

Hot money inflows and monetary stability in China: how the People's Bank of China took up the challenge

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

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1 Introduction

Financial liberalization in China has progressed steadily over the last decade. Capital controls have become less effective and can no longer provide long lasting protections against capital inflows (Ma and McCauley, 2004; Prasad and Wei, 2005). Moreover, reforms in the banking sector highlight the transformation of the Chinese economy from a centrally planned economy to a market-based one (Mo, 1999; Woo, 2002; Barnett, 2004). Greater decision-making autonomy have been granted to the banking sector, and fluctuations in bank lending now have major implications for the macroeconomic situation (Hu, 2003) even if the efficiency of the banking sector remains low (Allen *et al.*, 2005; Yao *et al.*, 2007). As a result, the magnitude and the nature of capital inflows in China has changed greatly. Non-foreign direct investment capital inflows can henceforth fuel the Chinese financial system and provide excess liquidity to the banking sector. This led to a classic conflict between internal and external balances under a fixed exchange rate system.

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 are frequently called 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 determined by current account balances and financial account balances. Hot money inflows in 2003 and 2004 have led therefore to a rapid accumulation of international reserves in China. The central bank has been challenged to manage the expansion of the monetary base and more

generally the expansion of monetary conditions¹. Excess liquidity may have been provided to the banking sector, promoting inflationary pressures and an excessive credit expansion.

In this paper, we investigate whether the rapid build-up in international reserves in 2003 and 2004 was a source of monetary instability. Domestic credit and international reserves are the two counterparts of money supply. 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 keep the exchange rate stable (following hot money inflows, for example), net foreign assets increase in its balance sheet, leading (all else being equal) to an expansion in the monetary base. This injection of liquidity could positively affect the growth of monetary aggregates, domestic credit and output. 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 (all else being equal) negatively related so that if one counterpart of money supply increases, the other decreases, suggesting that the overall money supply is stable.

First, we examine with a Vector Error Correction Model (VECM) on monthly data from January 1997 to March 2006 the relationship between real international reserves and real domestic credit. Empirical results show that this relationship was negative, which suggests that the central bank succeeded in slowing down real domestic credit when real international reserves increased. Second, we explain how the PBC proceeded to manage the upsurge in international reserves and to keep domestic credit under control. The PBC implemented sterilization measures in the narrow sense (with open market operations) as well as in the broader sense (with a reserve requirement ratio and window guidance). We

¹The monetary base equals the sum of net domestic assets plus net foreign assets (i.e. international reserves).

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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 has led to excess liquidity. Nevertheless, we find that the PBC succeeded in shaping domestic credit using open market operations and 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 net amount of hot money inflows (Tung and Baker, 2004; Rzepkowski, 2004; Genberg *et al.*, 2005; Prasad and Wei, 2005). In Table

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

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 billion. 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 billion of its international reserves in order to recapitalize two state commercial banks. This operation was recorded negatively 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, official figures suggest that net other investment inflows represented \$-5.89 in 2003 but they actually represented \$39.11 billion in 2003. Net other investment inflows also represented \$37.91 billion in 2004. Finally, some capital inflows escape regulatory controls but are nevertheless recorded in the statistical discrepancy of the balance of payments. Net errors and omissions increased significantly during 2003 and 2004, and represented respectively \$18.42 and \$27.05 billion³ 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 depositors in the Chinese banking system stopping the accumulation of foreign currency deposits (Ma and McCauley 2003, 2004; Rzepkowski, 2004). Hot money inflows are estimated at \$68.96 and \$84.64 billion respectively in 2003 and 2004 (Table 1). They are stronger than current account surpluses (respectively \$45.87 and \$68.66 billion) or net FDI inflows (respectively \$47.23 and \$53.13 billion) during these two years. Hence, the rapid accumulation of international

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

reserves during 2003 and 2004 offset mainly non-FDI capital inflows rather than trade surplus or net FDI inflows.

The US interest rate could be an important factor in explaining these hot money inflows. The US interest rate decreased strongly in 2001 and remained low until 2005, whereas the Chinese interest rate has been roughly stable over this period. In addition, exchange rate expectations could constitute a second important factor in explaining hot money inflows. The PBC applied a fixed exchange rate against the US dollar up to July 2005, but speculation on RMB appreciation has been increasing in parallel to the general dollar weakness and the trade 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 can no longer 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 +/- 0.3% around the exchange rate announced the day before. The remaining concerns are how China might continue its move toward more exchange rate flexibility and how China might undertake the liberalization of its capital account (Eichengreen, 2004; Prasad *et al.*, 2005; Obstfeld, 2006)

The US interest rate has been rising since mid-2004, while the Chinese interest rate

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

has barely changed. Incentives for hot money inflows have been therefore removed, and indeed hot money inflows evaporated in 2005. During the first half of 2005, net hot money inflows are estimated at \$8.56 (Table 1) and they became negative over the whole year 2005 (\$-25.72)⁵.

2.2 International reserves and monetary stability

The following equations show how domestic credit might 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 its two counterparts are domestic credit and international reserves. The equilibrium in the money market is defined by

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

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 $L(\cdot)$ the money demand function with $L_y(\cdot) > 0$ and $L_i(\cdot) < 0$ ⁶.

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

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

⁵We can notice in Table 1 that negative net hot money inflows in 2005 are mainly explained by negative net errors and omissions (\$-16.77).

⁶ $L_j(\cdot)$ is the partial derivative with respect to variable j .

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

$$D_t = \frac{MB_t}{\tau + \theta}, \quad (3)$$

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 are determined by net capital inflows and the current account

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

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. $NK(\cdot)$ represents net capital inflows and depends positively on deviation from uncovered real interest rate parity ($q_t - E_t(q_{t+1}) + i_t - i_t^* - \rho_t$)⁷.

⁷We assume that purchasing power parity holds so that there is no Balassa Samuelson effect.

The bank lending level is therefore given by

$$DC_t = [(1 - \tau) \frac{NFA_t + NDA_t}{\tau + \theta}] \gamma(i_t, \hat{y}_t). \quad (5)$$

Equations (1), (4) and (5) show how international reserves can affect monetary conditions. Equation (4) suggest that changes in the foreign interest rate and in exchange rate expectations justify hot money inflows and consequently the build-up of international reserves. This accumulation of international reserves leads to an expansion in the monetary base. This expansion is reflected in deposits and can finally cause an excessive credit expansion as suggested in equation (5). As a result, the two counterparts of money supply could increase (equation (1)) and the central bank could lose the control of money supply. The central bank can implement sterilization operations to control domestic monetary conditions⁸. 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.

If we consider the situation of China in 2003 and 2004, hot money inflows challenged the PBC to limit the credit expansion. An excessive expansion in domestic credit could lead to a new round of non-performing loans in the banking sector, undermining efforts made by the PBC to strengthen the banking sector.

3 Empirical assessment of monetary stability

A VECM is estimated using monthly data from January 1997 to March 2006 to investigate the stability of monetary conditions. We examine the relationship between real interna-

⁸See Brissimis *et al.* (2002) for a model analysing offsetting capital flows and sterilization.

tional reserves and real domestic credit. This relationship should be negative if the PBC succeeded in managing the accumulation of international reserves and in keeping domestic credit under control.

3.1 Data and VECM specification

Endogenous variables used in the first specification of the VECM are real gross international reserves less gold (IR_t), real domestic credit (DC_t), real industrial production (y_t) and the Chinese real interest rate (r_t). Due to data availability of the Chinese interest rate, the sample starts in January 1997 (we use the IFS, ARIC and EcoWin databases). The real interest rate differential between China and the US ($r_t - r_t^*$) and gross domestic product (GDP) at constant prices (y_t^{gdp})⁹ are also considered in different specifications (see the data appendix for the data sources). No other control variables are included in the model specification in order to limit the scope of the model.

Four unit root tests are implemented: Augmented Dickey-Fuller (ADF), Elliott-Rootenbergs-Stock (DF-GLS), Phillips-Perron (PP) and Kwiatkowski-Phillips-Schmidt-Shin (KPSS). We conclude that all the variables are non-stationary in level but stationary in first-difference (these tests are available upon request). The VECM specification is therefore

$$\Delta Y_t = \mu_0 + \sum_{i=1}^k \phi_i(\Delta Y_{t-i}) + \alpha(\beta' Y_{t-1} + \mu_1) + \varepsilon_t, \quad (6)$$

where $Y_t' = [DC_t \ IR_t \ y_t \ r_t]$, μ_0 is a (4×1) constant vector, α is a $(4 \times r)$ matrix where r is the number of cointegration relation, β' is a $(r \times 4)$ matrix 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 $\det(\Omega) \neq 0$.

⁹The 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 real industrial production index (IPI) as related series.

The matrix β contains the cointegrating vectors and the matrix α contains the weights attached to the cointegrating relations in the individual equations of the model. The model is estimated with two lags ($k = 2$) 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 third lag can be excluded (Table 2).

If there is only one cointegrating relation ($r = 1$), this relation can be written as

$$(\beta' Y_{t-1} + \mu_1) = \beta_{dc} DC_{t-1} + \beta_{ir} IR_{t-1} + \beta_y y_{t-1} + \beta_r r_{t-1} + \mu_1 = ec_{t-1}, \quad (7)$$

where ec_{t-1} is the error-correction term, i.e. the deviation from the long run equilibrium.

The Johansen and Juselius (1990) cointegration method is used to estimate equation (6). This method allows one 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 due to the finite sample bias and the possible cointegration rank inconstancy. Consequently, backward and 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 trace test with the finite sample bias correction supports the existence of one cointegrating vector at the 5% level over the whole sample (Table 2, column β_1). This result is confirmed by the maximum eigenvalue test (Table 2, column β_1). The backward recursive trace test¹¹ (Figure 1a) supports the existence of one cointegrating vector at the 10% level but this test also shows instabilities in the cointegrating vector in the baseline sample. The trace statistic decreases

¹⁰This 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.

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

when data before 2000 are considered in the sub-sample. The forward recursive trace test (Figure 1b) confirms that there are instabilities in the cointegrating vector. Instabilities appear in particular during the first semester of 2004 when the trace statistic is temporarily below the 10% level. These instabilities are more cautiously analysed below with the estimation of the cointegrating vector since the stability of the trace statistic depends on the stability of parameters α and β .

3.2 Estimated cointegrating vectors

Table 2 displays several specifications of the long run relationship (β). The first specification (β_1) represents the cointegrating relationship between real domestic credit (DC_t), real international reserves (IR_t), real industrial production (y_t) and the Chinese real interest rate (r_t) without any restrictions. This cointegrating relation is written as¹²

$$DC_t = -0.622 IR_t + 2.901 y_t + 0.068 r_t - 13.695 + ec_t. \quad (8)$$

(0.146) (0.386) (0.014)

The coefficient of DC_t is normalized to one to represent the cointegrating vector as a reduced equation for real domestic credit. Real international reserves exhibit a negative relationship with real domestic credit. The coefficient associated with real international reserves is high in absolute value (-0.622). Restrictions on this coefficient can be tested with a LR test (the null hypothesis is that restrictions are not rejected). We find that this coefficient is significantly different from 0 and not significantly different from -1 (Table 2) at the 10% level. This suggests that the central bank would have managed the accumulation

¹²The cointegrating relation presented in equation (7) can be written as

$$\beta_{dc} DC_t = -\beta_{ir} IR_t - \beta_y y_t - \beta_r r_t - \mu_1 + ec_t.$$

of international reserves very well to ensure the stability of domestic monetary conditions. The PBC succeeded in adjusting real domestic credit downward when real international reserves increased, which indicates that the accumulation of international reserves did not lead to an excessive monetary expansion.

Real industrial production exhibits a positive relationship with real domestic credit. The coefficient associated with real industrial production index is high (2.901) in this first specification, and therefore suggests a strong pro-cyclical evolution of domestic credit. The *LR* test supports at the 10% level that this coefficient is different from 0 (Table 2).

The Chinese real interest rate exhibits a positive relationship with real domestic credit which seems counter-intuitive and the *LR* test supports at the 10% level that this coefficient is different from 0. However, variable r_t could reflect the capital flight effect. Indeed, the interest rate liberalization has been gradual over the last decade (Mo, 1999; Garcia-Herrero *et al.*, 2006). This gradual switch from administrative measures to market-oriented measures is not completed; moreover the functioning of the banking system is not very sensitive yet to market practices. The financial integration of China with the rest of the world is also an ongoing process, but this might affect domestic monetary conditions more. Cheung *et al.* (2003) find evidence for financial integration between China and the US, which confirms the erosion of capital controls. A rise in the domestic real interest rate could therefore lead to capital inflows which in turn could positively affect the growth of real domestic credit and real international reserves. In specification β_2 , the real interest rate differential between China and the US ($r_t - r_t^*$) is used instead of Chinese real interest rate (r_t). This cointegrating vector is given by

$$DC_t = \underset{(0.064)}{-0.341} IR_t + \underset{(0.143)}{1.970} y_t + \underset{(0.006)}{0.032} (r_t - r_t^*) - 9.022 + ec_t. \quad (9)$$

This specification is more appropriate for taking into account the capital flight effect. The coefficient associated with real international reserves is lower in absolute value (-0.341) in this specification. In addition the LR test shows that this coefficient is significantly different from 0 and also significantly different from -1 (Table 2). The accumulation of real international reserves could have therefore led to partial downward adjustments in real domestic credit.

In specifications β_3 and β_4 (Table 2), a GDP monthly estimate (obtained with the Chow and Line (1971) method, see footnote 9) is used instead of the real industrial production index. Specification β_3 is estimated with the Chinese real interest rate (r_t) and specification β_4 is estimated with the real interest rate differential between China and the US ($r_t - r_t^*$). The GDP monthly estimate does not seem to improve the measurement of economic activity. The trace statistic over the whole sample does not reject the no cointegration hypothesis at the 10% level (Table 2). Specifications β_3 and β_4 are also estimated with three lags because the lag exclusion test in Table 2 shows that the third lag is significant at the 5% level (these estimations are available upon request). However, these specifications with three lags do not allow one to reject the no cointegration hypothesis at the 10% level. As a result, the GDP monthly estimate does not provide an interesting alternative to represent economic activity, and real industrial production is used in the next specifications.

In specifications β_5 and β_6 (Table 2), restrictions on the vector of adjustment coefficients (α) are imposed to test the weak exogeneity of variables except real domestic credit. Specification β_5 is estimated with the Chinese real interest rate and is given by

$$DC_t = \underset{(0.089)}{-0.371} IR_t + \underset{(0.243)}{2.104} y_t + \underset{(0.008)}{0.028} r_t - 9.708 + ec_t. \quad (10)$$

Specification β_6 is estimated with the real interest rate differential between China and the

US and is given by

$$DC_t = -0.286_{(0.058)} IR_t + 1.789_{(0.132)} y_t + 0.020_{(0.006)} (r_t - r_t^*) - 8.120 + ec_t. \quad (11)$$

The joint weak exogeneity hypothesis in all individual equations except in the real domestic credit equation is supported (LR test in Table 2) at the 1% level in specification β_5 but not at the 5% level. It is supported at the 10% level in specification β_6 . As a result, we can conclude with specification β_6 that real domestic credit is the only variable which responds to deviations from the long-run equilibrium. The adjustment coefficient on the error-correction term in the real domestic credit equation (α_{dc} in Table 2) is negative (-0.0742 in specification β_5 and -0.1007 in specification β_6) and significant at the 5% level which is consistent with equilibrium correction behavior. The cointegrating vector represents therefore the long run determination of real domestic credit since other variables are weakly exogenous. When the error-correction term is positive, due for example to a rise in real international reserves, real domestic credit decreases to reach its equilibrium value. The speed of adjustment is equal to one minus the first order autoregressive coefficient of the error-correction term (Phylaktis and Kassimatis, 1994). We find that 28% in specification β_5 and 36% in specification β_6 of the gap between real domestic credit 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 7.10 months in specification β_5 and in 5.16 months in specification β_6 ¹³.

In specifications β_7 and β_8 , the homogeneity hypothesis between real international reserves (IR_t) and real domestic credit (DC_t) is added to the weak exogeneity hypothesis

¹³If 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).

tested in specifications β_5 and β_6 . Specification β_7 is estimated with the Chinese real interest rate and is given by

$$DC_t = -IR_t + \underset{(0.388)}{4.031} y_t + \underset{(0.032)}{0.125} r_t - 19.319 + ec_t. \quad (12)$$

Specification β_8 is estimated with the real interest rate differential between China and the US and is given by

$$DC_t = -IR_t + \underset{(0.489)}{3.224} y_t + \underset{(0.032)}{0.132} (r_t - r_t^*) - 15.006 + ec_t. \quad (13)$$

The LR test does not supports these specifications at the 1% level (Table 2) and we cannot therefore accept the homogeneity restriction between real international reserves and real domestic credit. As a result, the PBC succeeded in slowing down real domestic credit when real international reserves increased but the homogeneity tests in specifications β_7 and β_8 show that it was insufficient to fully offset the accumulation of international reserves. This led to loose monetary conditions in China, even if the PBC succeeded in keeping real domestic credit under control.

Figure 3 displays the error-correction term corresponding to specification β_6 . The error-correction term is scaled so that the deviations from the long run equilibrium level average zero over the sample period¹⁴. It is clear from Figure 3 that the error-correction term is a stationary process. Deviations from the horizontal axis might be interpreted as deviations from the long run equilibrium. When the error correction term is above the horizontal axis, real domestic credit is above its long run equilibrium level implied by the model. In particular, the error correction term is above the horizontal axis in 2003 and 2004 when

¹⁴In specification β_6 , the error-correction term (ec_t) is defined as $ec_t = DC_t + 0.299IR_t - 1.831y_t - 0.021(r_t - r_t^*) + 8.324$ where the constant term 8.324 is computed so that the average of ec_t is zero.

strong hot money inflows led to a rapid accumulation of international reserves. Therefore, real domestic credit decreased gradually to reach its equilibrium value.

Specification β_6 is recursively estimated in order to investigate its constancy. Figures 4a-d display recursive estimations of cointegrating vector β_6 and adjustment coefficient α_{dc} . The value of these coefficients increases or decreases over time, which explains instabilities in the cointegrating relation exhibited by the recursive trace tests. The coefficients of the real industrial production (Figure 4a) and of the interest rate differential (Figure 4b) are constitently significant and increase gradually over the sample period, respectively from 1.50 to 2.00 and from 0.01 to 0.02. The coefficient of the real international reserves (Figure 4c) also increases gradually (in absolute value) from -0.10 to -0.30 but the two times standard error band is above the horizontal axis before 2004. Adjustment coefficient α_{dc} (Figure 4d) decreases gradually (in absolute value) from -0.16 to -0.10, which suggests that the deviations from the long term equilibrium became more persistent. These recursive estimations do not exhibit structural breaks in the cointegrating relation but rather the convergence of the estimated coefficients toward their long term value when the sample is increases.

3.3 Impulse responses

Impulse responses are used to analyze the dynamic interactions between variables and more precisely between real international reserves and real domestic credit. We use specification β_6 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 parameters¹⁵. This strategy allows one to fit a subset model, removing insignificant coef-

¹⁵The 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.

ficients. Second, a Choleski decomposition is used to implement orthogonalized impulse responses. The variables are ordered as: y_t , DC_t , $(r_t - r_t^*)$, IR_t , so that real domestic credit can respond contemporaneously to y_t but needs a time lag to respond to $(r_t - r_t^*)$ and IR_t . However, impulse responses do not depend much on the order of the variables because the reduced-form residuals are not strongly correlated.

We compute Hall's studentized confident intervals based on 1500 bootstrap replications and 100 replications for estimating the variance in each of the outer replication rounds. Standard and Hall confident intervals based on 1500 bootstrap replications give similar results but they are not displayed on Figures 5a-d for clarity. We also use these three methods to compute confident intervals based on 1000 bootstrap replications. Similar results are obtained, which confirms the robustness of the confident intervals displayed on Figures 5a-d.

First, we consider a shock in real domestic credit (Figure 5a). Other variables do not respond significantly, and so this shock is transitory. The adjustment force (α_{dc}) pushes real domestic credit back to its equilibrium level. The two times standard error band intersects with the horizontal axis after 16 periods. Second, we consider a shock in real international reserves (Figure 5b). Real domestic credit reacts negatively and significantly to this shock, but the two times standard error band intersects with the horizontal axis after 8 periods (Figure 5c). This impulse response therefore supports the negative relationship between real international reserves and real domestic credit estimated in the cointegrating vector. The PBC adjusts real domestic credit downward when real international reserves increase to stabilize domestic monetary conditions, but this adjustment has a limited scale. Real industrial production also reacts significantly to the shock in real international reserves and exhibits a positive impulse response (Figure 5d). The positive shock in international

reserves could correspond to current account surpluses, net FDI inflows and/or hot money inflows. Current account surpluses and net FDI inflows are particularly favourable for output growth, while hot money inflows can lead to an overheating situation. This might explain the positive impulse response exhibited by real industrial production. After approximately 16 months, the series seems to reach equilibrium¹⁶.

We conclude that the PBC did not lose control of domestic monetary conditions during the rapid accumulation of international reserves in 2003 and 2004. The estimated cointegrating relations and impulse responses show that the interaction between real domestic credit and real international reserves was negative. This suggests that the PBC succeeded in keeping domestic credit under control, even if downward adjustments in real domestic credit offset partially and gradually increases in real international reserves. We can now examine how the PBC proceeded to manage the rapid accumulation of international reserves.

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 the consequences of these capital inflows on the domestic monetary sector¹⁷.

¹⁶Shocks in real industrial production and in the real interest rate differential are not displayed. They lead to a positive and significant response of real domestic credit. These impulse responses are available upon request.

¹⁷Monetary authorities can also directly influence demand and supply in the foreign exchange market in order to manage 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).

4.1 The sterilization policy

The PBC used open market operations to sterilize hot money inflows. Central bank bills were issued while treasury bonds were managed to drive the money market interest rate (Xie, 2004; Green, 2005). Central bank bills are recorded as liabilities in the central bank balance sheet but they are frequently merged with net other assets (NOA) to simplify the central bank balance sheet (Hu, 2003)¹⁸. We can therefore investigate to what extent the PBC used these open market operations to manage the monetary base. Figure 6 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 expansion of the monetary base but this only partially offsets the build-up of international reserves. From end-2000 to end-2003, Higgins and Klitgaard (2004) estimate that roughly half of the NFA increase was sterilized by open market operations. Figure 6 also shows that the PBC intensified open market operations in 2004 and 2005 to offset the upsurge in net foreign assets resulting, in particular, from hot money inflows and from the strong current account surplus in 2005.

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 the monetary base but not necessarily 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 the 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

¹⁸Central bank bills can therefore be recorded negatively as net other assets and the central bank balance sheet is resumed by the relation:

$$NDA_t + NFA_t + NOA_t = MB_t,$$

where NDA_t are net domestic assets, NFA_t are net foreign assets, NOA_t are net other assets and MB_t is reserve money.

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 have been efficient (Hu, 2003).

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 over the banking sector. The state-owned banks were used as sterilization bond buyers and also to implement the window guidance (Hu, 2003; Roubini and Setser, 2005a; Koivu, 2005). Thus, even if the banking sector obtained greater decision-making autonomy in its relations with firms during the last decade, the central bank kept the ability to directly intervene in the banking sector in order to ensure the stability of monetary conditions. This approach with VAR models therefore allows one to investigate the efficiency of sterilization when various monetary measures at various times in various intensities have been used (Takagi and Esaka, 2001).

We analyse with Granger causality tests whether net foreign assets non sterilized by open market operations (NFOA) affect the monetary sector. These tests allow one to investigate whether reserve requirements and window guidance have been effective in completing the sterilization process. We use the Toda and Yamamoto (1995) and Dolado and Lutkepohl (1996) procedure. This procedure does not require a cointegration analysis and allows one 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

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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 in applying 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, real industrial production, the Chinese real interest rate and real broad money or real domestic credit. Real industrial production and the Chinese real interest rate are taken into account in these systems, which allows one 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 the Chinese real interest rate. In addition, VAR systems are estimated using monthly data from January 1997 to March 2006. Four unit root tests are implemented: ADF, DF-GLS, Phillips-Perron and KPSS. We conclude that all variables are non-stationary in levels but stationary in first-differences (these tests are available upon request). The optimal lag order of the VAR system in stationary form is chosen according to residual statistical properties (normality and independence). We conclude that each system needs three lags and we take into account dummies¹⁹ 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 7a displays the 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

¹⁹April 2001 in the bivariate systems; June 2000 and April 2001 in the trivariate system.

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 provided banks with their main opportunity to get out of excess liquidity (Roubini and Setser, 2005a). Figure 7b shows the 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, open market operations combined with window guidance enabled the curbing of credit growth and so the PBC succeeded in keeping domestic credit under control.

4.3 Indirect causality tests

NFOA could all the same indirectly affect domestic credit. Figure 7c 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 even if the causality from domestic credit to broad money is not systematically confirmed by the recursive procedure. 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

$$W_{t+1} = \mu + \sum_{l=1}^4 \pi_l W_{t+1-l} + e_{t+1}, \quad (14)$$

where $t = 0, \dots, T - 1$, $W'_{t+1} = (NFOA_{t+1} \quad DC_{t+1} \quad M2_{t+1})$, 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 (14) 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

$$W_{t+h} = \mu^{(h)} + \sum_{l_1=1}^4 \pi_{l_1}^{(h)} W_{t+1-l_1} + \sum_{l_2=0}^{h-1} \varphi_{l_2} e_{t+h-l_2}, \quad (15)$$

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 (but not all lagged coefficients). 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 $h = 4 (= 1 \times 3 + 1)$ 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 7d displays recursive indirect causality tests from NFOA to domestic credit. We conclude that NFOA did not indirectly Granger cause 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 result is not robust after January 2004. Open market operations and window guidance therefore allowed the PBC 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 bond 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's weaknesses. Second, reserves management did not cause a profitability issue for 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 appreciation in 2004 would have represented a \$150 billion loss which corresponds to 10% of China's 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, 2001).

These costs associated with the upsurge in net foreign assets justify China's move toward greater exchange rate flexibility in July 2005. This evolution is most apt to temper the excess of the domestic financial system, and will enhance the ability of the PBC to tailor money and credit conditions to domestic needs (Eichengreen, 2004; Prasad *et al.*, 2005; Obstfeld, 2006).

5 Conclusion

Capital controls do not prevent hot money inflows into China anymore. These controls have become less effective over time, and hot money inflows were particularly strong in 2003 and 2004. As a result, the accumulation of international reserves in China increased significantly in 2003 and 2004. The Chinese authorities delayed for a long time the move toward greater exchange rate flexibility but they succeeded in managing the international reserves build-up. The estimated VECM suggests that the PBC succeeded in keeping domestic credit under control, even if downward adjustments in real domestic credit offset partially and gradually the accumulation of real international reserves. Moreover, direct and indirect causality tests show that the sterilization policy implemented by the PBC allowed to manage the effects of net foreign assets on domestic credit, even if the upsurge in international reserves led to excess liquidity. However, the sterilization policy was costly and it was not sustainable in the long run for the banking sector. Consequently, the PBC decided to make a shift in its currency policy. It 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 evolution is most apt to temper the excesses of the domestic financial system and will enhance the ability of the PBC to tailor money and credit conditions to domestic needs (Eichengreen, 2004).

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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 series retrieved from the ARIC database are international reserves (total reserves minus gold), the consumer price index (CPI), the industrial production index (IPI), the three-month interbank real interest rate, the gross domestic product. The price series has been seasonally adjusted by the Census X-12 routine (with multiplicative factors on the levels).

The series retrieved from the EcoWin database is the Libor 3 month interest rate.

The series retrieved from IFS are the US consumer price index, domestic credit, 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 surveys are interpolated from quarterly data before 1999.

We use the log transformation of index variable (January 1997=100) for all variables except interest rates. 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 accumulation of international reserves. Second, data on domestic credit showed a strong break in January 2002 corresponding to a 13% monthly growth rate whereas it was around 1% during 2001. We therefore consider a 1% monthly growth rate in January 2002. These two modifications allow one to obtain residual normality without the introduction of dummy variables.

Table 1: The balance of payment

	2002	2003	2004	2005	
				First half	End
Current Account	35.42	45.87	68.66	67.26	160.82
Financial Account	32.34	97.77	110.73	36.14	58.86
<i>Direct Investment</i>	46.79	47.23	53.13	22.48	67.82
<i>Portfolio Investment</i>	-10.34	11.43	19.69	-0.97	-4.93
<i>Other Investment</i>	-4.11	39.11	37.91	14.63	-4.03
Errors and Omissions	7.79	18.42	27.05	-5.11	-16.77
Hot Money	-6.65	68.96	84.64	8.56	-25.72
Reserve Assets	-75.51	-117.02	-206.36	-100.45	-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: Estimated cointegrating vectors

	β_1	β_2	β_3	β_4
IR_t	-0.622 (0.146)	-0.341 (0.064)	-0.834 (0.260)	-0.306 (-0.089)
y_t	2.901 (0.386)	1.970 (0.143)	-	-
r_t	0.068 (0.014)	-	0.139 (0.027)	-
$(r_t - r_t^*)$	-	0.032 (0.006)	-	0.050 (0.009)
y_t^{gdp}	-	-	5.332 (0.928)	2.688 (0.268)
μ_1	-13.695	-9.022	-25.835	-12.591
Trace statistic [p-stat]	51.755 [0.020]	48.083 [0.047]	41.553 [0.176]	37.422 [0.327]
Max-Eigenvalue statistic [p-stat]	29.313 [0.029]	25.286 [0.095]	27.012 [0.059]	23.458 [0.154]
α_{dc}	-0.024 (0.009)	-0.063 (0.020)	-0.0142 (0.005)	-0.040 (0.015)
Speed of adjustment	0.32	0.45	0.44	0.51
90% adjustment (months)	5.97	3.85	3.97	3.23
$\chi^2(1)$ $\beta_{ir} = 1$	[0.512]	[0.014]	[0.864]	[0.060]
$\chi^2(1)$ $\beta_{ir} = 0$	[0.010]	[0.006]	[0.022]	[0.030]
$\chi^2(1)$ $\beta_y = 0$	[0.027]	[0.003]	[0.048]	[0.013]
$\chi^2(1)$ $\beta_r = 0$	[0.000]	[0.005]	[0.000]	[0.000]
Jarque-Bera test [p-stat]	$\chi^2(8)$ 4.858 [0.773]	$\chi^2(8)$ 6.234 [0.621]	$\chi^2(8)$ 12.400 [0.134]	$\chi^2(8)$ 13.630 [0.091]
Lag 3 exclusion test [p-stat]	$\chi^2(16)$ 5.941 [0.988]	$\chi^2(16)$ 9.191 [0.905]	$\chi^2(16)$ 29.341 [0.021]	$\chi^2(16)$ 30.189 [0.017]

Note 1: According to equation (7), specification β_1 is defined as :

$$DC_t = -\beta_{ir}IR_t - \beta_y y_t - \beta_r r_t - \mu_1 + ec_t = -0.62IR_t + 2.90y_t + 0.07r_t - 13.69 + ec_t$$

Note 2: 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 $\ln(0.10)/\ln(1-s)$ where s is the speed of adjustment (Phylaktis and Kassimatis, 1994).

Note 3: Standard errors are in parentheses.

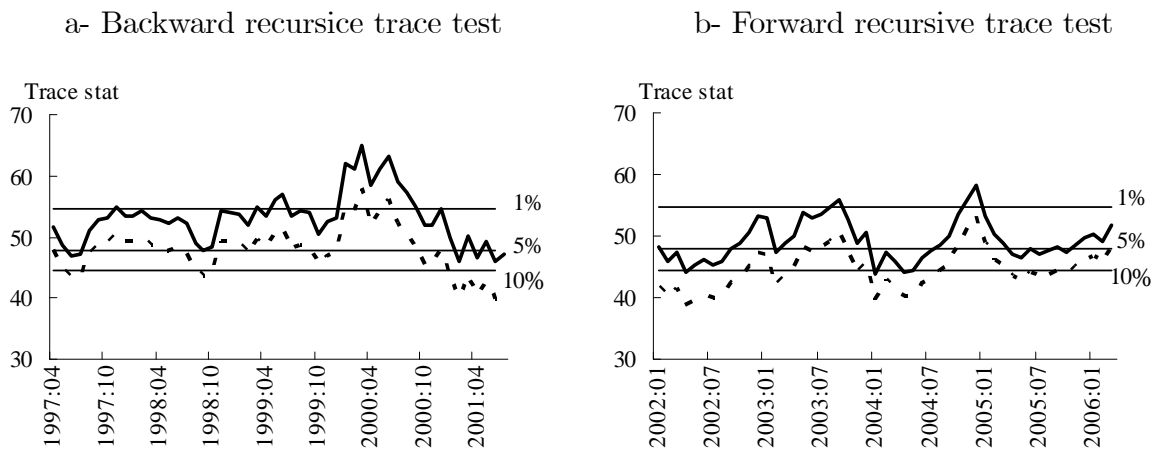
Table 2: Estimated cointegrating vectors (continued)

	β_5	β_6	β_7	β_8
IR_t	-0.371 (0.089)	-0.286 (0.058)	-1 (-)	-1 (-)
y_t	2.104 (0.243)	1.789 (0.132)	4.031 (0.388)	3.224 (0.498)
r_t	0.028 (0.008)	-	0.125 (0.032)	-
$(r_t - r_t^*)$	-	0.020 (0.006)	-	0.132 (0.059)
μ_1	-9.708	-8.120	-19.319	-15.006
Trace statistic [<i>p</i> -stat]	51.755 [0.020]	48.083 [0.047]	51.755 [0.020]	48.083 [0.047]
Max-Eigenvalue statistic [<i>p</i> -stat]	29.313 [0.029]	25.286 [0.095]	29.313 [0.029]	25.286 [0.095]
α_{dc}	-0.075 (0.016)	-0.104 (0.023)	-0.018 (0.004)	-0.010 (0.003)
Speed of adjustment	0.29	0.33	0.32	0.27
90% adjustment (months)	6.72	5.75	5.97	7.31
LR test [<i>p</i> -stat]	$\chi^2(3)$ 8.161 [0.042]	$\chi^2(3)$ 5.809 [0.121]	$\chi^2(4)$ 14.378 [0.006]	$\chi^2(4)$ 16.725 [0.002]
Jarque-Bera test [<i>p</i> -stat]	$\chi^2(8)$ 5.113 [0.745]	$\chi^2(8)$ 5.481 [0.705]	$\chi^2(8)$ 5.942 [0.653]	$\chi^2(8)$ 5.309 [0.724]
Lag 3 exclusion test [<i>p</i> -stat]	$\chi^2(16)$ 7.795 [0.954]	$\chi^2(16)$ 10.793 [0.822]	$\chi^2(16)$ 5.984 [0.988]	$\chi^2(16)$ 8.749 [0.923]

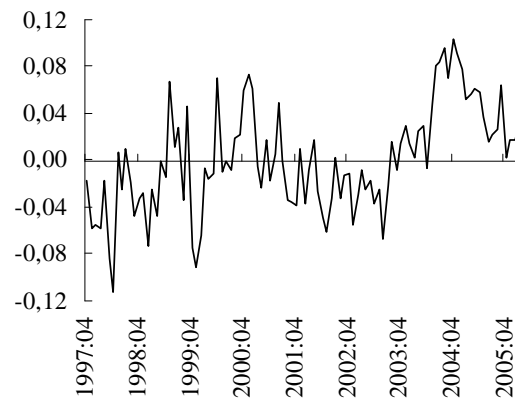
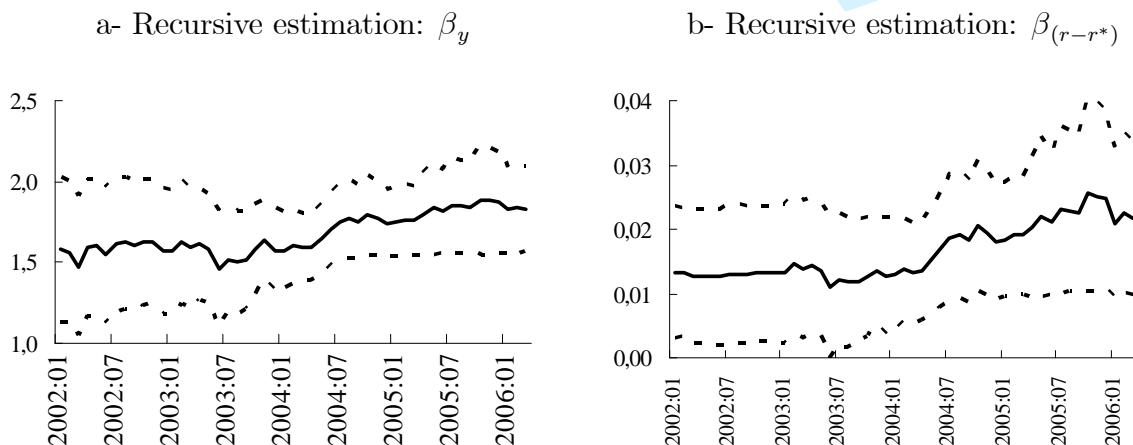
Note 1: The speed of adjustment is equal to one minus the first order autoregressive coefficient of the error-correction term (ec_t). The 90% adjustment is equal to $\ln(0.10)/\ln(1-s)$ where s is the speed of adjustment (Phylaktis and Kassimatis, 1994).

Note 2: Standard errors are in parentheses.

Figure 1: Backward and forward recursive trace tests



Note: The backward recursive trace test checks the cointegrating rank constancy in the baseline sample. Figure 1a has therefore to be read from the right side to the left side.

Figure 3: Error-correction term (ec_t)Figure 4: Recursive estimation (β_6): $DC_t = -\beta_{ir}IR_t - \beta_y y_t - \beta_{(r-r^*)}(r_t - r_t^*) - \mu_1 + ec_t$ 

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

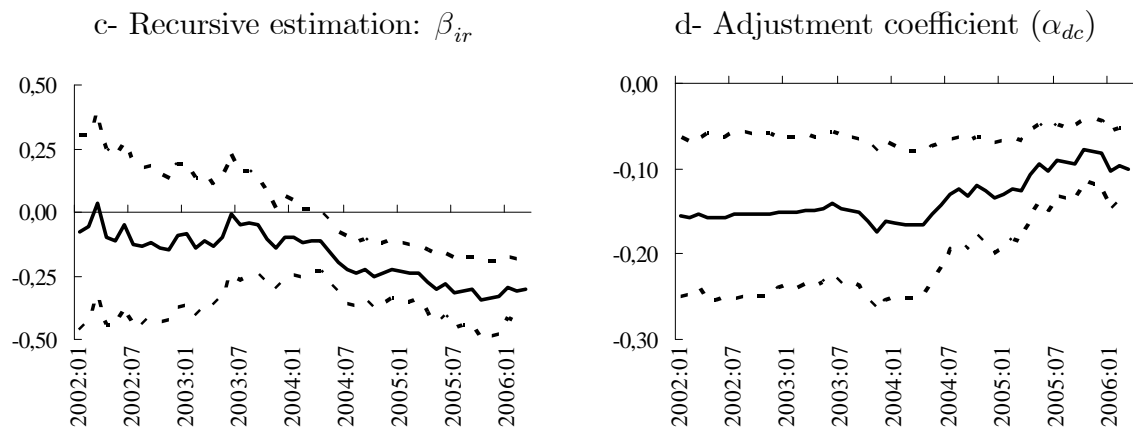
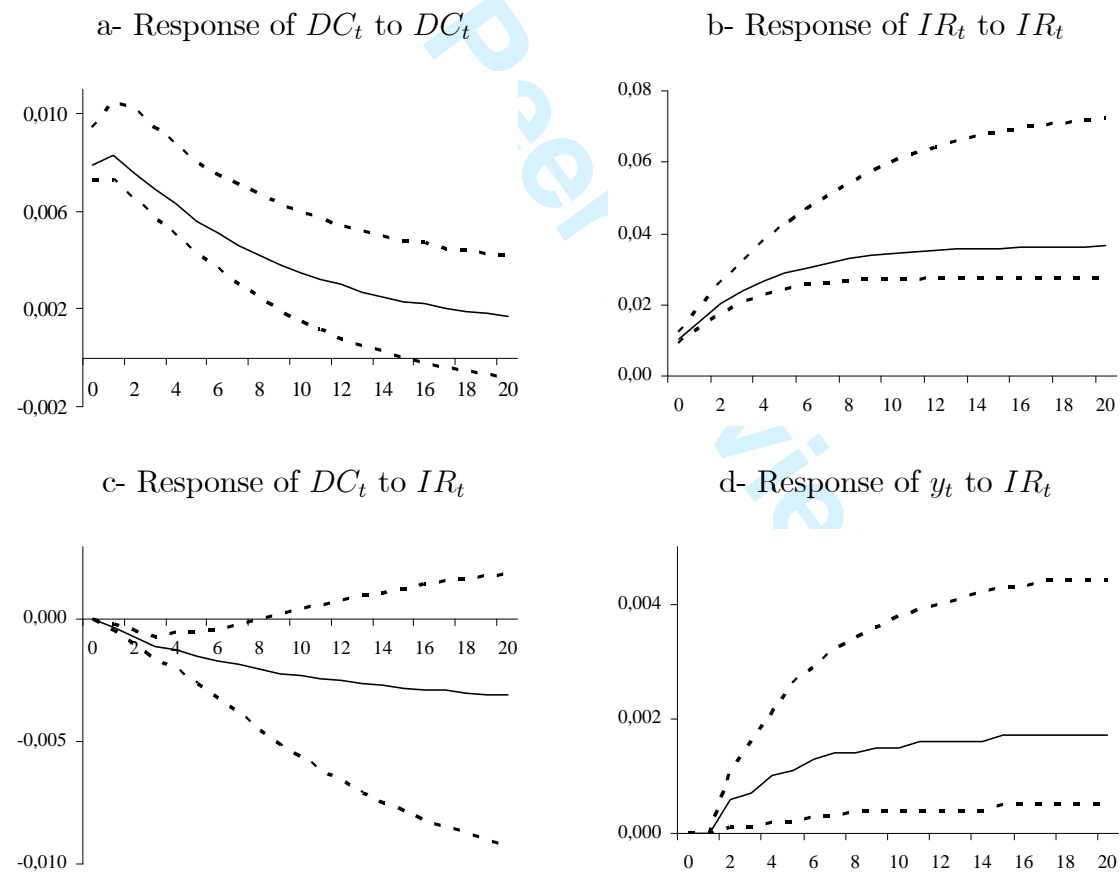
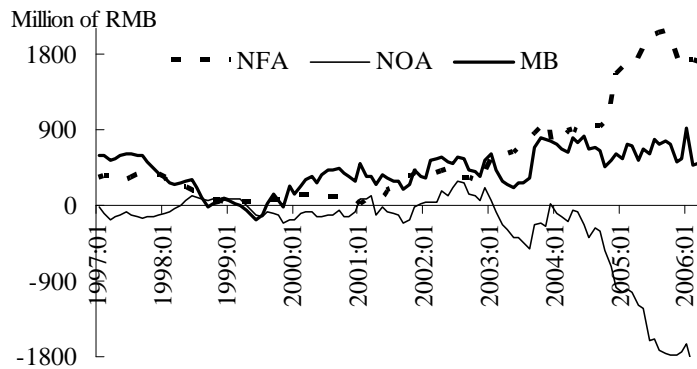


Figure 5: Impulse responses



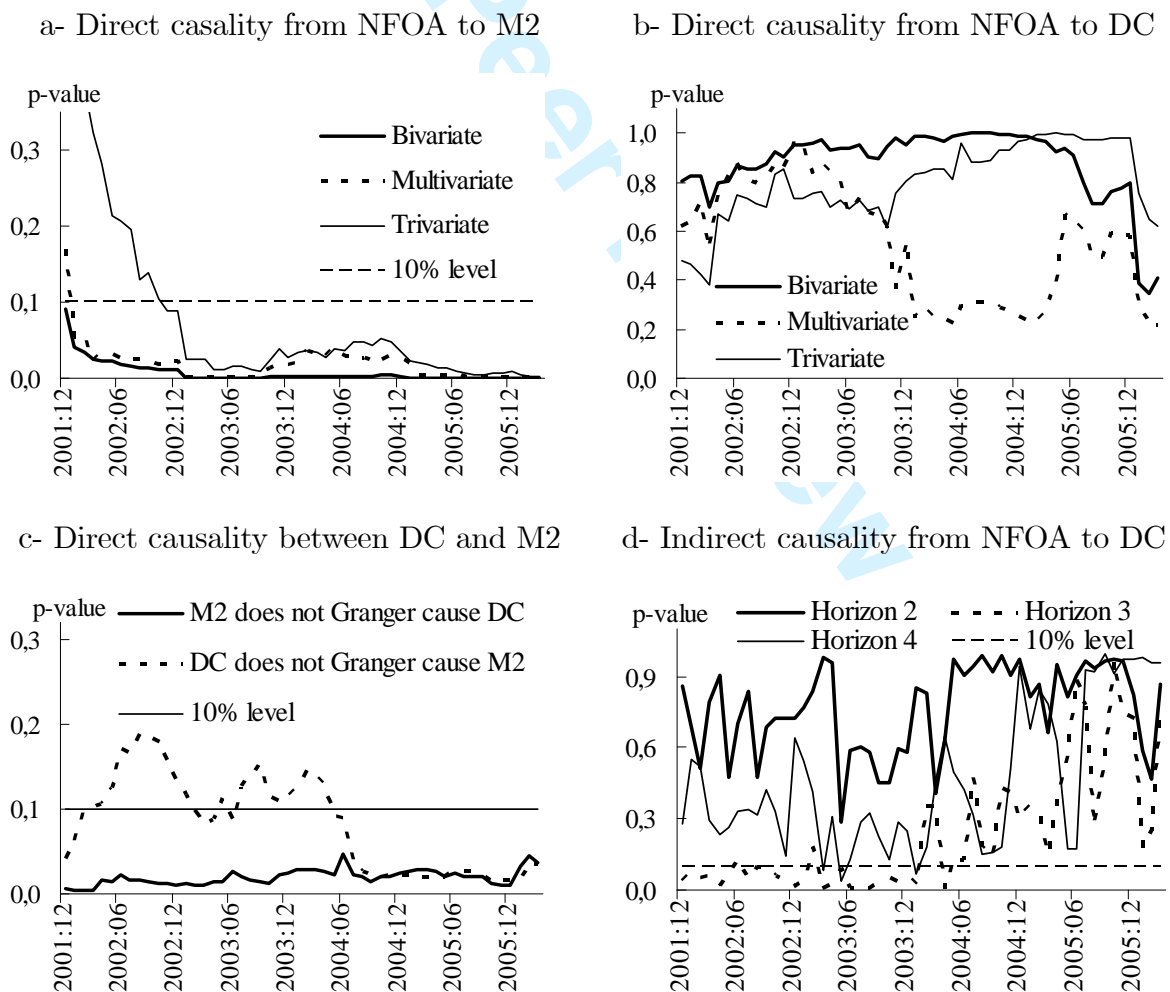
Note: Confident intervals represent the 90% studentized Hall intervals based on 1500 bootstrap replications and 100 replications for estimating the variance in each of the outer replication rounds. These impulses responses are computed with JMulti 4.02 (Lütkepohl and Krätzig, 2004)

Figure 6: 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. NOA_t equals the difference between other assets and other liabilities and can therefore either be positive or negative. Source: IMF IFS database.

Figure 7: Forward recursive causality tests



Note: H_0 : variable X does not Granger cause variable Y.