm_t+r\varphi_1\varphi_3 mm_t]/u_2\}G_{c,t} \\
& -\{[\beta c\alpha_2\pi_3(\pi_1+\pi_3\psi_1+c\alpha_1\varphi_1\pi_3)mm_t]/u_2\}REER_{t-1} \\
& -\{[\beta\pi_3(\pi_1+\pi_3\psi_1+c\alpha_1\varphi_1\pi_3)mm_t]/u_2\}\Delta(r_t^*+E_t S_{t+1}) \\
& -\{[\delta\theta\eta(d_1-1)]/u_2\}\sigma_{r,t-1}
\end{aligned}
$$

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

Eqs. (12) and (13) are the capital inflow and the monetary reaction functions, respectively. The former estimates the impact of a change in net domestic assets (NDA) on net foreign assets (NFA) -- so-called "offset coefficient". The expected value of the offset coefficient is bound by 0 on the upper end in the event of no capital mobility, and -1 in the event of perfect capital mobility. The sterilization coefficient can be measured by the estimated coefficient of the change of net foreign assets in the monetary reaction function. 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.

The capital inflow function (Eq. 12) consists of seven control variables incorporating both "push" versus "pull" factors. The former refers to factors that motivate capital to leave creditor countries in search of better returns. The latter refers to factors that motivate capital flows into specific recipient countries[15]. One, a rise in the money multiplier for M2 might increase the domestic money and push interest rates down, hence reducing capital inflows. Two, higher inflation could perpetuate concerns about exchange rate depreciation and interest rate hikes and capital losses thereof, hence causing a reduction in capital inflows.[16] Three, foreign reserves will be decumulated due to a fall in the current account if the real effective exchange rate appreciates (price effect). Four, higher lagged real output could worsen the current account (due to the income effect), hence reducing foreign reserve accumulation.[17] Five, an expansionary fiscal policy stance (higher government expenditure) will raise cyclical income and once again worsen the current account as discussed above. Six, higher exchange rate-adjusted foreign interest rates could also lead to capital withdrawals from the country. Seven, higher volatility of exchange may increase investment risks and uncertainty for foreign investors, hence diminishing the extent of capital inflows.

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[15] To be sure, while "push" factors from industrial countries determine the timing and magnitude of capital flows, "pull" factor determine the geographical distribution of the flows (see Montiel and Reinhart, 1999).

[16] Additionally, in practice, higher inflation could engender greater uncertainty, leading to reduced capital flows.

[17] Three caveats should be noted. One, it is important to consider the context of expansionary fiscal policy. If done in the event of an economic downturn, the impact may not be similar as if when done when output is at or above trend. Two, the focus here is on short term rates; in most circumstances one would expect higher budget deficits to cause a rise in long term interest rates. Three, it is also important to consider the impact of market expectations. If higher government expenditure is viewed as a sign of fiscal profligacy, this could lead to rise in country risk premium and consequent capital flight.

The monetary policy function (Eq. 13) consists of the same vector of controls as the capital inflow function with the one exception being that the volatility of the exchange rate is replaced by the volatility of interest rates.[18]

3.2 Data, Definitions and Methodology

The estimation is based on quarterly data over the sample period 1995: q1 to 2004: q4. All the data are obtained either from the *IMF-IFS* or the *TEJ Great China* Database. Table 2 summarizes the definitions and sources of the various data used in the estimating equations. Table 3 provides some summary statistics of the key variables to be used in the empirical exercise.

Note that relevant variables -- viz. change of net foreign assets, the change of net domestic assets, and cyclical fiscal balance -- were each scaled using GDP and the lagged value of reserve money. To be sure, some like Sarijito (1996) use lagged values of reserve money as a scaling variable, while others such as Rooskareni (1998) prefer to use nominal GDP as the scale. We do not have strong priors as to which might be a better scaling variable, so we have tried both in the first instance. To preview the main conclusion, while there is no discernible difference in the estimated values of the sterilization and offset coefficients using the two scales, in terms of overall fit as well as statistical significance of individual independent variables the reserve money as a scaling variable is preferable.

We applied the unit roots test on each variable to check the stationarity of all variables. All variables appear to be stationary except the change of net foreign asset scaled by GDP and the lagged value of reserve money respectively (Table 4). We therefore detrended change of net foreign asset scaled by GDP and the lagged value of reserve

[18] Thus, Eqs. (10) and (11) were included for identification purposes.

money respectively to do our estimation. We used the Hodrick-Prescott method to measure the trend of real output growth and government fiscal balance. We used the standard deviation of the within quarter change in the monthly exchange rate (real effective exchange rate) and interest rate (bank rate) to proxy the volatility of exchange rate and volatility of domestic interest rate. On the other hand, we assumed that economic agents have perfect foresight in forming their expectations on exchange rate. Hence we used the difference between the actual nominal exchange rate at the next period and the current nominal exchange rate to proxy the expected exchange rate for the next period.

The simultaneous Equations (Eq. 12 and 13) were estimated using Two-stage least squares (2SLS). The estimated results of the Ordinary Least Squares (OLS) have also been included solely for comparison and for the sake of ensuring full transparency of results. Since our sample is based on quarterly data, we included three seasonal dummies to account for seasonality effects. We have also included the lagged values of the explanatory and dependent variables as controls as it is common to find a dynamic relationship between macroeconomic variables.[19]

3.3 Empirical Results

Table 4 provides the summary statistics of the various variables used in the model. Tables 5 and 6 summarize the results of the estimating equations using two-stage least squares as well as simple OLS for both scaling factors (lagged reserve money and GDP).[20]

With regard to the capital inflows function, the estimated offset coefficient for China using the 2SLS is about -0.55 (Table 5).[21] The results indicate that net foreign assets

[19] We recognize that including too many lagged values of explanatory variables may cause serious multicollinearity problems if the sample size is small and the explanatory variables do not change much or move fairly regularly. Hence, the lag length is determined by the F-test.

[20] As noted, OLS estimates are provided solely for comparison / information.

tend to decline if the money multiplier for M2 increases, the lagged real effective exchange rate appreciates, or the exchange rate adjusted foreign interest rates go up. These results are consistent with the priors discussed previously. In addition, the lagged value of international reserves is statistically and positively significant. The macroeconomic variables (viz. cyclical income, fiscal balance and inflation) are statistically insignificant. The overall fit using lagged reserve money as a scaling variable is superior to that using GDP as the scale.

2SLS estimates of the monetary reaction function reveals that China has sterilized around 75 percent of capital inflows on average since 1995 (Table 6). With regard to other explanatory variables, the money multiplier and the exchange rate adjusted foreign interest rates are negative and statistically significant as expected a priori. In addition, the lagged real effective exchange rate, the lagged inflation rate, and lagged net domestic assets are also statistically significant with appropriate signs in the regression estimates based on the lagged value of reserve money as a scaling variable (the latter two variables at the 10% level). The cyclical government balance and interest rate volatility are also statistically significant based on the lagged value of reserve money as a scaling variable at the 10% level, though they have different expected signs from our theoretical model.

Following Cumby and Obstfeld (1983) and Siklos (2000), we have applied the forward recursive method to estimate the changing dynamics of the offset and sterilization coefficients (Figure 7 and 8 respectively). The first estimate is obtained by using the sample from 1995: q1 to 2002: q1, and then each time we add one more observation to re-

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[21] For comparison, Table 7 highlights the estimated coefficients for other developing countries during various times in the 1990s. Two caveats should be noted. One, there are no studies we are aware that compute these coefficients for China that could serve as a better yardstick of comparison. Two, the summary in Table 7 is by no means exhaustive. Only some relatively recent studies (since 1990) on developing countries, and only those that use similar technique to ours (i.e. simultaneous equations) have been included.

estimate the simultaneous equations to get the offset and sterilization coefficients till 2004: q4. Note that the estimated offset coefficients are quite stable, hovering around -0.5 to -0.6. This is suggestive that China has experienced moderate capital mobility in the latest few years. Also note that the estimated sterilization coefficient increased markedly from moderate sterilization (-0.45 to -0.55) in 2002 to heavy sterilization in 2004 (-0.7 to -0.8).[22]

4. Concluding Remarks

The empirical analysis in the preceding section highlights that China has been actively sterilizing capital inflows since the late 1990s and has consequently borne the quasi-fiscal costs of this policy (Calvo, 1991). These quasi-fiscal costs arise if the central bank uses open market operations to offset the growth in reserves as it is effectively selling high-yielding domestic assets for low-yielding foreign ones. The sterilization costs may be unsustainable over time and can be counterproductive as they prevent interest rates from falling, thus prolonging capital inflows. On the basis of data for 15 developing countries in Asia and Latin America over the period 1990-1996, Montiel and Reinhart (2000) conclude that sterilization increases the volume of capital inflows but also biases it towards more volatile short-term capital flows (compared to FDI). These concerns clearly seem to be surfacing in recent times in China, especially in 2003-2004.[23]

One way to overcome these costs is to reduce the monetary base directly by requiring banks to hold greater levels of reserves which may generate low-to-zero returns. While the PBOC has made frequent use of this policy as well (by raising reserve

[22] While these results are instructive, an important caveat should be kept in mind. Since each forward recursive estimated offset and sterilization coefficients could be viewed as the average level of capital mobility and the average extent of sterilization respectively before the specific period, the estimation inherently puts more weights on the previous periods and makes the estimates bias toward it.

[23] In Asia, Malaysia has also been faced with such a problem.

requirements), the quasi-fiscal costs are merely transformed into banking costs as domestic banks' profitability is reduced, while bank management decisions (regarding asset allocation) are constrained. The costs to China’s financial system could become quite burdensome over time (if they have not already) considering the already weak state of the domestic financial system. Allowing for a higher degree of exchange rate flexibility should go some way in overcoming the inflationary pressures in China, though the extent and manner in which a more flexible exchange rate regime is to be introduced is too involved an issue to be discussed here.

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Table 1: Legal Reserve Requirement Ratio in China, 1984 - 2004

1984	Reserve requirement was 20% on business deposits, 40% on demand deposits, and 25% on demand deposits in rural credit cooperatives.
1985	Reserve requirement was reduced to 10% for all deposits.
1987	Reserve requirement was raised to 12%.
1988	Reserve requirement was raised further to 13%.
March 1998	Reserve requirement was reduced to 8%.
November 1999	Reserve requirement was reduced to 6%.
September 2003	Reserve requirement was raised to 7%.
April 2004	The system of differentiated reserve requirement ratio was adopted again. Legal reserve requirement was raised to 7.5% for most of financial institutions. However, in order to support the agricultural credit and the reform of the rural credit cooperatives, the reserve requirement for the urban and rural credit cooperatives were still 6%. The reserve requirement for the financial institutions with poor capital adequacy and asset quality was raised to 8%.

Source: Adapted from China's 2003 and 2004 Annual Monetary Report and the website of *ChinaMoney.com*.

Table 2: Definitions and Measurement of the Variables Used in Empirical Study

Variables	Definitions	Measured as	Data (Source)
ΔNFA	The change in NFA scaled either by the GDP or by the lagged value of reserve money.	$\Delta NFA_t / GDP_t$ *or* $\Delta NFA_t / RM_{t-1}$	*IFS*
ΔNDA	The change in NDA scaled either by the GDP or by the lagged value of reserve money.	$\Delta NDA_t / GDP_t$ *or* $\Delta NDA_t / RM_{t-1}$	*IFS*
mm_t	Money Multiplier for M2	*M2/Reserve Money*	*IFS*
Δmm_t	The change in money multiplier for M2	$Log(mm_t) - Log(mm_{t-1})$	
$REER_t$	Real Effective Exchange Rate		*IFS*
$Y_{c,t}$	Cyclical Income. The real output growth rate deviated from its trend. The trend is measured by HP filter.	*Real GDP growth rate – HP filter Trend*	*IFS and TEJ Great China Database*
Δp_t	Inflation Rate	$Log(CPI_t)$-$Log(CPI_{t-1})$	*TEJ Great China Database*
Δr_t^*	The change in foreign interest rate	$Log(1+ \text{US treasury rate})_t$ – $Log(1+\text{US treasury rate})_{t-1}$	*IFS*
$\Delta E_t S_{t+1}$	The expected change in nominal exchange rate depreciation (Yuan/US).	$Log(E_{t+1}) - Log(E_t)$ *if perfect foresight.*	*IFS*
$G_{c,t}$	Cyclical government fiscal balance scaled either by the GDP or by the lagged value of reserve money. The trend is measured by HP filter.	*Cyclical Fiscal Balance / GDP or Cyclical Fiscal Balance/* RM_{t-1}	*IFS*
σ_{ex}	Volatility of exchange rate	*The standard deviation of the within quarter change in the monthly real effective exchange rate.*	*IFS*
σ_r	Volatility of domestic interest rate.	*The standard deviation of the within quarter change in the monthly domestic interest rate (bank rate).*	*IFS*
d_1	Dummy variable for $\Delta NDA < 0$	d_1*=2 if* $\Delta NDA < 0$; *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.*	

Table 3: Summary Statistics of Variables Used in Empirical Study

Variables	N	Mean	Std Dev	Minimum	Maximum
Net Foreign Asset	40	1717.94	928.792	499.27	4376.88
Net Domestic Asset	40	1846.84	338.264	1197.44	2451.24
Reserve Money	40	3564.78	1128.600	1729.70	5947.21
Nominal Exchange Rate (RMB/US$)	40	8.29	0.028	8.28	8.43
Real Effective Exchange Rate (REER)	40	97.30	5.702	81.79	106.50
M2	40	13329.19	5943.410	5028.33	25220.02
GDP	40	2266.51	700.444	982.76	4337.04
Bank Rate	40	5.26	2.993	2.70	10.44
US Treasury Rate	40	3.84	1.814	0.92	6.04
CPI	40	103.16	5.656	97.83	122.60
Fiscal Balance	38	-31.39	117.537	-378.28	244.22
Money Multiplier for M2	40	3.60	0.528	2.83	4.52
Volatility of REER	40	0.88	0.513	0.09	2.03
Volatility of Bank Rate	40	0.09	0.267	0.00	1.25

Table 4: Unit Roots Test: Augmented Dickey Fuller Test

Variables	Type of Test	Unit Root? (ADF test Statistic)
ΔNDA_t (Scaled by lag value of monetary base)	Drift and Trend	No (-6.921***)
ΔNDA_t (Scaled by GDP)	Drift and Trend	No (-6.507***)
ΔNFA_t (Scaled by lag value of monetary base)	None	Yes (0.538)
ΔNFA_t (Scaled by GDP)	None	Yes (-0.174)
Δmm_t	Drift	No (-6.63***)
$REER_t$	Drift	No (-3.301**)
$Y_{c,t}$	None	No (-6.084)
Δp_t	None	No (-2.471**)
$\Delta(r_t^* + E_t S_{t+1})$	None	No (-1.857*)
$G_{c,t}$ (Scaled by lag value of monetary base)	None	No (-7.534***)
$G_{c,t}$ (Scaled by GDP)	None	No (-7.307***)
$(d_1 - 1)\sigma_{r,t-1}$	Drift and Trend	No (-5.326***)
$(d_2 - 1)\sigma_{ex,t-1}$	Drift	No (-5.176***)

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

Table 5: Estimated Capital Inflows Function

Period: 1995: q1 - 2004: q4	Dependent Variable: ΔNFA_t			
	Scaled by Lag (RM)		Scaled by GDP	
	OLS	Simultaneous	OLS	Simultaneous
Intercept	**0.15573*****	**0.155797*****	**0.16832***	**0.166013****
	(0.04645)	(0.037382)	(0.08905)	(0.075676)
ΔNDA_t	**-0.56207*****	**-0.55828****	**-0.52528*****	**-0.54634****
	(0.11933)	(0.255927)	(0.12980)	(0.255396)
Δmm_t	**-0.53112*****	**-0.52742****	**-0.72259*****	**-0.75336***
	(0.12974)	(0.253499)	(0.21804)	(0.382976)
$REER_{t-1}$	**-0.0016*****	**-0.00161*****	**-0.00183****	**-0.00179****
	(0.00046)	(0.000380)	(0.00087)	(0.000791)
$Y_{c,t-1}$	-0.0105	-0.01049	0.04081	0.040687
	(0.02917)	(0.023322)	(0.05583)	(0.044669)
Δp_{t-1}	-0.16847	-0.1661	-0.13733	-0.15976
	(0.19524)	(0.215305)	(0.35948)	(0.380035)
$\Delta(r_t^* + E_t S_{t+1})$	**-0.0572****	**-0.05737****	-0.07386	**-0.07223***
	(0.02457)	(0.022333)	(0.04583)	(0.040838)
$G_{c,t}$	0.20547	0.205084	0.08838	0.080183
	(0.17263)	(0.140088)	(0.21174)	(0.192159)
$(d_2 - 1)\sigma_{ex,t-1}$	0.0015	0.001485	0.0018	0.001906
	(0.00285)	(0.002522)	(0.00535)	(0.004445)
ΔNFA_{t-1}	**0.26062***	**0.26152****	**0.3076****	**0.303083****
	(0.12675)	(0.115885)	(0.14533)	(0.126538)
Q2	0.00112	0.001161	0.03144	0.031045
	(0.02024)	(0.016431)	(0.03907)	(0.031555)
Q3	0.01231	0.012333	0.01772	0.017276
	(0.00888)	(0.007206)	(0.01769)	(0.014965)
Q4	0.02312	0.023081	0.01441	0.013412
	(0.01936)	(0.015704)	(0.03561)	(0.030552)
R-square	0.7864	0.74016	0.6979	0.63286
Adj. R-square	0.6749	0.6046	0.5403	0.4413

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

Table 6: Estimated Monetary Reaction Function

Period: 1995: q1 - 2004: q4	Dependent Variable: ΔNDA_t			
	Scaled by Lag (RM)		Scaled by GDP	
	OLS	Simultaneous	OLS	Simultaneous
Intercept	**0.13685****	**0.115045****	0.12596	0.129698
	(0.05404)	(0.050556)	(0.09907)	(0.090877)
ΔNFA_t	**-0.84644*****	**-0.73104*****	**-0.7732*****	**-0.78682*****
	(0.14240)	(0.176571)	(0.15627)	(0.204985)
Δmm_t	**-0.94344*****	**-0.93764*****	**-1.36736*****	**-1.36782*****
	(0.06995)	(0.057104)	(0.13198)	(0.105657)
$REER_{t-1}$	**-0.00151****	**-0.00129****	-0.00135	-0.00139
	(0.00056)	(0.000526)	(0.00103)	(0.000956)
$Y_{c,t-1}$	0.01396	0.016761	0.05246	0.052593
	(0.03390)	(0.027670)	(0.06545)	(0.052349)
Δp_{t-1}	-0.31989	**-0.31662***	-0.53074	-0.52843
	(0.20876)	(0.169268)	(0.39061)	(0.313483)
$\Delta(r^*_{t-1} + E_{t-1}S_t)$	**-0.06511****	**-0.05978****	**-0.09621***	**-0.09707****
	(0.02893)	(0.024252)	(0.05349)	(0.043961)
$G_{c,t}$	0.3249	**0.32653***	-0.11027	-0.10827
	(0.19621)	(0.159067)	(0.23648)	(0.190562)
$(d_1 - 1)\sigma_{r,t-1}$	0.01054	**0.011848***	0.02103	0.020834
	(0.00827)	(0.006875)	(0.01540)	(0.012534)
ΔNDA_{t-1}	0.09801	**0.097199***	0.04169	0.041602
	(0.06398)	(0.051874)	(0.07792)	(0.062298)
Q2	0.02235	0.02301	0.03942	0.039648
	(0.02554)	(0.020720)	(0.05048)	(0.040449)
Q3	**0.02199***	**0.021056***	0.01243	0.012681
	(0.01266)	(0.010320)	(0.02403)	(0.019434)
Q4	**0.05068****	**0.050707****	0.00931	0.009529
	(0.02409)	(0.019529)	(0.04377)	(0.035090)
R-square	0.9696	0.96771	0.9467	0.94479
Adj. R-square	0.9537	0.95086	0.9189	0.91598

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

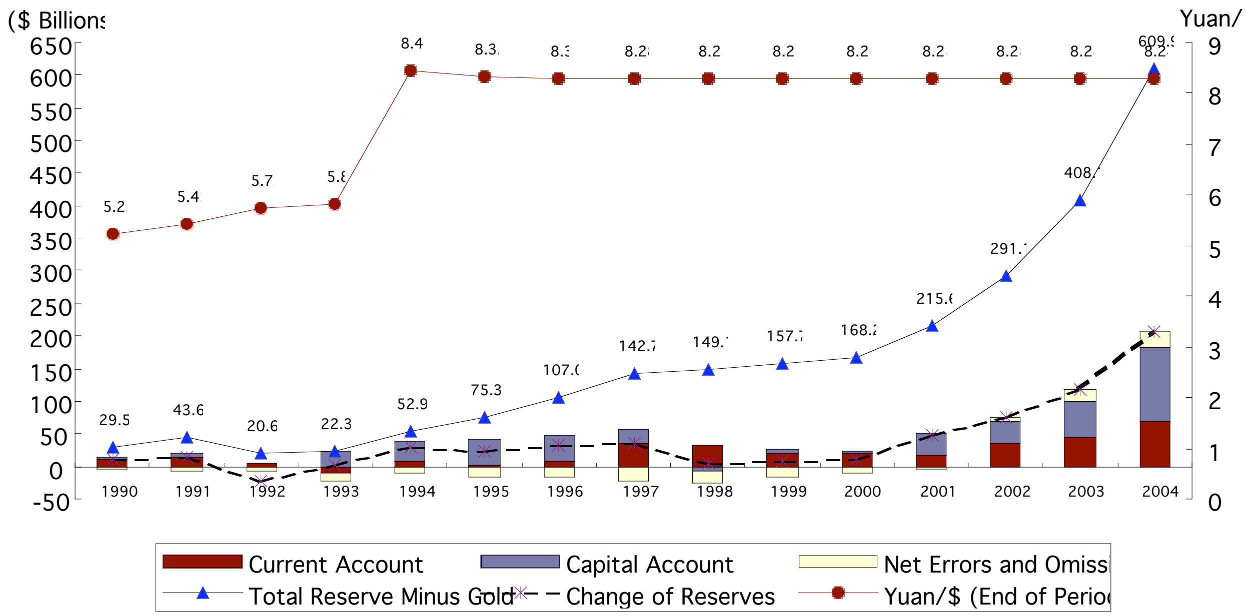
Table 7: Summary of Sterilization and Offset Coefficients Estimated from Previous Studies Since 1990[1]

Author(s)	Country(s) / Freq. & Interval	Estimated Sterilization Coefficient	Estimated Offset Coefficient
Fry (1990)	Sri Lanka / A: 1960-87	0.89	-0.65
Kim (1995)	Korea / Q: 1980-1994	-0.76	-0.35
Fry (1996)	27 Developing Countries[2] 6 Pacific Basin Countries / A: 1960-1991 Indonesia Korea Malaysia Philippines Taiwan Thailand	-0.18 to -0.17 -0.41 -2.88 -0.25 1.30 1.17 1.86 -2.92	-0.23 to -0.25 -0.13 -0.27 -0.24 0.15 -0.33 -0.49 0.33
Sarjito (1996)	Indonesia/ Q: 1976-92	-0.67 to -0.47	-0.50
Rooskareni (1998)	Indonesia / M: 1978:2-1993:3	-0.68 to -0.42	-0.25
Savvides (1998)	Cameroon / A: 1975-88; Cote d'lvoire / A: 1970-91; Gabon / A 1969-92; Ghana / A: 1966-92; Nigeria / A: 1964-91	-0.13	-0.23
Siklos (2000)[3]	Hungary / M: 1992:01-1997:03	-1 to -1.14	n.a.
BGT (2002)	Germany / Q: 1979-92	-0.74	-0.22
Emir et al. (2002)	Turkey / M: 1990-93 : 1995-99	-0.54 -0.88	-0.29 -0.78
Clavijo et al. (2003)	Colombia / Q: 1990-2003	-0.42	-0.78

Notes: 1) All of these offset coefficients are estimated by simultaneous equations.
2) 27 developing countries are Algeria, Argentina, Brazil, Chile, Côte D'Ivoire, Egypt, Ghana, Greece, India, Indonesia, Korea, Malaysia, Mexico, Morocco, Nigeria, Pakistan, Peru, Philippines, Portugal, Sri Lanka, Taiwan, Tanzania, Thailand, Turkey, Venezuela, Yugoslavia and Zaire.
3) The sterilization coefficient in Siklos (1998) is estimated by OLS. But he also indicates that there is not much difference between the OLS estimation and two stage least squares.

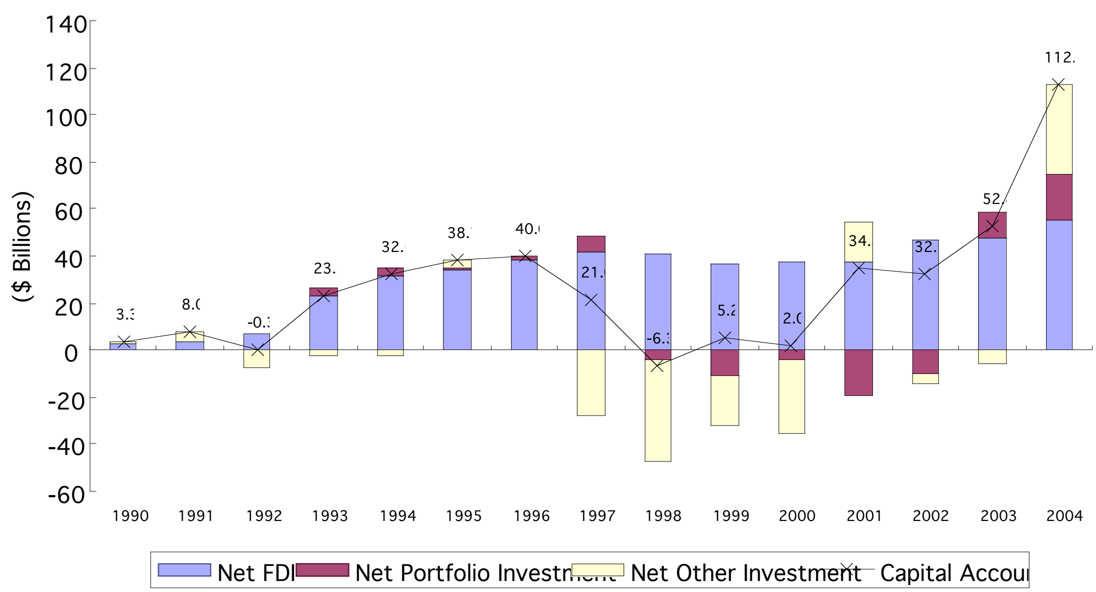
Source: Compiled by authors

Figure 1: Trends in China's Balance of Payments Transactions (Billions of US$), 1990 - 2004



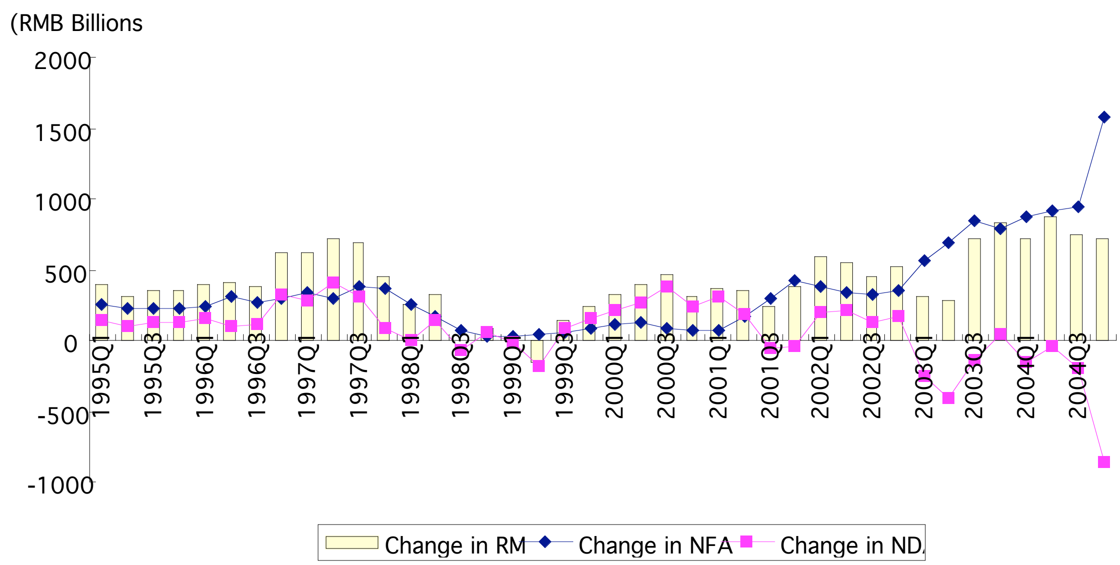
Source: IFS, the SAFE website and TEJ Great China Database

Figure 2: Capital Account Components (Billions of US$), 1990 - 2004



Source: IFS and the SAFE website

Figure 3: Annual Changes in NFA, NDA, and Reserve Money in China, 1995 - 2004

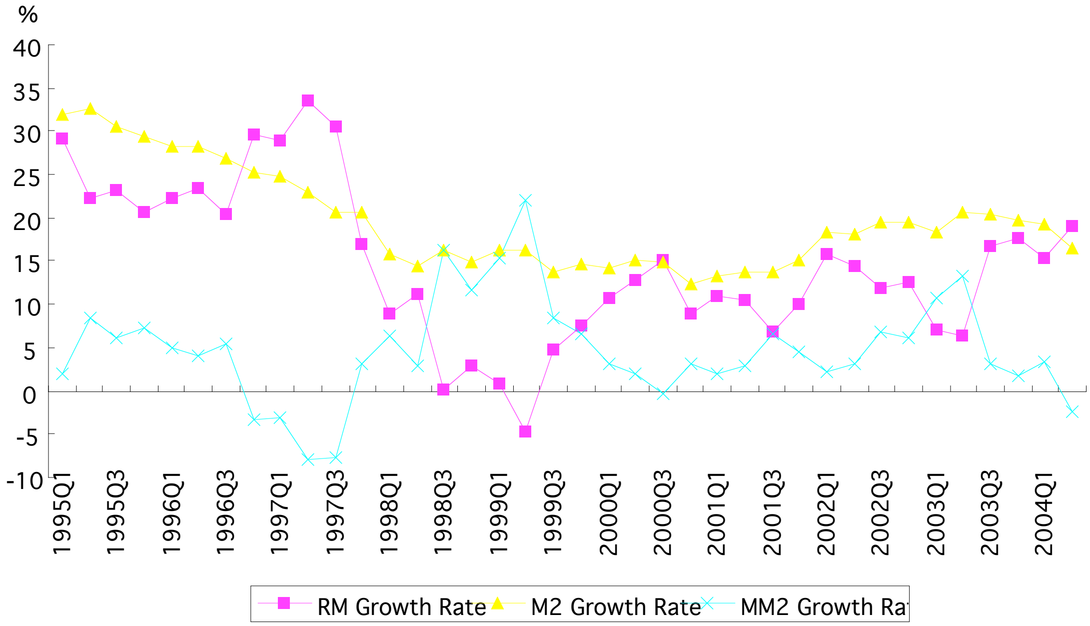


Source: IFS

Figure 4: Issuance of Central Bank Bills by the PBOC, 2002 - 2004

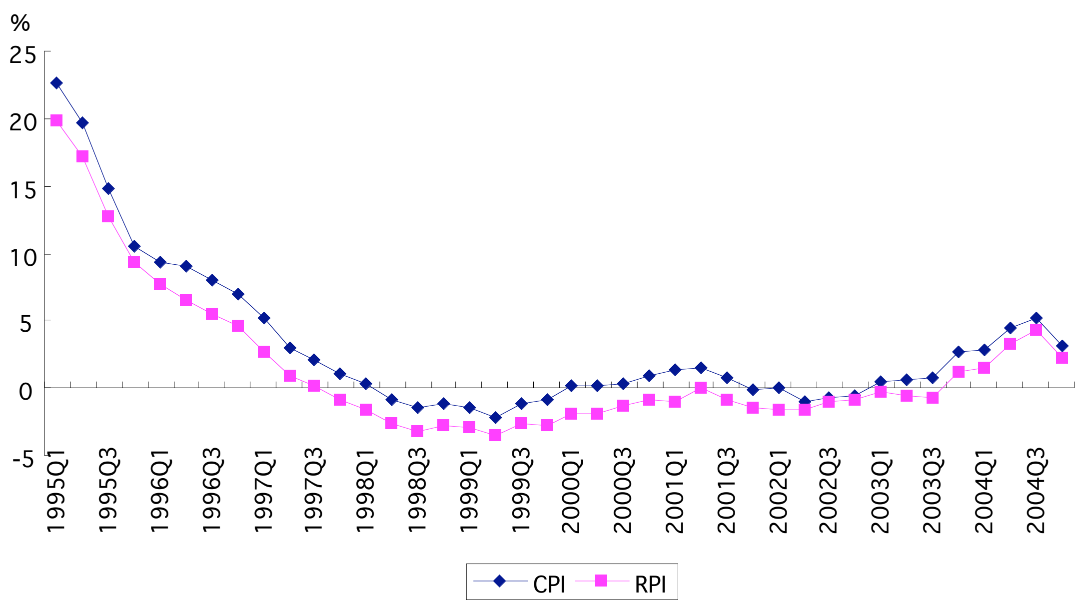
Source: PBOC website

Figure 5: Quarterly Annual Growth Rate of Reserve Money, M2, and the Money Multiplier for M2, 1995 - 2004



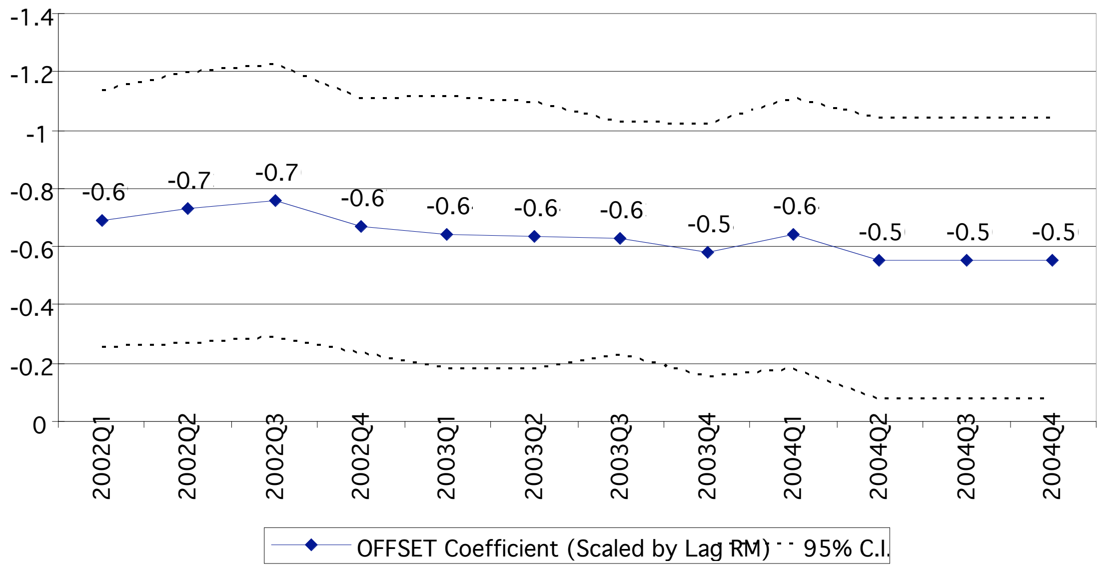
Source: IFS

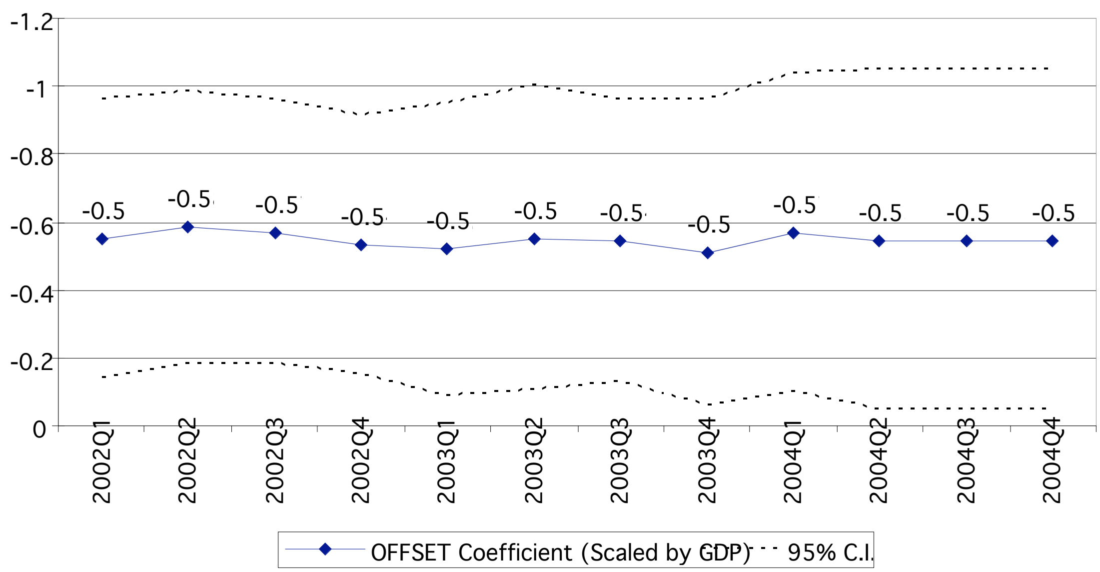
Figure 6: Inflation Rate in China (CPI and RPI), 1995 - 2004



Source: TEJ Great China Database

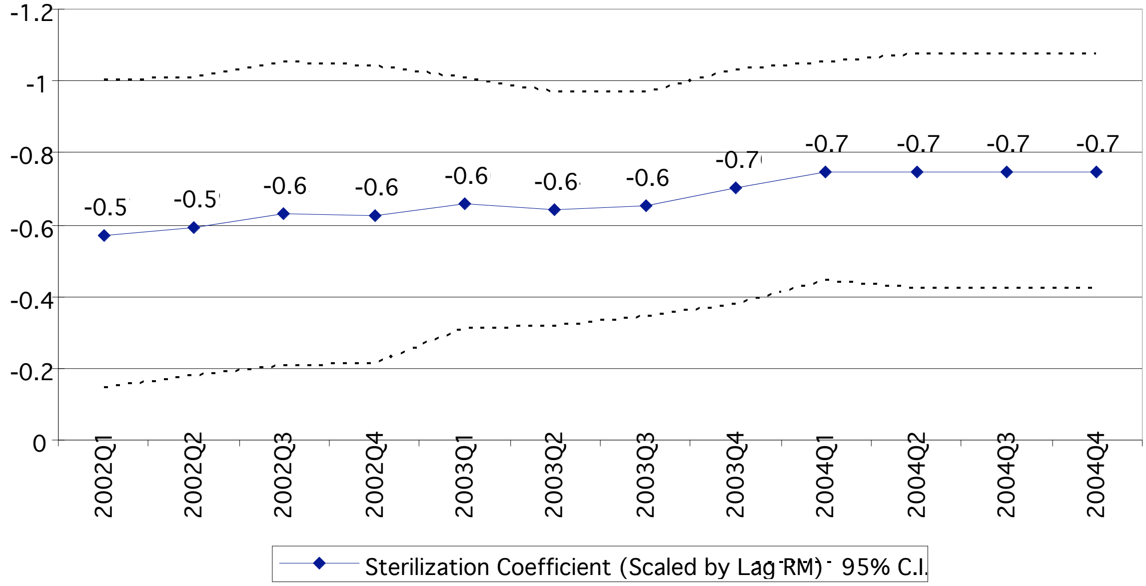
Figure 7: Forward Recursive Estimated Offset Coefficients

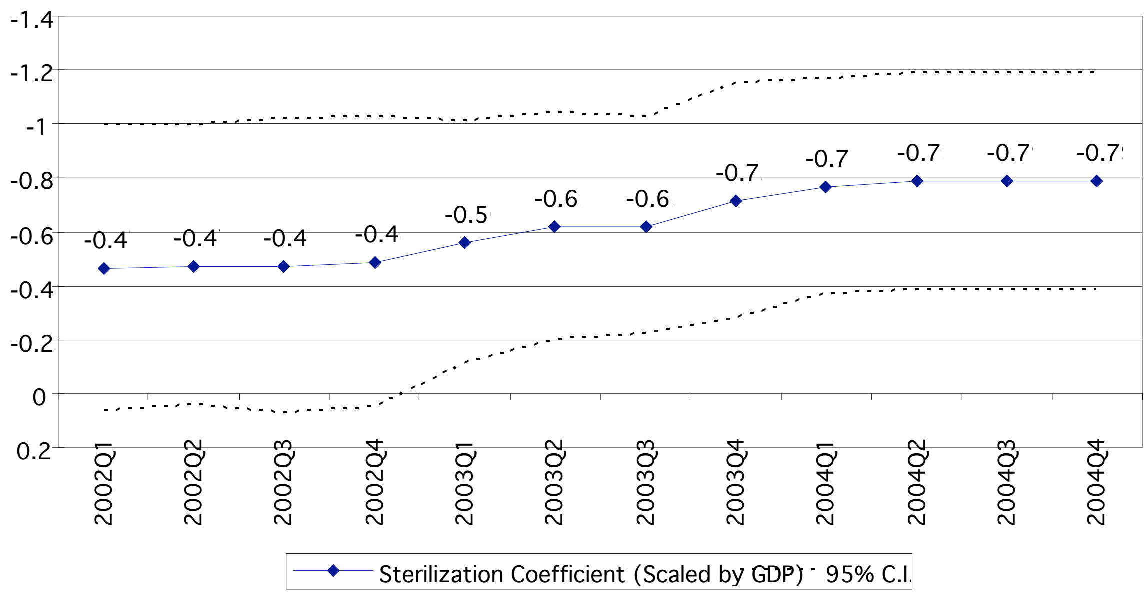




Note: The offset coefficients estimated recursively by the simultaneous equations (12) and (13). The first estimate is estimated by using the sample from 1995:q1 to 2002:q1 and then adding one more observation each time to re-estimate the offset coefficients.

Figure 8: Forward Recursive Estimated Sterilization Coefficients





Note: The sterilization coefficients estimated recursively by the simultaneous equations (12) and (13). The first estimate is estimated by using the sample from 1995:q1 to 2002:q1 and then adding one more observation each time to re-estimate the sterilization coefficients.