Hot Money Inflows and Monetary Stability in China: How the People's Bank of China Took up the Challenge*

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Abstract

Non-foreign direct investment capital inflows in China were particularly strong in 2003 and 2004. They were even stronger than current account surpluses or net foreign direct investment inflows. As a result, the pace of international reserves accumulation in China increased significantly. This paper investigates if the rapid build up of international reserves in 2003 and 2004 was a source of monetary instability in China. The relationship between international reserves and domestic credit is examined with a Vector Error Correction Model (VECM), estimated on monthly data from March 1995 to December 2005. Empirical results show that this relationship was stable and consistent with monetary stability. Direct and indirect Granger causality tests are implemented to show how the People's Bank of China (PBC) achieved this monetary stability.

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Keywords: hot money inflows, international reserves, VECM, Granger causality

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1 Introduction

During the 1997-1998 Asian financial crisis, the Chinese economy performed well. The limited financial liberalization is the main feature explaining why China's financial system had been insulated from the crisis. Its relatively closed financial account prevented the accumulation of foreign-currency-denominated liabilities in the private sector. Capital controls also prevented destabilizing currency attacks (Fernald and Babson, 1999). However, the financial liberalization in China progressed gradually over the last decade. The magnitude and the nature of capital flows in China deeply changed. Capital controls became less effective and cannot provide a long lasting protection anymore if incentives for capital inflows linger (Ma and McCauley, 2004; Prasad and Wei, 2005). Besides, reforms in the banking sector highlight the transformation of the Chinese economy from a centrally planned economy to a market-based economy (Mo, 1999; Woo, 2002; Barnett, 2004). A greater decision-making autonomy have been given to the banking sector and fluctuations in bank credit have now large implications for the macroeconomic situation[1] (Hu, 2003). As a result, hot money inflows can henceforth fuel the Chinese financial system and provide excess liquidity to the banking sector.

Over the last decade, China recorded strong current account surpluses and strong net foreign direct investment (FDI) inflows. Prasad and Wei (2005) show also that non-FDI capital inflows in China were particularly strong in 2003 and 2004. They were even stronger than current account surpluses or net FDI inflows. These non-FDI capital inflows can be considered as hot money inflows. They were mainly driven by the interest rate differential between China and the United States (US), coupled with expectations of a renminbi (RMB) revaluation. Current account surpluses and FDI inflows are rather driven by fundamentals.

Changes in international reserves of the People's Bank of China (PBC) are given by current account surpluses and financial account surpluses. Hot money inflows in 2003 and 2004 increased therefore significantly the pace of international reserves accumulation in China. In addition, the

[1] Even if the efficiency of the banking secor remains low (Allen et al., 2005)

central bank balance sheet identity defines the monetary base as the sum of net domestic assets plus net foreign assets (i.e. international reserves). Upsurges in international reserves, specially if they offset hot money inflows, challenge therefore the PBC to manage the monetary base expansion and more generally the money supply expansion. The rapid build-up in international reserves in 2003-2004 could have been a source of monetary instability. Excess liquidity could have been provided to the banking sector, promoting inflation pressures and an excessive credit expansion.

In this paper, we investigate if the rapid build-up in international reserves in 2003 and 2004 was a source of monetary instability. Money supply is made up of domestic credit and international reserves. The monetary stability that we consider is therefore related to the relationship between international reserves and domestic credit. When the central bank intervenes in the foreign exchange market to offset hot money inflows and to keep the exchange rate stable, net foreign assets increase in its balance sheet, leading (ceteris paribus) to a monetary base expansion. This injection of liquidity could positively affect the growth of output, monetary aggregates and domestic credit. The central bank could lose the control of money supply and more precisely the control of domestic credit. As a result, monetary stability implies that international reserves and domestic credit should be (ceteris paribus) negatively related so that if one component of money supply increases, the other one decreases to stabilize the overall money supply.

First, we examine with a Vector Error Correction Model (VECM) on monthly data from March 1995 to December 2005 the relationship between international reserves and domestic credit. Empirical results show that this relationship was stable and consistent with monetary stability. Second, we explain how the PBC proceeded to manage the upsurge in international reserves and keep domestic monetary condition under control. The PBC implemented sterilization measures in the narrow sense (with open market operations) as well as in the broader sense (with reserve requirement ratio and window guidance). We examine with direct and indirect causality tests how broad money and domestic credit had been affected by these sterilization measures. Empirical results show that open market operations and reserve requirements did not drain all the liquidity. The upsurge in international reserves led to monetary expansion. Nevertheless, we find that the PBC

succeeded to shape domestic credit using window guidance.

The remainder of the paper is organized as follows. Section II briefly reviews causes and implications of the upsurge in international reserves. Section III presents the empirical assessment of monetary stability. Section IV investigates the management of net foreign assets. Section V concludes.

2 Causes and implications of the upsurge in international reserves

2.1 Hot money inflows in China

The RMB has been convertible for current account transactions since 1996, but financial account transactions are still under control (Xiaopu, 2003, Yongding, 2004): portfolio investments are constrained, foreign direct investments are oriented and main short term capital inflows are forbidden. Nevertheless, the People's Republic of China (PRC) is not fully isolated from hot money inflows. Capital controls are not applied to each category of capital account transactions – several are free or loosely managed (Xie, 2004)[2].

The balance of payments roughly records the amount of hot money inflows (Tung and Baker, 2004; Rzepkowski, 2004; Genberg et al., 2005; Prasad and Wei, 2005). In Table 1, "Hot Money" is the sum of "Portfolio Investment", "Other Investment" and "Errors and Omissions" and corresponds therefore to non-FDI capital inflows. First, significant portfolio investment inflows are recorded in the financial account. During 2003 and 2004, net portfolio investment inflows were respectively \$11.43 and \$19.69 billions. Second, Chinese banks and depositors manage foreign assets. These transactions are recorded in the sub-section "Other Investment" in the financial account but official figures can be misleading. In December 2003, the PBC used \$45 billions of its international reserves in order to recapitalize two state commercial banks. This operation was

[2] Prasad and Wei (2005) provide an extensive chronology of capital controls over the period 1980 - January 2005.

recorded in the sub-section "Other Investment" and the funds were allocated to a holding company owned by the State Administration of Foreign Exchange (SAFE). As a result, other investment inflows represented $39.11 billions in 2003. Other investment inflows represented also $37.91 billions in 2004. Last, some capital inflows escape to regulatory controls but they are all the same recorded in the balance of payments in the statistical discrepancy. Errors and omissions increased significantly during 2003 and 2004 and represented respectively $18.42 and $27.05 billions[3] which contrasts with illegal capital outflows noticed during the 1990's (Gunter, 2004).

Hot money is mainly held by overseas Chinese (Chinese diaspora, mainly from Taiwan), Chinese banks converting their foreign assets into RMB assets and Chinese households stopping the accumulation of foreign deposits (Ma and McCauley 2003, 2004; Rzepkowski, 2004). Hot money inflows are estimated at $68.96 and $84.64 billions respectively in 2003 and 2004 (Table 1). They are stronger than current account surpluses (respectively $45.87 and $68.66 billions) or net FDI inflows (respectively $47.23 and $53.13 billions) during these two years. Hence, the rapid increase of international reserves during 2003 and 2004 offset mainly non-FDI capital inflows rather than trade surplus or net FDI inflows. Hot money inflows increased therefore significantly the pace of international reserves accumulation in China.

US interest rate changes could be the main factor explaining hot money inflows. Figure 1 shows that the international reserves upsurge started with the US interest rate cut in 2001 whereas the Chinese interest rate has been roughly stable. The interest rate differential between China and the US is linked to capital controls applied by the PBC but Cheung et al. (2003) also highlight an increasing financial integration between the PRC and the US. Thus, the PBC has to consider international issues as the financial liberalization comes into effect. In addition, exchange rate expectations could constitute a second important factor explaining hot money inflows. The PBC applied up to July 2005 a fixed exchange rate against the US dollar but speculation around the RMB appreciation has been going up according to the dollar general weakness and the commercial

[3] The evolution of the errors and omissions category may also in part reflect an accounting issue related to changes in the dollar value of foreign asset (Prasad and Wei, 2005).

imbalance between the US and China. The offshore interest rate implied by the markets for non-deliverable forwards (NDF) in Asian currency underlines this issue (Ma et al., 2004; Fung et al., 2004)[4].

According to Goldstein and Lardy (2003) and Tung and Baker (2004), the PBC could have implemented a 15% revaluation of the RMB but speculators cannot expect anymore such a large one-off revaluation. The new exchange rate arrangement announced in July 2005 makes clear that the PBC will move gradually toward more exchange rate flexibility. The PBC announced a 2.1% appreciation of the RMB against the dollar and a move to a managed float with reference to a basket of currencies. This new exchange rate arrangement is heavily managed, the PBC allows a daily trading band of +/- 3% around the exchange rate announced the day before. Besides, Figure 1 shows that the US interest rate is increasing since mid-2004, while the Chinese interest rate have barely changed. As a result, incentives for hot money inflows have been removed and hot money inflows evaporated in 2005 (Table 1).

2.2 International reserves and monetary stability

The following equations show how domestic credit and domestic prices can be affected by an upsurge in international reserves. The equilibrium condition in the money market is provided by the LM curve. The money demand results from a transaction motive and a speculative motive. The money supply is endogenous and made up of domestic credit and international reserves. The equilibrium in the money market is defined by

$$\frac{IR_t + DC_t}{P_t} = \mathrm{L}(y_t, i_t), \tag{1}$$

where P_t is the domestic price level, IR_t the international reserves, DC_t the domestic credit, y_t the output, i_t the real interest rate on domestic bonds and L(.) the money demand function with

[4]The evolution of Chinese foreign currency deposits is specially affected by the interest rate differential and the exchange rate expectations (Ma and McCauley, 2002, 2003; Rzepkowski, 2004).

$L_y(.) > 0$ and $L_i(.) < 0$[5].

Assuming simplified commercial bank balance sheets, where liabilities consist of deposits and where assets consist of required reserves, loans and bonds (Bernanke and Blinder, 1988; Greenwald and Stiglitz, 1990), the bank lending level is given by

$$DC_t = [(1-\tau)D_t]\gamma(i_t, \hat{y}_t), \tag{2}$$

where D_t are the deposits, τ the reserve requirement, $\hat{y}_t$ the output gap and $0 \leq \gamma(.) \leq 1$ the fraction of bank assets loaned with $\gamma_i(.) < 0$ and $\gamma_{\hat{y}}(.) > 0$. Risk-averse banks are less willing to invest in loans when the rate of return on the less risky government bonds is high. Further, an economic slowdown deteriorates the overall quality of the borrowing pool which reduces the willing of commercial banks to supply credit.

Assuming a simplified central bank balance sheet where assets consist of net foreign assets (NFA_t) and net domestic assets (NDA_t) and where the liability consists of the monetary base, the money multiplier theory defines deposits as

$$D_t = \frac{MB_t}{\tau + \theta}, \tag{3}$$

where $MB_t = NFA_t + NDA_t$ is the monetary base and θ the currency-demand deposit ratio.

In a fixed exchange rate system, changes in net foreign assets (ΔNFA_t) are determined by net capital inflows and current account.

$$\Delta NFA_t = CA_t + \mathrm{NK}(q_t - E_t(q_{t+1}) + i_t - i_t^* - \rho_t), \tag{4}$$

where CA_t is the current account balance, q_t the domestic real exchange rate, $E_t(q_{t+1}) - q_t$ the real expected depreciation of the domestic currency, i_t^* the US real interest rate on bonds, ρ_t the risk premium and the extent of capital controls. NK(.) represents net capital inflows and depends

[5] $L_j(.)$ is the partial derivative with respect to variable j.

positively on deviation from uncovered real interest rate parity $(q_t - E_t(q_{t+1}) + i_t - i_t^* - \rho_t)$.

Equations (1), (2), (3) and (4) show how international reserves can affect the monetary stability. Changes in the foreign interest rate and in exchange rate expectations justify hot money inflows and then the build-up of international reserves. This upsurge in international reserves leads to a monetary base expansion. This expansion is reflected in deposits and can finally cause an excessive credit expansion and/or inflation pressures if the money demand is stable. The central bank can implement sterilization operations to control domestic monetary conditions[6]. First, net domestic assets can be adjusted downward with open market operations. Second, the reserve requirement can be increased to reduce the money multiplier. Finally, the central bank can use administrative measures to curb domestic credit.

3 Empirical assessment of monetary stability

A VECM is estimated using monthly data from March 1995 to December 2005 to investigate the stability of monetary conditions. We examine if the relationship between international reserves and domestic credit was consistent with monetary stability. According to the equilibrium condition in the money market, international reserves and domestic credit should exhibit a negative relationship if the PBC succeeded in managing international reserves and in keeping domestic credit under control.

3.1 Data and VECM specification

Endogenous variables are gross international reserves less gold (IR_t), domestic credit (DC_t), GDP[7] at constant prices (y_t), consumer prices (P_t) and US real interest rate (i_t^*). Due to data availability and also to care about the scope of the VECM, the Chinese interest rate and exchange rate expectations are not taken into account. Time series available on the Chinese interest rate start

[6] See Brissimis et al. (2002) for a model analysing offsetting capital flows and sterilization.

[7] The Chow and Lin (1971) method is used to obtain the GDP monthly estimate. This method allows to obtain the best linear unbiased estimates of a monthly series by regression on related series. We use the industrial production index (IPI) as related series.

in March 1997 and time series available on NDF start in August 2001 (we use the IFS database, the ARIC database and the EcoWin database). Besides, the US interest rate is considered in the cointegrating vector. This variable does not pose the problem of data availability and was a driving force in the rapid upsurge in international reserves in 2003 and 2004. Finally, real effective exchange rate ($REER_t$) and banking system's reserves (BR_t) are considered as exogenous variables. These variables control respectively for a competitive effect and for the monetary base expansion.

We use the log transformation of index variable (January 1996=100) for all variables except US real interest rate (see the data appendix for the data sources). The original data on domestic credit and international reserves are modified. First, the \$45 billions used to recapitalize two national banks are added to international reserves in order to have a good specification of the upsurge in international reserves. Second, data on domestic credit showed a strong break in January 2002 corresponding to a 13% growth rate whereas it was around 1% during the previous months. We therefore consider a 1% growth rate in January 2002[8].

Four unit root tests are implemented[9]: Augmented Dickey-Fuller (ADF), Elliott-Rothenberg-Stock (DF-GLS), Phillips-Perron and Kwiatkowski-Phillips-Schmidt-Shin (KPSS). We conclude that domestic credit, GDP, US real interest rate, real effective exchange rate and banking system's reserves are non-stationary in level but stationary in first-difference. These variables are therefore considered as I(1) variables. Besides, we conclude that international reserves and consumer prices are non-stationary both in level and first difference but stationary in second difference. These variables are therefore considered as I(2) variables. These statistical properties highlight that the inflation rate and the growth rate of international reserves are non-stationary. This outcome could have been expected with Figure 1 and sums up the point of the paper: Did this I(1) growth rate in international reserves lead to monetary instability or did the PBC succeed to manage the rapid upsurge in international reserves and keep domestic credit under control?

The non-stationary growth rates of international reserves and consumer prices have strong

[8] These two modifications allow to get residual normality without the introduction of dummy variables. Moreover these two shocks would have introduced an isolated instability in the long term relation resulting from accounting procedures.

[9] These tests are available upon request.

implications for the VECM specification. First, the statistical relationship that we can investigate is between the first difference of international reserves and the level of domestic credit. Second, we have to use the first difference of consumer prices in the vector of endogenous variables which implies that we also have to use real domestic credit (DC_t^R) and real banking system's reserves (BR_t^R). The VECM specification is therefore

$$\Delta Y_t = \mu_0 + \sum_{i=1}^{k} \phi_i(\Delta Y_{t-i}) + \varphi_1(\Delta X_t) + \alpha(\beta Y_{t-1} + \mu_1) + \varepsilon_t, \tag{5}$$

where $Y_t' = [\ \Delta(IR_t) \quad \Delta(P_t) \quad DC_t^R \quad y_t \quad i_t^*\ ]$ and $X_t' = [\ REER_t \quad BR_t^R\ ]$ are random vectors, μ_0 and μ_1 are 5x1 constant vectors and the error vector ε_t is such that $E(\varepsilon_t) = 0$, $E(\varepsilon_t \varepsilon_s') = 0$ if $t \neq s$ and $E(\varepsilon_t \varepsilon_s') = \Omega$ if $t = s$ with $\det(\Omega) \neq 0$.

The model is estimated with three lags in order to achieve normality (Jarque-Bera test) and independence (LM test) of residuals. A lag exclusion (Wald) test is also implemented and we find that the fourth lag can be excluded (Table 2).

The Johansen and Juselius (1990) cointegration method is used to estimate equation (5). This method allows to test for the number of cointegrating vectors using a trace test. However, this test could lead to an over rejection of the no cointegration hypothesis if we do not check for the cointegrating rank constancy and if we do not correct for the finite sample bias. Consequently, forward recursive trace tests are implemented to investigate the cointegrating rank stability. Moreover, the trace test statistic is corrected for the finite sample bias as suggested by Reinsel and Ahn (1992) and Reimers (1991)[10]. The forward recursive trace tests with the finite sample bias correction (Figure 2) support the existence of one cointegrating vector[11]. Although the second cointegrating vector is significant for the whole sample at the 1% level with the corrected trace test, this relation is not significant at the 1% level before September 2005 and at the 5% level before September

[10] This correction does not consist in estimating new critical values but in multiplying the trace test statistic by the scale factor $(T - pk)/T$, where T is the number of observations, p the number of endogenous variables and k the number of lags .

[11] All the recursive procedures have to be cautiously considered. The range of the initial sub-samples is small.

2004[12].

3.2 Estimated cointegrating vectors

Table 2 displays the long term part of the VECM. The cointegrating vector (β) represents the long run relationship and adjustment coefficients (α) represent the weights attached to the cointegrating relation in the individual equations of the model. The first estimation (β_1, α_1) considers the homogeneity constraint between the first difference of international reserves and the first difference of consumer prices. The LR test shows that the homogeneity restriction is not rejected at the 5% level (Table 2). Besides, the LR test does not support the nullity of other coefficients in the cointegrating vector. As expected, the first difference of international reserves exhibit in the long-run a positive relationship with GDP and negative ones with real domestic credit and US real interest rate. We also check that the equilibrium error is a stationary process. As a result, the first difference of international reserves and real domestic credit have a common stochastic trend. Increases in the pace of international reserves accumulation are related to downward pressures in real domestic credit and vice-versa, real domestic credit expansions are related to decrease in the pace of international reserves accumulation. This outcome is consistent with monetary stability and need to be more closely investigated.

The second estimation (β_2, α_2) also tests for the weak exogeneity of real domestic credit, GDP, US real interest rate and the first difference of consumer prices. The LR test shows that these restrictions are not rejected at the 5% level (Table 2). The first difference of international reserves is therefore the only variable which responds to deviations from the long-run equilibrium. The adjustment coefficient on the error-correction term is negative (-0.8571) and highly significant which is consistent with equilibrium correction behavior. When the error-correction term is positive, due for example to a rise in US real interest rate, the first difference of international reserves decreases to reach is its equilibrium. The speed of adjustment is equal to one minus the first order autoregressive

[12] The backward recursive trace test – checking the cointegrating rank constancy in the baseline sample – also supports the existence of one cointegrating vector. This test is available upon request.

coefficient of the error-correction term (Phylaktis and Kassimatis, 1994). We find that 70% of the gap between the first difference of international reserves and its equilibrium level is eliminated every month. As a result, a given deviation in the cointegrating relation is reduced to 90% of its original amount in 1.9 months[13]. This outcome results from the fixed exchange rate system. Deviations in the cointegrating relation are corrected by the adjustment of international reserves. In addition the estimated cointegrating vector represents the long run determination of the first difference of international reserves since other variables are weakly exogenous.

The third estimation (β_3, α_3) directly considers the first difference of real international reserves. This specification allows to reduce the scope of the VECM. The cointegrating vector is robust to this specification. We also test if the exogenous variables should be introduced in the cointegrating vector (available upon request). We alternatively introduce real effective exchange rate and banking system's reserves in the cointegrating vector. The cointegrating vector is robust to these specifications and the LR test supports the nullity of the coefficient associated with real effective exchange rate and banking system's reserves. Hence, we conclude that real effective exchange rate and banking system's reserves do not have to be introduced in the cointegrating vector.

The cointegrating vector β_2 is recursively estimated in order to investigate its constancy. Several restrictions have been made to obtain β_2. Consequently, we also implement recursively the LR test. Figure 3 shows that the LR test support recursively these restrictions at the 1% level. The recursive estimations of coefficients associated to real domestic credit (Figure 4), GDP (Figure 5) and US real interest rate (Figure 6) support the stability of the VECM. Nevertheless we can notice that recursively, the coefficient associated to GDP is weakly significant, the two times standard error band intersects with the horizontal axis. In addition, the coefficient associated to real domestic credit is significant but it is decreasing from January 2004.

As a result, the cointegrating vectors estimated in Table 2 support the negative relationship between the first difference of international reserves and real domestic credit. This relationship is

[13] If s is the speed of adjustment and if f and g are the initial and final percentage deviation from equilibrium respectively, the number of intervals from f to g is given by $r = (\ln(g) - \ln(f))/\ln(1-s)$ (Phylaktis and Kassimatis, 1994).

robust to the different specifications but recursive estimation show that its magnitude is somewhat decreasing.

3.3 Impulse responses

Impulse responses are used to analyze the dynamic interactions between variables and more precisely between the first difference of international reserves and real domestic credit. We use the VECM specification (β_3, α_3) to implement these impulse responses. First, we implement a system Sequential Estimation of Regressors (SER) procedure in order to test restrictions for the short run parameters[14]. This strategy allows to fit a subset model removing insignificant coefficients.

The reduced-form residuals of this system are found to be instantaneously uncorrelated. We can therefore conclude to the absence of any instantaneous causality between variables and we can implement forecast error impulse responses.

We compute Hall's studentized confident intervals based on 2500 bootstrap replications and 100 replications for estimating the variance in each of the outer replication rounds. Standard and Hall confident intervals based on 2500 bootstrap replications give similar results but they are not displayed on Figures 7a-j for clarity. We also use these three methods to compute confident intervals based only on 1000 bootstrap replications. Similar results are obtained which confirm the robustness of the confident intervals displayed on Figures 7a-j.

First, we consider a one-time impulse in the first difference of real international reserves (Figure 7a) and a one-time impulse in real domestic credit (Figure 7d). The shock in the first difference of real international reserves is transitory because the adjustment force on international reserves is strong (Table 2). Real domestic credit reacts negatively and significantly (Figure 7c) to this shock. In addition the first difference of real international reserves reacts negatively and significantly to the shock in real domestic credit (Figure 7b). These impulse responses support the negative relationship between the first difference of real international reserves and real domestic credit. As

[14] The system SER procedure checks the parameter with the smallest t-ratio in each step. The elimination of this parameter is based on the AIC criteria.

a result, the increasing pace of international reserves accumulation in 2003 and 2004 did not lead to an excessive credit expansion. When one component of money supply faces a positive shock, the other one decreases to stabilize the overall money supply which is consistent with monetary stability.

Second, we consider a one-time impulse in GDP (Figure 7g). The first difference of real international reserves reacts positively and significantly to this shock (Figure 7e) which is consistent with the cointegrating relation obtained in Table 2. Figure 7f shows also that the increase in the pace of international reserves accumulation, caused by the GDP shock, is associated to downward pressures in real domestic credit. After approximately 15 months, the series seems to reach equilibrium.

Finally, we consider a one-time impulse in US real interest rate (Figure 7j). The first difference of real international reserves reacts negatively and significantly to this shock (Figure 7h) while real domestic credit reacts positively and significantly (Figure 7i). The cut in the US interest rate from 2001 to 2004 was therefore a driving force in the increasing pace of international reserves accumulation. However this upsurge in international reserves is also coupled with downward pressures in real domestic credit which stabilize the overall money supply.

We therefore conclude that the rapid upsurge in international reserves in 2003 and 2004 did not cause instability in domestic monetary conditions. The estimated cointegrating relations and impulse responses show that the interaction between domestic credit and the first difference of international reserves was negative and then consistent with monetary stability. We can now examine how the PBC proceeded to get this result.

4 The management of net foreign assets

In a fixed exchange rate system, hot money inflows lead the central bank to accumulate international reserves. As a result, net foreign assets (NFA) in the central bank balance sheet expand. Open market operations, reserve requirements and window guidance are the main instruments used by policymakers to manage consequences of these capital inflows on the domestic monetary

sector[15].

4.1 The sterilization policy

The PBC used open market operations to sterilize hot money inflows. Central bank bills rather than treasury bonds have been issued insofar as treasury bonds were managed to drive the money market interest rate (Xie, 2004; Green, 2005). Central bank bills are recorded as net other assets (NOA) in the central bank balance sheet (Hu, 2003). We can therefore investigate to which extent the PBC used these open market operations to manage the monetary base. Figure 8 shows year on year changes in components of the central bank balance sheet. Since 2003, the PBC has widely used central bank bills to slow down the monetary base expansion but this only partially offsets the international reserves build-up. From end-2000 to end-2003, Higgins and Klitgaard (2004) estimate that roughly half of NFA increase was sterilized by open market operations.

We can therefore compute an indicator of net foreign assets non sterilized by open market operations ($NFOA_t = NFA_t + NOA_t$). This indicator has a direct impact on monetary base but not necessary on monetary aggregates and domestic credit. Indeed, the PBC can use reserve requirements and window guidance to complete the sterilization process in a broader sense. Between the second half of 2003 and April 2004, the PBC raised banks' reserve requirements ratio from 6% to 7.5%. The PBC sought in this way to reduce the money multiplier in order to drain liquidity. Furthermore, the PBC implemented window guidance to curb new lending (Hagiwara, 2004; Green, 2005). The PBC directly intervened in the lending of specific banks to specific sectors. Since the four biggest banks – accounting for 69% of total bank deposits and 72% of total bank loans – are state-owned banks, bank instructions were efficient (Hu, 2003).

[15] Monetary authorities can also directly influence demand and supply in the foreign exchange market in order to manage of hot money inflows. Lu (2004) examines measures taken by Chinese authorities to ease appreciation pressures on the RMB. Nevertheless, the liberalization of capital outflows could be counterproductive since this could stimulate further inflows (Prasad et al., 2005).

4.2 Direct causality tests

The management of international reserves by the PBC is investigated with Granger causality tests on vector autoregressive (VAR) models. This specification without explicit theoretical ground is appropriate insofar as the PBC widely used, in a discretionary way, its control on the banking sector. The state-owned banks were used as sterilization bonds buyers and they were also used to implement the window guidance. Thus, even if the banking sector obtained a greater decision making autonomy in its relations with firms, the central bank kept the ability to directly intervene in the banking sector to ensure monetary stability. This approach with VAR models allows therefore to investigate the efficiency of sterilization when various monetary measures at various times in various intensities have been used (Takagi and Esaka, 1999).

We investigate with Granger causality tests if net foreign assets non sterilized by open market operations (NFOA) affect the monetary sector. We use the Toda and Yamamoto (1995) and Dolato and Lutkepohl (1996) procedure. This procedure does not require a cointegration analysis and allow to mix orders of integration processes. This procedure is implemented in two steps. First, we determine the maximum order of integration ($dmax$) of the variables in the system and the lag length (k) of a VAR system in stationary form. Second, we estimate a VAR in level with $p = k + dmax$ lags. Granger causality tests consist to apply standard Wald tests to the first k VAR coefficient matrix.

We consider several VAR systems. First, we consider two bivariate systems including NFOA and broad money (M2) or domestic credit. Second, we consider two multivariate systems including real NFOA, GDP at constant prices, Chinese real interest rate (Chibor 3 month) and real broad money or real domestic credit. Demand money motives are taken into account in these systems which allow to check the robustness of the results obtained with bivariate systems. Finally, we consider a trivariate system including NFOA, broad money and domestic credit in order to take into account interactions between broad money and domestic credit.

We use the log transformation of index variable (January 1997=100) for all variables except Chinese real interest rate. In addition, VAR systems are estimated using monthly data from March

1997 to March 2005[16].

Four unit root tests are implemented[17]: ADF, DF-GLS, Phillips-Perron and KPSS. We conclude that all variables are non-stationary in levels but stationary in first-differences. NFOA is therefore integrated of order one and unit root tests also showed that international reserves are integrated of order two. This different integration order underlines that open market operations were important to slow down the monetary base expansion.

The optimal lag order of the VAR system in stationary form is chosen considering residual statistical properties (normality and independence). We conclude that each system needs three lags and we take into account dummies[18] to get normality in the residuals. As a result, we estimate VAR systems in level with 4 lags and Granger causality is tested with restrictions placed on lagged terms up to the third lag.

Figure 9 displays the forward recursive causality tests from NFOA to M2. We conclude at the 10% level that NFOA Granger caused M2 in the three different VAR systems. Open market operations and rises in reserve requirements did not drain all the liquidity. Nevertheless, the monetary expansion would have been much more considerable without open market operations. These operations were therefore the main banks opportunity in order to get out of excess liquidity (Roubini and Setser, 2005a). Besides, Figure 10 shows the forward recursive causality tests from NFOA to domestic credit. We conclude at the 10% level that NFOA did not Granger cause domestic credit in the three estimated VAR systems. Hence, window guidance curbed credit growth and the PBC succeeded in keeping domestic credit under control.

4.3 Indirect causality tests

NFOA could all the same have an indirect impact on domestic credit. Figure 11 displays the forward recursive causality tests between broad money and domestic credit in the trivariate VAR system. We conclude that there is a bidirectional causality between these two variables on the

[16] The Chinese interest rate is not available before March 1997 in the EcoWin database.
[17] These tests are available upon request.
[18] April 2001 in the bivariate systems; February 1999 in the multivariate systems; June 2006 and April 2001 in the trivariate system.

whole sample although the causality from domestic credit to broad money is not systematically recursively confirmed. As a consequence, NFOA does not help to predict domestic credit one period ahead but can still cause domestic credit several periods ahead with indirect impacts via broad money.

Such indirect causality is investigated following Dufour et al. (2005). The trivariate VAR model written at time $t+1$ is established by

$$W_{t+1} = \mu + \sum_{l=1}^{4} \pi_l W_{t+1-l} + e_{t+1}, \tag{6}$$

where $t = 0, ..., T-1$, $W'_{t+1} = (\ NFOA_{t+1} \quad DC_{t+1} \quad M2_{t+1}\ )$ is a 3x1 random vector, μ is a 3x1 constant vectors and the error vector e_t is such that $E(e_t) = 0$, $E(e_t e'_s) = 0$ if $t \neq s$ and $E(e_t e'_s) = \Omega$ if $t = s$ with $\det(\Omega) \neq 0$.

Equation (6) represents a VAR model at horizon one. This model can be expanded to become an autoregressive process at horizon h. As suggesting by Dufour et al. (2005), we consider the following unrestricted model

$$W_{t+h} = \mu^{(h)} + \sum_{l_\&=1}^{4} \pi_{l_1}^{(h)} W_{t+1-l_1} + \sum_{l_2=0}^{h-1} \varphi_{l_2} e_{t+h-l_2}, \tag{7}$$

where $h < T$ and $\varphi_0 = I$.

The Granger causality is tested at horizon h applying standard Wald tests to the first 3 VAR coefficient matrix. Besides, we use the heteroskedasticity-autocorrelation consistent estimator developed by Newey and West (1987) to deal with the MA(h-1) error process. The cost of this simple procedure is a loss of efficiency since the unrestricted estimated model does not use all information.

The highest horizon we need to examine is $h = 4(= 1\text{x}3 + 1)$ according to Dufour and Renault (1998): we have one auxiliary variable (M2), the lag order of the VAR system in stationary form is three and direct causality corresponds to $h = 1$.

Figure 12 displays recursive indirect causality tests from NFOA to domestic credit. We conclude

that NFOA did not indirectly Granger causes domestic credit at the 10% level. The indirect causality test at horizon 3 is significant at the 10% level at the beginning of the recursive procedure but this outcome is not robust after January 2004. Open market operations and window guidance allowed therefore to manage direct and indirect (via the loose liquidity conditions) effects of net foreign assets on domestic credit.

4.4 Costs of the sterilization policy

Several costs resulting from the PBC sterilization policy have been highlighted (Roubini and Setser, 2005a-b; Goldstein and Lardy, 2005). First, the PBC used the state-owned banks as sterilization bonds buyers. Although these bonds pay more than the 1% associated with excess reserves, banks face a profitability issue. Sterilization bonds yield is close to the one on deposits and excess reserves result from quantitative constraints on bank lending. Consequently, the sterilization policy worsened the banking system weaknesses. Second, reserves management did not cause a profitability issue to the PBC insofar as its sterilization costs are largely offset by interest income on its reserves portfolio. Nevertheless, the PBC is threatened with an exchange rate risk and will face capital losses following an exchange rate revaluation. Roubini and Setser (2005a) estimate that a 33% RMB depreciation in 2004 would have represented a $150 billion loss which corresponds to 10% of China GDP. The PBC, that is taxpayers, is therefore exposed to the potential cost of the current sterilization policy. Lastly, sterilization measures can promote additional capital inflows since they limit the narrow and broad money expansions and therefore keep the level of domestic interest rates high. These additional capital inflows only occur when market participants consider that a higher risk premium on domestic assets does not offset these higher interest rates (Takagi and Esaka, 1999).

These costs associated with the upsurge in net foreign assets justify why China moved toward greater exchange rate flexibility in July 2005. This evolution is the more suitable to temper the excess of the domestic financial system and will enhance the ability of the PBC to tailor money and credit conditions to domestics needs (Eichengreen, 2004; Prasad et al. 2005).

5 Conclusion

Since the 1987 US stock market crash, the Federal Reserve has been using demand stimuli during downturns to flood the financial system with liquidity. Following the "dot com" bubble crash, the Federal Reserve kept interest rate lower and longer than in previous cycles. These loose monetary conditions led to hot money inflows in China, which boosted economic performances, triggered expectations of currency appreciation and finally caused more capital inflows.

Capital controls did not prevent hot money inflows since these controls have become less effective over time. As a result, the pace of international reserves accumulation in China increased significantly in 2003 and 2004. Chinese authorities delayed for a long time the move toward more exchange rate flexibility but they succeeded in managing the international reserves build-up. The estimated VECM shows that the relationship between domestic credit and the first difference of international reserves was stable and consistent with monetary stability. Moreover, direct and indirect causality tests display that the sterilization policy implemented by the PBC allowed to manage the effect of net foreign asset on domestic credit.

However, the sterilization policy was costly and it was not sustainable in the long run for the banking sector. Consequently, the PBC decided to start a shift in its currency policy. The PBC announced a 2.1% appreciation of the RMB against the dollar and a move to a managed float with reference to a basket of currencies in July 2005. This managed floating exchange rate suggests that the Chinese demand for dollar-denominated asset is likely to be reduced. This evolution is the more suitable to temper the excess of the domestic financial system and will enhance the ability of the PBC to tailor money and credit conditions to domestics needs (Eichengreen, 2004).

References

Allen, F., Qian, J., and Qian, M., 2005. Law, finance, and economic growth in China. *Journal of Financial Economics* 77, 57–116.

Barnett, S., 2004. Banking sector developments. IMF, Occasional Paper 232 – China's growth and integration into the world Economy: prospects and challenges – Prasad, E. (Eds).

Bernanke, B., Blinder, A., 1988. Credit, money, and aggregate demand. *The American Economic Review* 78, 435–439.

Cheung, Y., Chinn, M., and Fujii, E., 2003. The Chinese economies in global context: the integration process and its determinants. NBER, Working Paper 10047.

Chow, G., Lin, A., 1971. Best linear unbiased interpolation, distribution and extrapolation of time series by related series. *Review of Economics and Statistics* 53, 372–375.

Dolato, J., Lutkepohl, H., 1996. Making Wald test work for cointegrated VAR systems. *Econometrics Review* 15, 369–386.

Dufour, J.M., Renault, E., 1998. Short run and long run causality in times series: theory. *Econometrica* 66, 1099–1125.

Dufour, J.M., Pelletier D., and Renault, E., 2005. Short run and long run causality in times series: inference. *Journal of Econometrics* 132, 337–362.

Eichengreen, B., 2004. Chinese currency controversies. CEPR, Discussion Paper 4375.

Fernald, J., Babson, O., 1999. Why has China survived the Asian crisis so well? What risks remain? Board of governors of the Federal Reserve System, International finance discussion papers 633.

Fung, H.G., Leung, W., and Zhu, J., 2004. Nondeliverable forward market for Chinese RMB: A first look. *China Economic Review* 15, 348–352.

Genberg, H., McCauley, R., Park, Y.C., and Persaud, A., 2005. Official reserves and currency management in Asia: myth, reality and the future. Centre for Economic Policy Research , Geneva Reports on the World Economy 7.

Goldstein, M., Lardy, N., 2003. Two-Stage Currency Reform for China. Asian Wall Street Journal, September 12.

Goldstein, M., Lardy, N., 2005. China's role in the revived Bretton Woods system: a case of mistaken identity. Institute for International Economics, Working Paper 05-02.

Green, S., 2005. Making monetary policy work in China: a report from the money market front line. Stanford Center for International Development, Working Paper 245.

Greenwald, B., Stiglitz, J., 1990. Macroeconomic models with equity and credit rationing. NBER, Working Paper 3533.

Gunter, F., 2004. Capital flight from China: 1984-2001. *China Economic Review* 15, 63–85.

Hagiwara, A., 2004. Reserve accumulation, sterilization and policy dilemma. Asian Development Bank, ERD Policy Brief 31.

Higgins, M., Klitgaard, T., 2004. Reserve accumulation: implication for global capital flows and financial markets. Federal Reserve Bank of New York, Current Issues in Economics and Finance 10.

Hu, F., 2003. China's credit boom: causes and implications. Stanford Center for International Development, Conference on China' s Market Reforms.

Johansen, S., Juselius, K., 1990. Maximum likelihood estimation and inferences on cointegration-with applications to the demand for money. *Oxford Bulletin of Economics and Statistics* 52, 169–210.

Lu, D., 2004. China's capability to control its exchange rate. *China Economic Review* 15, 343–347.

Lütkepohl, H., Krätzig, M., 2004. Applied time series econometrics. Lütkepohl, H., Krätzig, M. (eds), Cambridge University Press.

Ma, G., Fung, B., 2002. China's asset management corporations. BIS Working Paper 115.

Ma, G., Ho, C., and McCauley, R., 2004. The markets for non-deliverable forwards in Asian currencies. BIS quarterly review, June 2004.

Ma, G., McCauley, R., 2002. Rising foreign currency liquidity of banks in China. BIS quarterly review, September 2002.

Ma, G., McCauley, R., 2003. Opening China's capital account amid ample dollar liquidity. BIS Papers 15 – China's capital account liberalization: international perspectives.

Ma, G., McCauley, R., 2004. Effectiveness of China's capital controls: some empirical evidence. Kawai, M. (eds.), Korea Institute for International Economic Policy and Policy Research Institute, Ministry of Finance (Japan), 68–83.

Mo, Y., 1999. A review of recent banking reforms in China. BIS Policy Papers 7 – Strengthening the banking system in China: issues and experience.

Newey, W., West, K., 1987. A simple positive semi-definite, heteroskedasticity and autocorrelation consistent covariance matrix. *Econometrica* 55, 703–708.

Phylaktis, K., Kassimatis, Y., 1994. Black and official exchange rates in the Pacific Bassin countries: an analysis of their long-run dynamics. *Applied Economics* 26, 399-407.

Prasad, E., Rumbaugh, T., and Wang, Q., 2005. Putting the cart before the horse? Capital account liberalization and exchange rate flexibility in China. IMF Policy Discussion Paper 05/01.

Prasad, E., Wei, S., 2005. The Chinese approach to capital inflows: patterns and possible explanations. NBER, Working Paper 11306.

Reimers, H., 1992. Comparisons of tests for multivariate cointegration. *Statistical Papers* 33, 335–359.

Reinsel, G., Ahn, S., 1992. Vector autoregressive models with unit roots and reduced rank structure: estimation, likelihood ratio, and forecasting. *Journal of Time Series analysis* 13, 353–375.

Roubini, N., Setser, B., 2005a. China trip report. Roubini Global Economics (RGE) Monitor.

Roubini, N., Setser, B., 2005b. Will the Bretton Woods 2 regime unravel soon? The risk of a hard landing in 2005-2006. Federal Reserve Bank of San Francisco and UC Berkeley, Symposium on the Revived Bretton Woods system: a new paradigm for Asian development?

Rzepkowski, B., 2004. Speculation on the Yuan. La lettre du CEPII 234.

Takagi, S., Esaka, T., 2001. Sterilization and the capital inflow problem in East Asia, 1987-97. Ito, T., Krueger, A. (eds.), Regional and Global Capital Flows: Macroeconomic Causes and Consequances, NBER-EASE, Vol. 10, The University of Chicago Press.

Toda, H., Yamamoto, T., 1995. Statistical inference in vector autoregressions with possibly integrated processes. *Journal of Econometrics* 66, 225–250.

Tung, C.Y., Baker, S., 2004. RMB revaluation will serve China's self-interest. *China Economic Review* 15, 331–335.

Woo, W.T., 2002. Some unorthodox thoughts on China's unorthodox financial sector. *China Economic Review* 13, 388–393.

Xiaopu, Z., 2003. Capital account management and its outlook in China. BIS Papers 15 – China's capital account liberalization: international perspectives.

Xie, P., 2004. China's monetary policy: 1998-2002, Stanford Center for International Development, Working Paper 217.

Yongding, Y., 2004. China's capital flows liberalization and reform of exchange rate regime. Kawai, M. (eds.), Korea Institute for International Economic Policy and Policy Research Institute, Ministry of Finance (Japan), 130–154.

Data Appendix

Data are collected from three sources: the Asia Regional Information Center (ARIC) database, the EcoWin database and the International Financial Statistics (IFS) database..

The monthly series retrieved from the ARIC database are the international reserves (Total reserves minus gold), the consumer price index (CPI), the gross domestic product (GDP) and the industrial production index (IPI) used in the Chow and Lin (1971) method. The price series has been seasonally adjusted by the Census X-12 routine (with multiplicative factors on the levels).

The monthly series retrieved from the EcoWin database are the Chibor 3 month interest rate and the Libor 3 month interest rate.

The monthly series retrieved from IFS are the US consumer price index, the real effective exchange rate, the domestic credit, the bank's reserves (claims on PBC), the broad money (money plus quasi-money), net foreign assets and net other assets in the PBC balance sheet. Series from monetary authorities, banking institutions and banking survey are interpolated from quarterly data before 1999.

Table 1: The balance of payment

	2001	2002	2003	2004	2005
Current Account	17.40	35.42	45.87	68.66	160.82
Financial Account	34.83	32.34	97.77	110.73	58.86
Direct Investment	37.35	46.79	47.23	53.13	67.82
Portfolio Investment	-19.41	-10.34	11.43	19.69	-4.93
Other Investment	16.88	-4.11	39.11	37.91	-4.03
Errors and Omissions	-4.86	7.79	18.42	27.05	-16.77
Hot Money	-7.38	-6.65	68.96	84.64	-25.72
Reserve Assets	-47.32	-75.51	-117.02	-206.36	-207.07

Unit: billion of dollars. Source: EcoWin database.

Note 1: "Other investment" in 2003 includes the $45 billions used to recapitalize two state commercial banks.

Note 2: "Hot Money" = "Portfolio Investment" + "Other Investment" + "Errors and Omissions"

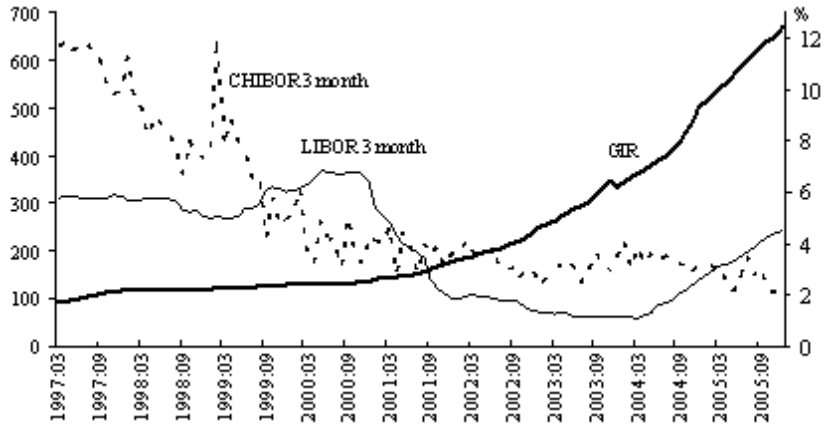
Table 2: Long term part of the VECM

$\alpha EC_t = \alpha(\beta Y_{t-1} + \mu_1)$ where $Y'_{t-1} = [\ \Delta(IR_{t-1}) \quad \Delta(P_{t-1}) \quad DC^R_{t-1} \quad y_{t-1} \quad i^*_{t-1}\ ]$

	β_1	α_1	β_2	α_2	β_3	α_3
$\Delta(IR_t)$	1	-0.8224	1	-0.8571		
	-	(0.1286)	-	(0.1274)	1	-0.8972
$\Delta(P_t)$	-1	0.0262	-1	0	-	(0.1277)
	-	(0.0447)	-	-		
DC^R_t	0.0855	0.0247	0.0757	0	0.0764	0
	(0.0284)	(0.1019)	(0.0282)	-	(0.0273)	-
y_t	-0.1130	-0.0014	-0.0981	0	-0.0992	0
	(0.0486)	(0.0146)	(0.0482)	-	(0.0467)	-
i^*_t	0.0080	-2.2249	0.0078	0	0.0077	0
	(0.0012)	(3.9350)	(0.0012)	-	(0.0011)	-
μ_1	0.0778	-	0.0556	-	0.0578	-
Speed of adjustment	0.7006		0.7084		0.7084	
90% adjustment (months)	1.9009		1.8684		1.8684	
LR test	Chi-square(1)		Chi-square(5)		Chi-square(3)	
	3.6482		4.2574		0.5703	
[prob]	[0.0561]		[0.5129]		[0.9031]	
Jarque-Bera	Chi-square(10)		Chi-square(10)		Chi-square(8)	
	9.8899		9.9717		11.3199	
[prob]	[0.4502]		[0.4430]		[0.1842]	
Lag 4 exclusion	Chi-square(25)		Chi-square(25)		Chi-square(16)	
	31.3019		31.3167		17.2788	
[prob]	[0.1792]		[0.1787]		[0.3677]	

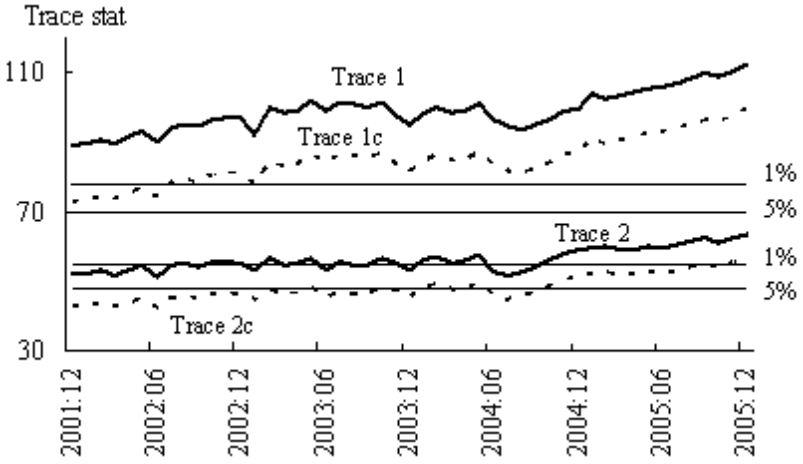
Note: The speed of adjustment is equal to one minus the first order autoregressive coefficient of the error-correction term (EC_t). The 90% adjustment is equal to ln(1.10)/ln(1-s) where s is the speed of adjustment (Phylaktis and Kassimatis, 1994).

Figure 1: Interest rates and China's GIR



Note: GIR: Index of Gross International Reserves (June 1997=100). Source: ARIC database and EcoWin database.

Figure 2: Forward recursive trace test



Note: Trace 1 (2) represents the trace statistic for 1 (2) cointegrating relation. Trace 1c (2c) represents the trace statistic for 1 (2) cointegrating relation including the finite sample bias correction.

Figure 3: Forward recursive LR test

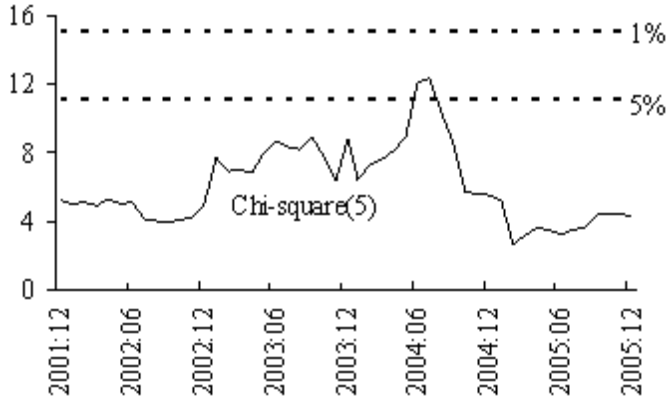
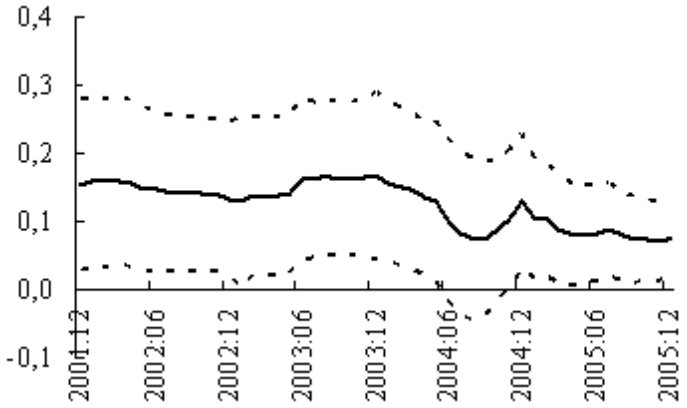


Figure 4: Forward recursive estimation: real domestic credit



Note: The dotted lines represent the two times standard error bands.

Figure 5: Forward recursive estimation: GDP

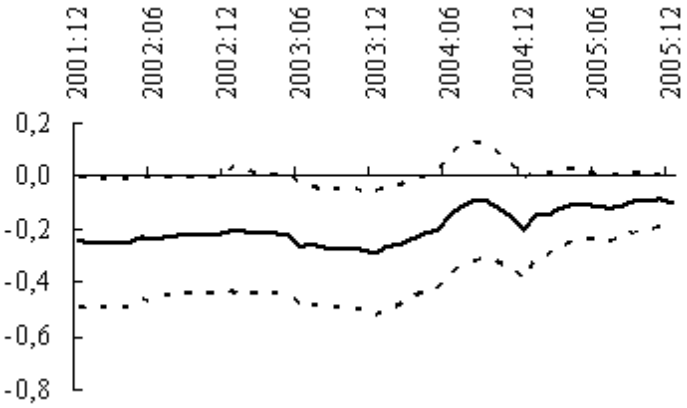


Figure 6: Forward recursive estimation: US real interest rate

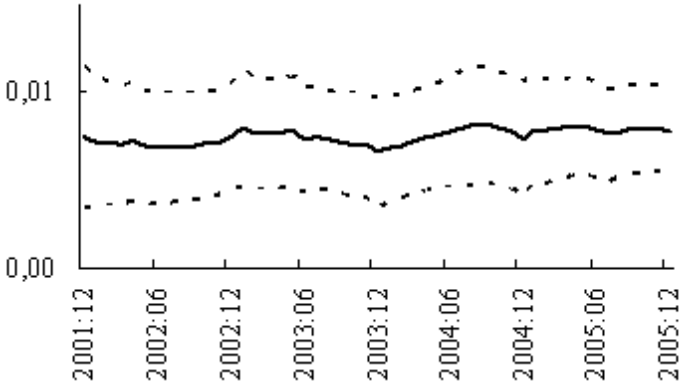
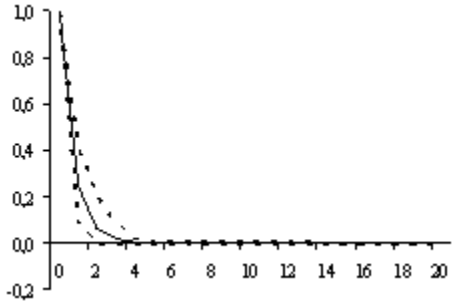
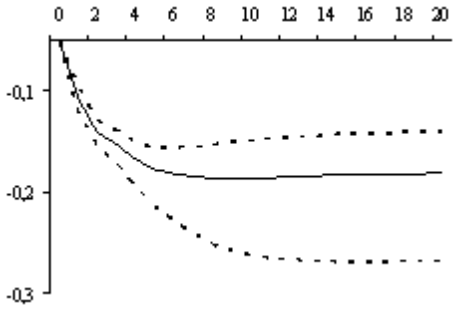


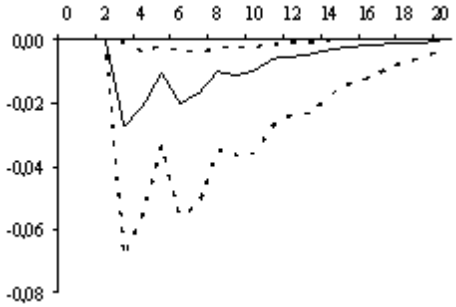
Figure 7a-j: VECM forecast error impulse reponses



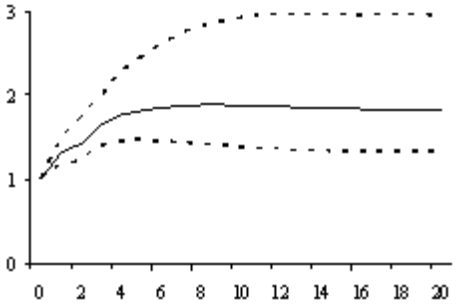
a- Response of $\Delta(IR_t)$ to $\Delta(IR_t)$



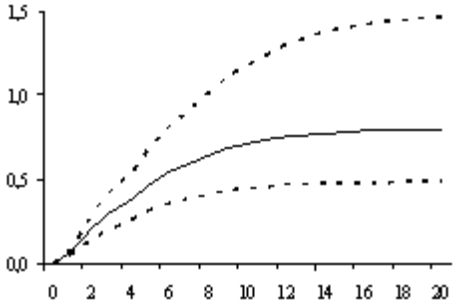
b- Response of $\Delta(IR_t)$ to DC_t



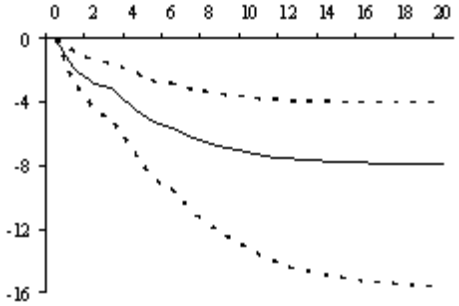
c- Response of DC_t to $\Delta(IR_t)$



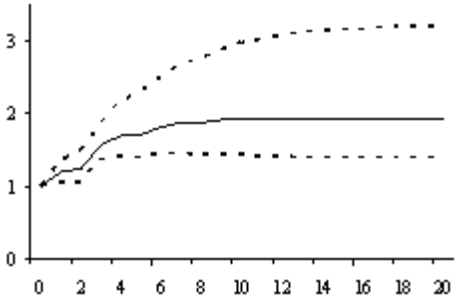
d- Response of DC_t to DC_t



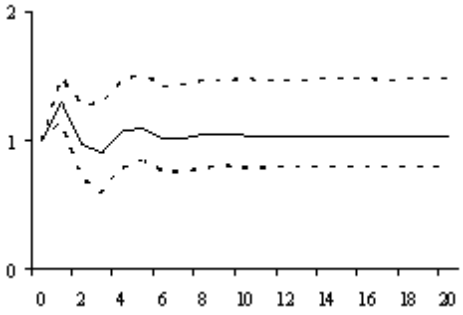
e- Response of $\Delta(IR_t)$ to GDP_t



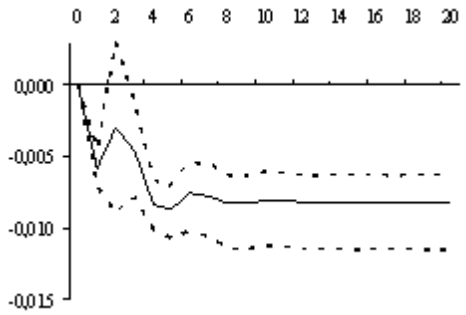
f- Response of DC_t to GDP_t



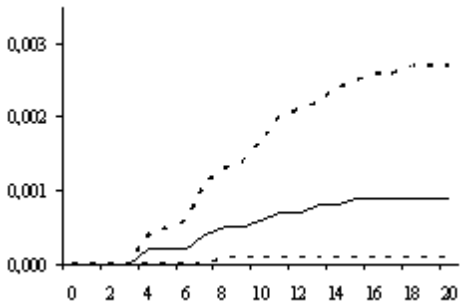
g- Response of GDP_t to GDP_t



j- Response of i_t^* to i_t^*



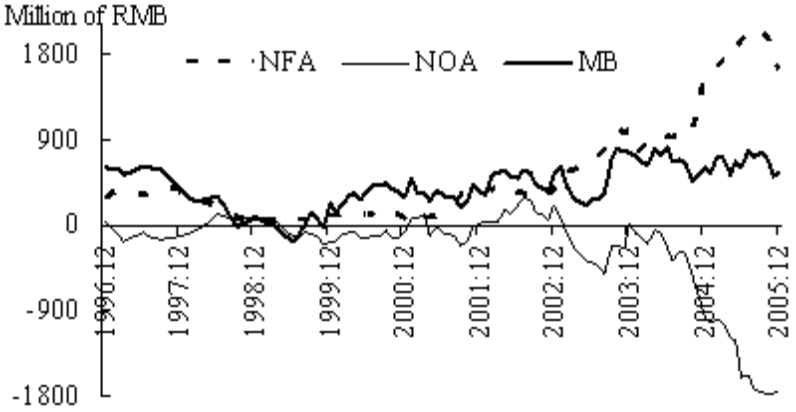
h- Response of $\Delta(IR_t)$ to i_t^*



i- Response of DC_t to i_t^*

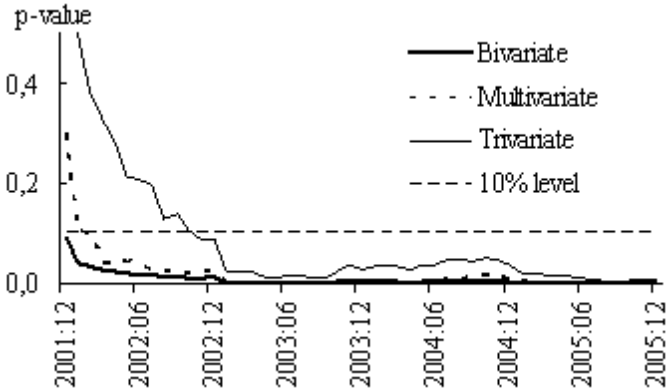
Note: Confident intervals represent the 95% studentized Hall intervals based on 2500 bootstrap replications and 100 replications for estimating the variance in each of the outer replication rounds. These impulses responses are computed with JMulti 4.02 (Lütkepohl and Krätzig, 2004)

Table 8: Year on year changes in the PBC balance sheet



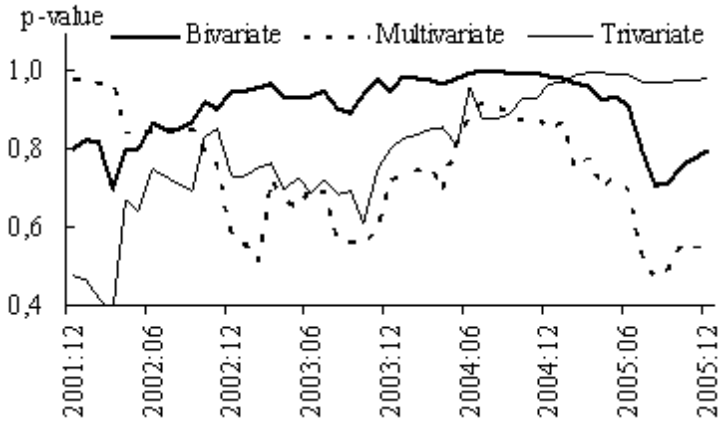
Note: $MB_t = NFA_t + NDA_t + NOA_t$. Changes in NDA_t are quite small since 2001, so they are not displayed. Source: IMF IFS database.

Figure 9: Forward recursive causality test from NFOA to M2



Note: H0: NFOA does not Granger cause M2.

Figure 10: Forward recursive causality test from NFOA to DC



Note: H0: NFOA does not Granger cause DC.

Figure 11: Forward recursive causality test between M2 and DC

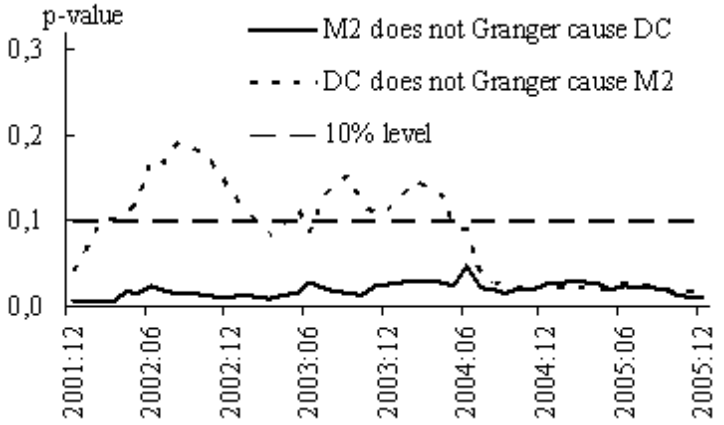
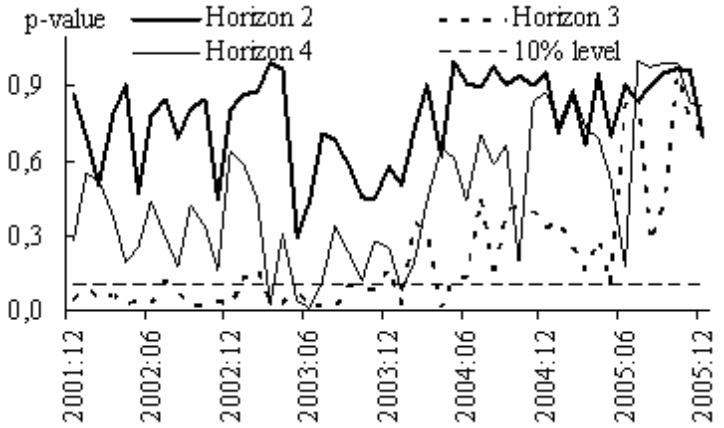


Figure 12: Forward recursive indirect causality test from NFOA to DC



Note: H0: NFOA does not Granger cause DC.