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Hot Money Inflows in China: How the People's Bank of China Took up the Challenge¹

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Résumé:

Cet article porte sur les entrées de capitaux spéculatifs en Chine. Le système financier chinois se libéralise progressivement et l'efficacité des contrôles des capitaux a tendance à diminuer. Ainsi, l'économie chinoise fait face à des entrées de capitaux spéculatifs. La forte baisse du taux d'intérêt US amorcée en 2001 et les anticipations portant sur l'ajustement du système de change chinois représentent les principaux facteurs expliquant ces entrées de capitaux spéculatifs. Cet article adapte le modèle de Bernanke et Blinder (1988) à une économie ouverte afin d'analyser les implications sur l'économie chinoise des entrées de capitaux spéculatifs. Un modèle à correction d'erreur sur données mensuelles (mars 1995-mars 2005) est estimé pour évaluer l'impact de l'accroissement des réserves de changes résultant des entrées de capitaux spéculatifs. Les interactions entre le crédit domestique et les réserves de change apparaissent stables et compatibles avec la stabilité monétaire. Des tests de causalité directe et indirecte à la Granger sont également mis en œuvre afin d'explicitier comment la banque centrale chinoise est parvenue à maintenir la stabilité monétaire.

Classification JEL: C32, E5, F32, F33

Mots-clés: capitaux spéculatifs, crédit domestique, VECM, causalité à la Granger

Abstract:

This paper investigates hot money inflows in China. The financial liberalization comes into effect and the effectiveness of capital controls tends to diminish over time. As a result, China is fuelled by hot money inflows. The US interest rate cut since 2001 and expectations of exchange rate adjustments are the main factors explaining these capital inflows. This study uses the Bernanke and Blinder (1988) model extended to an open economy to examine implications of hot money inflows for the Chinese economy. A Vector Error Correction Model (VECM) on monthly data from March 1995 to March 2005 is estimated to investigate the recent upsurge in foreign reserves and shows that the interaction between domestic credit and foreign reserves was stable and consistent with monetary stability. Granger causality tests are implemented to show how the People's Bank of China (PBC) achieved this result.

JEL classification: C32, E5, F32, F33

Keywords: hot money inflows, domestic credit, VECM, Granger causality

I. Introduction

The 1997-98 financial crises in Asia have been widely documented. Twin crises models, putting the emphasis on balance sheet approaches (Jeanne and Zettelmeyer, 2002), enlighten the stylized facts related to this crisis. In these models, the private sector builds up hot money and a reversal in creditor perceptions leads to a sudden stop (Dornbusch et al., 1995) with large deleterious effects on the economy. Consequently, most countries affected by the Asian crisis switched to managed float systems and tried to implement prudential regulation in order to deal with new financial and monetary imbalances. However, this strategy has not been able to cut hot money inflows sufficiently. Both financial development levels (Aghion et al., 2004) and the “original sin” theory (Eichengreen and Hausmann, 1999) emphasize this issue. As a result, complementary actions are needed to avoid the occurrence of new imbalances. For example, Thailand has been applying capital controls on inflows since September 2003 (Bank of Thailand, 2003a-b) to offset the negative effects of its weak financial development whereas Korea cares about exchange rate fluctuations when setting its monetary policy (Eichengreen, 2004a).

The gradual financial liberalization in China provides interesting insight into this issue. This strategy prevented the accumulation of foreign-currency-denominated liabilities in the private sector. Consequently, China did not accumulate hot money in the 1990’s and recorded a strong growth during the Asian crisis (Fernald and Babson, 1999). However, the financial liberalization in China is progressing. First, banking reforms highlight the transformation of the Chinese economy from a centrally planned economy to a market-based economy. Second, capital controls became less effective and cannot provide a long lasting protection anymore if incentives for capital inflows linger. Hence, hot money inflows can fuel the Chinese financial system.

In particular, Prasad and Wei (2005) show that non-FDI capital inflows are significantly increasing in China since 2001. They are mainly explained by the interest rate differential between China and the United States (US), coupled with expectations of a renminbi (RMB) revaluation. These hot money inflows could question the suitability of the currency peg. The People's Bank of China (PBC) has to intervene in the foreign exchange market to face hot money inflows which increase the pace of reserves accumulation. If these capital inflows are not fully sterilized, they lead to liquidity injections into the economy. The recent move (July 2005) toward more exchange rate flexibility is therefore appropriate to keep domestic monetary conditions under control and to stabilize the domestic banking sector.

The purpose of this paper is to identify hot money inflows in China and to consider their implications in the Chinese economy. More precisely, we investigate if the rise in foreign reserves was a source of monetary instability³ or if the PBC succeeded in keeping domestic monetary conditions under control. Indeed, Chinese authorities delayed for a long time the move toward more exchange rate flexibility. In addition, the initial move in July 2005 only means the beginning of a gradual process toward a free float. Thus, hot money inflows during this transition period could strengthen the rapid growth of bank credit which, in turn, could lead to an overheating situation and could complicate domestic monetary management.

The implications of hot money inflows for the Chinese economy are investigated with the Bernanke and Blinder (1988) model extended to an open economy. Furthermore, a VECM, draws on the theoretical model, is estimated to examine the monetary instability which could result from the increase in foreign reserves. The empirical estimations use monthly data from March 1995 to March 2005 and show that the interaction between domestic credit and foreign reserves was stable and consistent with monetary stability. Finally, the sterilization policy applied by the PBC to manage these capital inflows is investigated with Granger causality

³ Money supply is considered as endogenous and made up of domestic credit and international reserves. The monetary stability that we investigate is therefore mainly linked to the evolution of domestic credit.

tests. Empirical results show that reserve requirements – on top of open market operations – did not drain all the liquidity. Consequently, hot money inflows lead to monetary expansion. Nevertheless, we also show that the PBC succeeded to shape domestic credit using window guidance.

The remainder of the paper is organized as follows. Section II briefly reviews banking reforms and identifies hot money inflows resulting from the financial liberalization. Section III presents the stylized framework. Section IV discusses the empirical results. Section V concludes.

I. Financial liberalization in China

The financial liberalization of the Chinese economy is progressing which emphasize its transition to a market economy. In particular, the banking system obtained greater decision-making autonomy and capital controls have become less effective over time.

1. The banking sector

Allen et al. (2003, 2005a, 2005b) investigate China's financial system and its ability to support the economic growth, which provides a precise insight into financing channels in China.

The Shanghai Stock Exchange and the Shenzhen Stock Exchange were respectively created in 1990 and 1991 and some selected firms from Mainland China can henceforth be listed and traded on the Hong Kong Stock Exchange. These markets have been growing fast but the market-based channel of financing is still an inefficient way to raise funds in China. The underdeveloped legal system explains this situation which is consistent with the law-finance-growth literature notably developed by La Porta et al. (1997, 1998).

The financial system is therefore dominated by a large banking sector characterized by a high ratio of total bank credit to GDP (111%). However, the efficiency of this banking sector is low with an overhead cost to total assets (12%) much higher than the ones estimated by La Porta et al. (1997, 1998) on other banking sectors (between 2% and 5%). Credit allocation also varies across sectors. Most bank credits are granted to the State Sector⁴ and the Listed Sector, the ratio of bank credit issued to the Private Sector to GDP is only 24%. Moreover, Allen et al. (2003, 2005a, 2005b) show that the Private Sector grows much faster than the two other sectors which suggests that the Chinese financial system is also characterized by alternative financing channels.

However, this result must not lead to underestimate the role of bank credit in the Chinese macroeconomic situation (Hu, 2003). The financial liberalization especially in the banking sector has been essential in the Chinese transition to a market economy and the review of these reforms (Mo, 1999; Wong and Wong, 2001; Barth et al., 2004; Barnett, 2004) highlights the deep modifications that occurred in the banking sector.

Prior to 1978, the banking sector was only made up of the PBC which acted as both the central bank and a commercial bank. The year 1978 marked therefore the inception of banking reforms. The PBC was established as China's central bank while commercial bank activities were mainly assigned to three specialized state-owned banks: the Bank of China, the People's Construction Bank of China and the Agriculture Bank of China. In 1984, the fourth state-owned commercial bank (the Industrial and Commercial Bank of China) and some non-state owned bank expanded the banking sector while the sectoral specialization barriers were reduced. The central bank status and the scope of business for commercial banks were clarified afterwards in 1995 with the Central Bank Law and The Commercial Banking Law allowing the implementation of a legal framework based on international standards.

⁴ Allen et al (2005b) define the State Sector as state-owned enterprises (SOE), the Listed Sector as firms that are listed on an exchange and are publicly traded, and the Private Sector as all the other firms.

The credit plan was abolished at end-1997 but its effectiveness and its scope were decreasing before this official abolition. The banking sector expansion and an increasingly market-driven economy explain that the credit plan became less effective over time (Montes-Negret, 1995; Mo, 1999). In particular, three policy lending banks were established in 1994 (the State Development Bank, the China Export-Import Bank and the China Agricultural Development Bank) to implement the government-directed policy lending. Pressures from central and local governments on state-owned banks were therefore reduced.

Over the recent period, China's accession to the World Trade Organization in 2001 became a driving force in the deregulation process since this agreement commits China to completely open its financial-services industry to foreigners in December 2006 (Woo, 2002).

All these reforms have been leading to a greater decision-making autonomy of the banking sector and ensure the foundation of a competitive, modern banking system. Chen et al. (2005) show that the overall efficiency of Chinese banks significantly increased from the early 1990s until 1996. This result is mainly due to the 1995 reform program. Decisions are more profit-oriented and thus more based on creditworthiness, which represents a significant progress to deal with future flows of problem loans. However, Chen et al. (2005) also show that the efficiency of Chinese banks gradually fell from 1997 to 2000, especially as a result of an increase in state-owned enterprises (SOE) non-performing loans. Reforms on deregulation will not solve the stock problem of non performing loans resulting from the financing of loss-making SOE during the credit plan. Equity injections (like the ones of \$32.5 billion in August 1998 and \$45 billion in December 2003) and the creation of Asset Management Corporations (AMC) are the two orientations followed by the central bank to solve this structural problem (Mo, 1999; Ma and Fung, 2002).

2. Hot money inflows in China

The RMB has been convertible for current account transactions since 1996, but capital account transactions are still under control (Xiaopu, 2003): portfolio investments are constrained, foreign direct investments (FDI) are oriented and 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)⁵.

The balance of payments roughly records the amount of hot money inflows (Tung and Baker, 2004; Rzepkowski, 2004; Prasad and Wei, 2005). First, significant portfolio investments inflows are recorded in the capital account. During the second half of 2003 and the first half of 2004, net portfolio investments inflows were respectively \$15.7 and \$27.7 billions (Table 1). Second, Chinese banks and depositors manage foreign assets. These transactions are recorded in the sub-section "Other investments" in the financial account but official figures can be misleading. In December 2003, the PBC used \$45 billion of its exchange reserves in order to recapitalize two state commercial banks. This operation was recorded in the sub-section "Other investments" and the funds were allocated to a holding company owned by the State Administration of Foreign Exchange (SAFE). As a result "Other investments" inflows represented in fact \$39.1 billions in 2003 and were mainly explained by the behavior of Chinese banks and depositors. Lastly some capital inflows escape to regulatory controls but they are all the same recorded in the balance of payments in the statistical discrepancy. Indeed, in 2003, errors and omissions increased significantly⁶ and have represented \$18.4 billions which contrast with illegal capital outflows noticed during the 1990's (Gunter, 2004).

⁵ Prasad and Wei (2005) provide an extensive chronology of capital controls over the period 1980 - January 2005.

⁶ 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).

According to Andy Xie – economist at Morgan Stanley – the hot money is mainly held by overseas Chinese (Chinese diaspora, mainly from Taiwan), Chinese banks converting their foreign assets into RMB assets while Chinese households stop accumulating foreign deposits. These hot money inflows are estimated at 70 billions dollars in 2003 and 30 billions dollars during the first half of 2004 (Table 1). Hence, the rapid increase in international reserves of China offset mainly non-FDI capital inflows rather than trade surplus.

US interest rate fluctuations could be the main factor explaining hot money inflows. Figure 1 shows that the foreign 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 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).

The interest rate differential and the exchange rate expectations have specially affected the evolution of Chinese foreign currency deposits (Ma and McCauley, 2002, 2003). Foreign currency deposit in proportion to RMB deposit held by households and firms are decreasing since 2002 (Rzepkowski, 2004).

III. Theoretical design

We consider the Bernanke and Blinder (1988) model extended to an open economy. This model was also developed by Greenwald and Stiglitz (1990) and includes a financial accelerator mechanism.

1. Asset markets equilibrium: the AA schedule

The AA schedule simultaneously refers to the money market and the foreign exchange market as the asset markets. 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 whereas the money supply is endogenous and made up of domestic credit and international reserves:

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

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

The equilibrium condition in the foreign exchange market is provided by the interest parity relation (*IP*). The expected appreciation of the dollar equals zero since China applied a fixed exchange rate regime with the US dollar during the considered period. The domestic interest rate can therefore be written as the sum of the US interest rate plus the risk premium:

$$i_t = i_t^* + \rho_t, \quad (2)$$

where i_t^* is the US real interest rate on bonds and ρ_t the risk premium.

The AA schedule, combining the *LM* curve and the interest parity, is defined by the following equation:

$$\frac{IR_t + DC_t}{P_t} = L(y_t, i_t^* + \rho_t). \quad (3)$$

This schedule provides therefore a nice insight into interactions between the monetary market and the exchange market which is relevant for the paper.

2. Output market equilibrium: the *CC* schedule

The *CC* schedule refers to the goods and services market (G&S) and the equilibrium condition is provided by the equality between an aggregate demand function and the aggregate supply. Furthermore, we consider the specificities of loans – which are imperfectly substitutable for bonds – to stress their importance on aggregate demand. Following Stiglitz and Weiss (1981), the loan market is characterized by the following assumptions. First, lenders are unable to distinguish among borrowers because of informational asymmetries. Second, borrowers accept a common fixed loan size. Third, as interest rate on loans rises, the quality of borrower pools falls. Finally, banks are assumed to be risk averse and characterized by declining absolute risk aversion as their financial positions improve. These assumptions underline adverse selection and incentive effect resulting from asymmetric information faced by banks about borrowers. As a result, the loan market equilibrium can be characterized by credit rationing.

Besides, we assume simplified commercial bank balance sheets where liabilities consist of deposits and bank capital while their assets consist of required reserves, excess reserves, loans and bonds. Drawing on Bernanke and Blinder (1988) and Greenwald and Stiglitz (1990), the bank lending level is therefore specified by the following relation:

$$DC_t = [(1-\tau)D_t + \gamma_{t-1}] \beta(i_t, \hat{y}_t), \quad (4)$$

where D_t are the deposits, τD_t the required reserves plus the excess reserves, γ_t the bank capital, \hat{y}_t the output gap and $0 \leq \beta \leq 1$ the fraction of bank assets loaned with $\beta_i < 0$ and $\beta_y > 0$ ⁷. The risk-averse banks are therefore less willing to invest in loans when the rate of

⁷ β_j is the partial derivative with respect to variable j .

return on the less risky government bonds is high. Further, the financial position of firms is related to the output gap. An economic slowdown deteriorates therefore the overall quality of the borrowing pool which reduces the willing of commercial banks to supply credit.

In order to specify the total deposit amount, we assume a simplified central bank balance sheet where the asset consists of net foreign asset (*NFA*) and net domestic asset (*NDA*) and where the liability consists of the monetary base (high-powered money) made of banks' reserves (claims on PBC) and currency in circulation. As a result, according to the money multiplier theory, deposits are given by the following relation:

$$D_t = \frac{B_t}{\tau + \theta}, \quad (5)$$

where B_t is the monetary base, τ the reserve requirement plus the excess reserve-demand deposit ratio and θ the currency-demand deposit ratio.

The contractual interest rate in the credit rationing equilibrium is given by:

$$r_t = \alpha(i_t, \hat{y}_t), \quad (6)$$

where r_t is the interest rate on loans, $\alpha_i \geq 0$ and α_y may be either positive or negative⁸.

The credit demand can correspond to a smaller amount than that available as a result of the bank portfolio decisions. There is therefore no credit rationing in such a situation and competition among banks will drive down the interest rate on loans.

The financial liberalization in China makes appropriate this specification of the banking sector. Banks were simply allowed to adjust lending interest rates around the administrative rate but the discretionary bands were gradually enlarged during the 1990's (Xie, 2004) and since the second half of 2003, the ceiling on most commercial lending rates have been removed. Moreover lending decisions became more prudent and based on creditworthiness.

For example, only 80% of the credit quota was fulfilled in 1997 since banks refused to lend to

⁸ See Greenwald and Stiglitz (1990). A modification in the financial position of firms affects both the loan return frontier and the slope of the efficient frontier.

loss-making SOE (Mo, 1999). The banking sector obtained therefore a greater decision-making autonomy in the credit allocation between firms.

The equilibrium condition in the G&S market is therefore provided by the *CC* curve including a financial accelerator:

$$y_t = Y(i_t, r_t, DC_t, q_t), \quad (7)$$

where q_t is the real effective exchange rate and $Y(\cdot)$ is the aggregate demand function.

Financial market conditions do not just depend on the interest rate on bonds. They also depend on the loan market conditions, which are both relevant to the loan rate and the credit supply.

3. The build-up of monetary instabilities

Figure 1 shows that the US interest rate (LIBOR 3 month) was cut from 6.7% end-2000 to 1.1% during the first quarter of 2004. Such an external shock affects the equilibrium of the model.

Without any intervention by the PBC, the US interest rate cut should produce an appreciation of the RMB according to the *AA* schedule. Indeed, capital inflows in China are boosted following the modification of the interest rate differential. Consequently, the PBC has to intervene in the foreign exchange market in order to keep the exchange rate stable, which increases its foreign reserves. The central bank balance sheet shows that the monetary base is related to net foreign assets. Consequently, hot money inflows lead to a monetary base expansion.

It will have a positive impact on the *CC* schedule through the financial accelerator mechanism. Banks get more resources which positively affect the growth of output, monetary aggregates and domestic credit. As a result, this loose monetary condition has a direct impact on aggregate demand and can lead to an overheating situation. Besides, a sudden reversal of hot money flows could stop monetary creation. This liquidity squeeze might strengthen

balance sheet pressures and commercial banks might face up to non performing loans. The economy might therefore have to deal with a hard landing scenario.

Monetary authorities can implement sterilization measures in the narrow sense⁹ (open market operations) as well as in the broader sense (with reserve requirement ratio and window guidance) to manage the impact of hot money inflows on the growth of monetary aggregates and domestic credit. However, these measures do not reduce incentives for hot money inflows by keeping the level of domestic interest rates high (Takagi and Esaka, 1999).

Prasad et al. (2005) argue that China should move toward greater exchange rate flexibility to deal with domestic and external shocks and that capital account liberalization should be implemented cautiously and gradually, given weaknesses in the domestic financial system. The effective path toward greater exchange rate flexibility could be provided by a “two-stage currency reform”, including a revaluation of the renminbi (roughly 15%) followed by a switch to a currency basket peg with a gradually widening band (Goldstein and Lardy, 2003; Tung and Baker, 2004).

IV. Empirical results

A VECM, drawn on the variables highlighted in the asset markets equilibrium condition, is estimated using monthly data from March 1995 to March 2005 to investigate the stability of monetary conditions. We therefore examine if the foreign reserves increase created monetary instability, or if the PBC succeeded in managing hot money inflows and in keeping domestic credit under control.

⁹ The full sterilization by open market operations requires deep local financial markets which is not the case in China.

1. Asset markets equilibrium

1.1 Data and cointegration analysis

Dependent variables¹⁰ are gross international reserves (*IR*), domestic credits (*DC*), GDP (*y*), consumer prices (*P*) and US real interest rate (i^*). Real effective exchange rate (*REER*) and bank's reserves (*BR*) are considered as exogenous variables in order to take into account impacts from the demand side. The Chow and Lin (1971) method¹¹ is used to obtain the GDP monthly estimate. We use the log transformation of index variable (October 1993=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 hot money inflows. 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 2002¹².

Table 2a reports the unit root tests both in level and first difference using Augmented Dickey-Fuller (ADF), Elliott-Rothenberg-Stock (DF-GLS), Phillips-Perron (PP) and Kwiatkowski-Phillips-Schmidt-Shin (KPSS) tests. We conclude that domestic credit, GDP, US real interest rate, real exchange rate and bank'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 gross 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

¹⁰ A better fit with the theoretical model should also take into account the risk premium and exchange rate expectations but we do not have any appropriate variable to represent these two concepts and we have also to care about the scope of the empirical model.

¹¹ 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.

¹² 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 linked to accounting procedures.

gross international reserves were not 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 foreign reserves lead to monetary instability or did the PBC succeed to manage hot money inflows and keep domestic credit under control?

To deal with the $I(2)$ propriety of consumer prices, we use in our estimations the real domestic credit, the real US interest rate and real bank's reserves whereas the GDP is at constant prices.

We can conclude that all these series are $I(1)$ process.

The model therefore consists of the following equations:

$$\Delta Y_t = \mu + \sum_{i=1}^k \phi_i (\Delta Y_{t-i}) + \phi_1 (\Delta X_t) + \alpha (\beta Y_{t-1} + \mu') + \varepsilon_t, \quad (8)$$

where $Y_t = [\Delta(IR_t) \quad \Delta(P_t) \quad GDP_t \quad i_t^* \quad DC_t]'$ and $X_t = [REER_t \quad BR_t]'$ are random vectors, μ is a 5×1 constant vector 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 two lags in order to achieve normality (Jarque-Bera test) and independence (LM test) of residuals.

The Johansen and Juselius (1990) cointegration method is followed. This method allows to test for the number of cointegrating vectors using a trace test. Nevertheless, this test could lead to an over rejection of the no cointegration hypothesis if we do not check the cointegrating rank constancy and if we do not deal with the possible finite sample bias. We therefore implement forward and backward recursive trace tests to investigate the cointegrating rank stability. Furthermore, we correct the trace test statistic for the finite sample bias as suggested by Reinsel and Ahn (1992) and Reimers (1991). This correction

does not consist in estimating new critical values but in multiplying the trace test statistic by the scale factor¹³: $(T - pk)/T$.

The recursive¹⁴ trace tests with the finite sample bias correction (Figure 2) support the existence of one cointegrating vector. Although the second cointegrating vector is significant for the whole sample at 1% level with the corrected trace test, this relation is not significant before June 2002 with the forward recursive trace test (Figure 2a). Moreover, the backward recursive trace test – checking the cointegrating rank constancy in the baseline sample – strongly support the existence of only one cointegrating vector. In Figure 2b, the corrected trace statistic for two cointegrating relations is above the 1% critical value only when we consider the whole sample.

1.2 Estimated cointegrating vectors

Table 3 displays cointegrating vectors (β_i) and adjustment coefficients (α_i). The first estimation (β_1, α_1) only considers the homogeneity constraint between international reserves and consumer prices. The LR test shows that the homogeneity restriction is not rejected at the 5% level. Besides, the LR test does not support the nullity of other coefficients. As expected, international reserves exhibit in the long-run a positive relationship with GDP and negative ones with domestic credit and US interest rate. We also check that the equilibrium error is a stationary process.

The second estimation (β_2, α_2) tests – on top of homogeneity – for the weak exogeneity of consumer prices, domestic credit, GDP and US interest rate. The LR test shows that these restrictions are not rejected at the 5% level. The adjustment coefficient is therefore only significant on international reserves. This coefficient is consistent with equilibrium correction behavior, and exhibits a strong level feedback. Adjustment forces pull the process back

¹³ With T the number of observations, p the number of endogenous variables and k the lag number.

¹⁴ All the recursive procedures have to be cautiously considered. The range of the initial sub-samples is small.

toward the steady state in 1.3 periods. This outcome is consistent with the fixed exchange rate system applied by the PBC.

The third estimation (β_3, α_3) directly considers real international reserves. This estimation allows to remove an equation from the VECM and then to reduce the ratio between the number of estimated coefficients and the number of observations from 58% to 40%. The cointegrating vector is robust to this modification.

Finally, the estimations (β_4, α_4) and (β_5, α_5) investigate if bank's reserves should be introduced in the cointegrating relation. Indeed, hot money inflows fuel bank's reserves which are related to domestic credit. The estimation (β_4, α_4) simply introduces bank's reserves in the cointegrating vector and shows that the former relation is quite robust to this modification. The estimation (β_5, α_5) enlightens this outcome. The LR test supports the nullity of the coefficient associated with bank's reserves. Hence, we conclude that bank's reserves do not have to be introduced in the cointegrating vector.

The long run relation (β_2, α_2) is now recursively estimated in order to investigate its constancy. The long term coefficients associated to domestic credit, GDP and US interest rate are quite stable (Figure 3), although a transitory instability can all the same be pointed on coefficients associated with domestic credit and GDP. During the third quarter of 2004, their two times standard error bands intersect with the horizontal axis. This analysis has to be completed with a recursive LR test. Indeed, several restrictions were made in order to obtain the estimation (β_2, α_2) . Figure 4 shows that these restrictions are recursively supported at the 1% level. We therefore conclude that the long term structure of the estimated model, i.e. the asset markets equilibrium condition, was stable. As a result, the PBC succeeded in managing hot money inflows and in keeping domestic credit under control.

1.3 Impulse responses

Impulse responses are used to analyze the dynamic interactions between variables – and more precisely between foreign reserves and domestic credits – in the system characterized by the cointegrating relation (β_3, α_3) . First, we implement a system Sequential Estimation of Regressors (SER) procedure in order to test restrictions for the short run parameters¹⁵. 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 intervals¹⁶ based on 2000 bootstrap replications and 50 replications for estimating the variance in each of the outer replication rounds. Standard and Hall confident intervals based on 2000 bootstrap replications give similar results but they are not displayed on Figure 5 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 Figure 5.

We observe that both international reserves and domestic credits react negatively and permanently to a one-time impulse in the US interest rate residual (Figure 5a-c). The US interest rate cut initiated in 2001 explains therefore a part of hot money inflows, leading simultaneously to a credit expansion. Nevertheless, figure 5d-g shows that the PBC succeeded in keeping monetary expansion under control. Domestic credits react negatively to a one-time impulse in international reserves residual and vice-versa, international reserves react negatively to a one-time impulse in domestic credit residuals.

¹⁵ 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.

¹⁶ We use JMulTi 4.02 (Lütkepohl and Krätzig, 2004).

We note that the response of international reserves to its own impulse (Figure 5d) is not permanent. This outcome results from the fixed exchange rate system applied by the PBC and was highlighted in Table 3 by the strong adjustment force on international reserves. In addition, the extent of permanent responses of international reserves to impulses in domestic credits and US interest rate is related to coefficients estimated in the cointegrating vector (β_3, α_3) . Responses of international reserves are -0.1862 and -0.0076 following respectively a 1.5675 increase in domestic credits and a 0.8627 increase in US interest rate which approximately give back the estimated relationships respectively of 0.1221 and 0.0089 (Table 3).

We therefore conclude that hot money inflows did not cause instability in domestic monetary conditions. The estimated cointegrating relations and impulse responses show that the interaction between domestic credit and foreign reserves was stable and consistent with monetary stability. We can now examine how the PBC proceeded to get this result.

2. The management of hot money inflows

2.1 The sterilization policy

Hot money inflows lead the central bank to accumulate foreign reserves in a fixed exchange rate system. 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 sector¹⁷.

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

¹⁷ 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).

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 (*MB*) growth. Figure 6 shows year on year variations in components of the central bank balance sheet. Since 2003, the PBC widely has 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 ($NFOA=NFA+NOA$). 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).

2.2 Direct causality tests

The management of hot money inflows 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 the effects of our indicator on the monetary sector with Granger causality tests using the Toda and Yamamoto (1995) and Dolado and Lutkepohl (1996) procedure which 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 our indicator ($NFOA$) and broad money ($M2$) or domestic credit (DC). Secondly, 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 money and credit.

We use the log transformation of index variable (January 1995=100) for all variables except Chinese real interest rate. In addition, VAR systems are estimated using monthly data from March 1997 to March 2005¹⁸. Table 2b displays unit roots test results in both level and first difference. We conclude that all variables are non-stationary in levels but stationary in first-differences. Besides the optimal lag order of the VAR system in stationary form is chosen

¹⁸ The Chinese interest rate is not available before March 1997 in the EcoWin database.

considering information criteria and residual statistical properties. We conclude that each system needs two lags and we take into account dummies¹⁹ to get normality in the residuals.

As a result, we estimate VAR systems in level with 3 lags and Granger causality is tested with restrictions placed on lagged terms up to the second lag. Figure 7 displays the forward recursive causality tests from *NFOA* to *M2*. On the whole sample, the test support that *NFOA* Granger caused *M2* at the 10% level in the three different VAR systems. This outcome is recursively confirmed both in the bivariate and in the trivariate system whereas the p-value in the multivariate system is up above the 10% level from September to December 2004. We can all the same conclude that hot money inflows lead to a monetary expansion and hence reserve requirements did not drain all the liquidity. Furthermore, 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).

On the other hand, Figure 8 shows the results of 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.

2.3 Indirect causality tests

NFOA could all the same have an indirect impact on domestic credit. Figure 9 displays the forward recursive causality tests between broad money and domestic credit in the trivariate VAR. We conclude that we have a bidirectional causality between these two variables on the whole sample although the causality from *M2* to *DC* is not systematically recursively confirmed. As a consequence, *NFOA* does not help to predict *DC* one period ahead but can still cause *DC* several periods ahead with indirect impacts via *M2*.

¹⁹ April 2004 in the bivariate systems; February 1999 and January 2002 in the multivariate systems; December 1999 and January 2002 in the trivariate system.

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

$$W_{t+1} = \mu + \sum_{l=1}^3 \pi_l W_{t+1-l} + e_{t+1}, \quad t = 0, \dots, T-1, \quad (9)$$

where $W_{t+1} = (NFOA_{t+1}, DC_{t+1}, M2_{t+1})'$ is a 3x1 random vector, μ is a 3x1 constant vector and the error vector e_t is such that $E(e_t) = 0$, $E(e_t e_s') = 0$ if $t \neq s$ and $E(e_t e_t') = \Omega$ if $t = s$ with $\det(\Omega) \neq 0$.

Equation (9) 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:

$$W_{t+h} = \mu^{(h)} + \sum_{l_1=1}^3 \pi_{l_1}^{(h)} W_{t+1-l_1} + \sum_{l_2=0}^{h-1} \varphi_{l_2} e_{t+h-l_2}, \quad t = 0, \dots, T-h, \quad (10)$$

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

The Granger causality is tested at horizon h applying standard Wald tests to the first 2 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 $h=3$ ($=1 \times 2 + 1$) according to proposition 4.5 in Dufour and Renault (1998): we have only one auxiliary variable ($M2$), the lag order is two and direct causality corresponds to $h=1$. Table 4 displays indirect causality tests from $NFOA$ to domestic credit. These tests support at the 10% level that $NFOA$ Granger causes DC at horizon 3 but not at horizon 2. Consequently, window guidance allowed to manage the direct impact of hot money inflows on domestic credit but hot money inflows had all the same an indirect impact on domestic credit *via* the loose liquidity conditions underlined by Figure 7.

2.4 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).

However, the point is not to blame the partial sterilization applied by the PBC. The credit boom would have been bigger without any sterilization intervention and overlending have exhibited particular high costs in China in the past. Inflationary pressures would also have been stronger without any sterilization intervention. Hence, the partial sterilization policy was more suitable than a full sterilization or no sterilization at all to manage costs associated with hot money inflows.

V. Concluding remarks

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. However, Chinese authorities were clearly aware of these issues. They delayed for a long time the move toward more exchange rate flexibility but they succeeded in managing the foreign reserves increase. The estimated VECM shows that the interaction between domestic credit and foreign reserves was stable and consistent with monetary stability. Moreover, direct and indirect causality tests display that the partial sterilization implemented by the PBC allowed to manage the impact of capital inflows 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 implemented a 2.1% revaluation of the RMB (21 July 2005) and linked it to a basket of currencies. This managed floating exchange rate suggests that the Chinese demand for dollar-denominated asset is likely to be reduced. The instant impact of this turning point was quite small and the new exchange rate system is heavily managed – the PBC allows a daily trading band of +/- 3% around the exchange rate announced the day before – but it represents the first move toward more flexibility. 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 domestic needs (Eichengreen, 2004b).

Another central issue resulting from this step toward more exchange rate flexibility is to call the revived Bretton Woods System (Dooley et al., 2003) into question, i.e. to call into question the sustainability of the large US current account deficit. The starting point of this paper was the challenging task for the PBC to deal with the international liquidity conditions mainly driven by the US monetary policy. We can conclude that the Chinese monetary and exchange rate policy could henceforth represent an increasing challenge for US monetary policy.

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Data Appendix

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

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 the Federal Reserve is the Treasury Bill 3 month constant maturity.

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

	S1-2001	S2-2001	S1-2002	S2-2002	S1-2003	S2-2003	S2-2003*	S1-2004
Current Account	5.10	12.31	13.63	21.79	11.12	34.75	34.75	7.47
Capital Account	-0.02	-0.03	-0.02	-0.03	-0.02	-0.03	-0.03	-0.03
Financial Account	19.00	15.83	12.27	20.07	44.43	8.35	53.35	66.83
<i>Direct Investment</i>	18.32	19.04	22.71	24.08	26.92	20.30	20.30	30.48
<i>Portfolio Investment</i>	-10.00	-9.40	-7.00	-3.34	-4.29	15.72	15.72	27.71
<i>Other Investment</i>	10.68	6.20	-3.44	-0.67	21.79	-27.68	17.32	8.64
Errors and Omissions	-8.50	3.65	5.27	2.52	4.73	13.69	13.69	-7.29
Reserve Assets	-15.57	-31.75	-31.15	-44.36	-60.25	-56.77	-101.77	-66.98

Unit: billion of dollars

Source: EcoWin database

* : this column includes the \$45 billions used to recapitalize two state commercial banks.

Table 2: Unit root tests

a- The VECM model: 1995:03-2005:03

	ADF		ADF-GLS		PP		KPSS	
	<i>Level</i>	<i>1st Difference</i>	<i>Level</i>	<i>1st Difference</i>	<i>Level</i>	<i>1st Difference</i>	<i>Level</i>	<i>1st Difference</i>
<i>IR</i>	>10%	5%	>10%	>10%	>10%	1%	1%	1%
<i>DC</i>	>10%	1%	>10%	1%	>10%	1%	1%	>10%
<i>GDP</i>	>10%	1%	>10%	10%	>10%	1%	5%	>10%
<i>i*</i>	>10%	1%	>10%	1%	>10%	1%	1%	>10%
<i>P</i>	5%	1%	>10%	>10%	>10%	1%	10%	1%
<i>REER</i>	>10%	1%	>10%	1%	>10%	1%	1%	>10%
<i>BR</i>	>10%	1%	>10%	1%	>10%	1%	5%	>10%

b- VAR systems: 1997:03-2005:03

	ADF		ADF-GLS		PP		KPSS	
	<i>Level</i>	<i>1st Difference</i>	<i>Level</i>	<i>1st Difference</i>	<i>Level</i>	<i>1st Difference</i>	<i>Level</i>	<i>1st Difference</i>
<i>NFOA</i>	>10%	1%	>10%	1%	>10%	1%	1%	>10%
<i>M2</i>	>10%	1%	>10%	>10%	>10%	1%	1%	>10%
<i>DC</i>	>10%	1%	>10%	1%	>10%	1%	>10%	>10%
<i>Chibor</i>	>10%	1%	>10%	>10%	>10%	1%	1%	>10%
<i>GDP</i>	>10%	1%	>10%	1%	>10%	1%	1%	1%

Note: Tables 2a-b report probabilities associated with the null hypothesis. The null hypothesis under the ADF, DF-GLS and PP unit root tests is the presence of a unit root whereas the null hypothesis under the KPSS unit root test is the stationarity. Lag lengths for the ADF and DF-GLS tests are based on Schwartz information criterion. The bandwidth for the PP and KPSS unit root tests are based on the Newey-West estimator using a Quadratic spectral kernel (Hobijn, Franses and Ooms, 1998). Unit root tests include a linear time trend and/or a constant if they are significant.

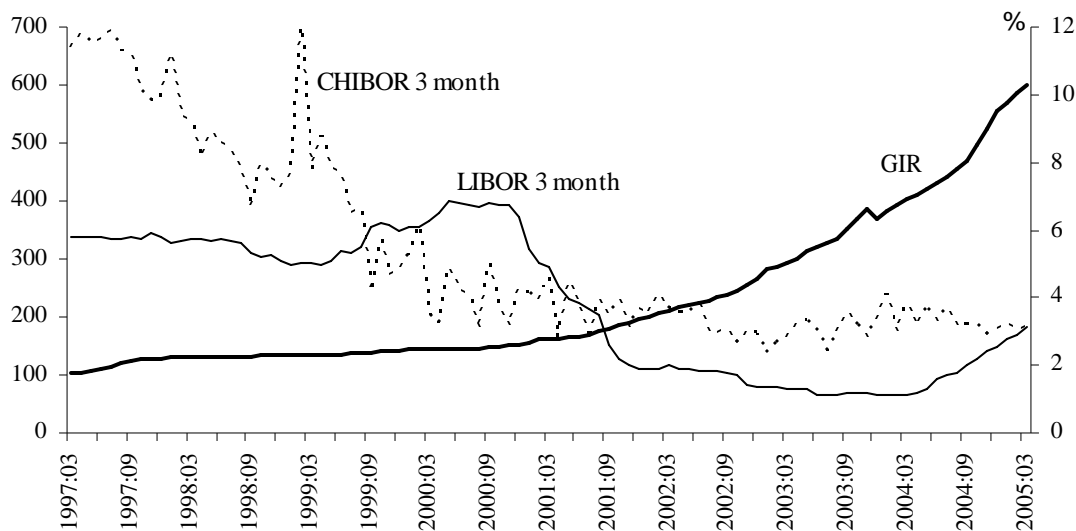
Table 3: VECM estimation

	IR	CPI	DC	GDP	i^*	μ'	BR	LR test
β_1	1	-1	0.1149	-0.1753	0.0079	0.2534	-	3.62 (0.0570)
α_1	-0.7435 [-5.94]	0.0741 [1.58]	-0.0201 [-0.20]	0.0162 [0.99]	-0.4730 [-0.13]	-	-	-
β_2	1	-1	0.1208	-0.1802	0.0090	0.2449	-	8.35 (0.1379)
α_2	-0.7694 [-6.45]	0 [NA]	0 [NA]	0 [NA]	0 [NA]	-	-	-
β_3	1		0.1221	-0.1818	0.0089	0.2461	-	0.96 (0.8086)
α_3	-0.8051 [-6.69]		0 [NA]	0 [NA]	0 [NA]	-	-	-
β_4	1		0.1491	-0.2512	0.0079	0.3912	0.0127	2.84 (0.5840)
α_4	-0.8825 [-7.51]		0 [NA]	0 [NA]	0 [NA]	-	0 [NA]	-
β_5	1		0.1174	-0.1735	0.0085	0.2298	0	4.35 (0.4998)
α_5	-0.9006 [-7.43]		0 [NA]	0 [NA]	0 [NA]	-	0 [NA]	-

Table 4: Indirect causality from *NFOA* to *DC*

Test Statistic	<i>h=2</i>			<i>h=3</i>		
	Value	df	Probability	Value	df	Probability
F-statistic	0.8955	(2, 82)	0.4123	2.7687	(2, 81)	0.0687
Chi-square	1.7910	2	0.4084	5.5374	2	0.0627

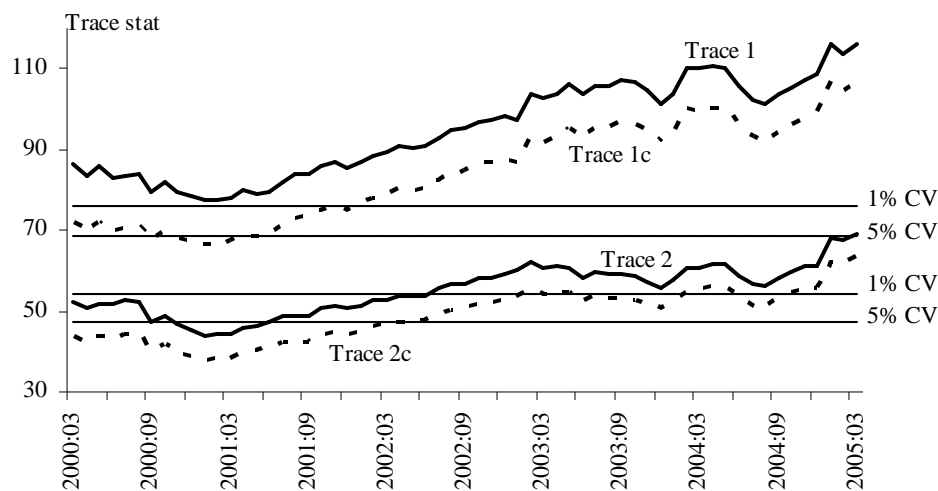
Figure 1: Interest rate and China's GIR



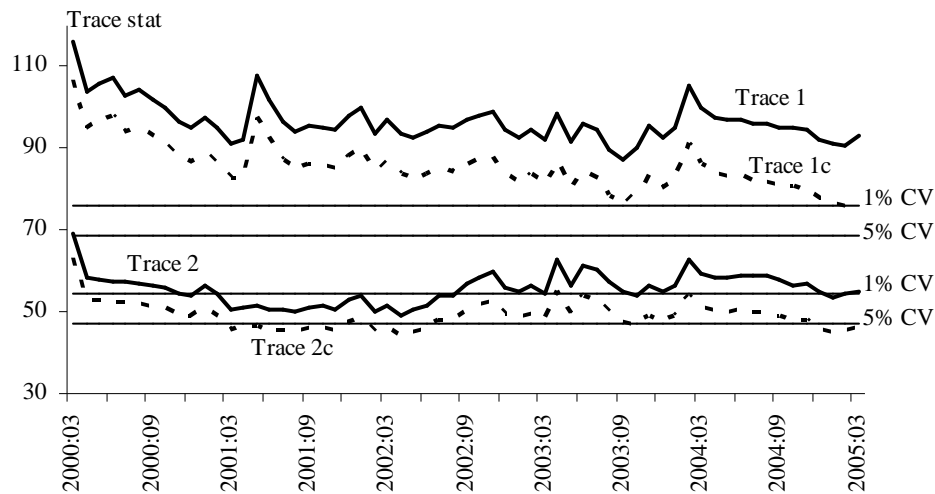
Note : GIR: Index of Gross International Reserves (January 1997=100)
 Source: ARIC database and EcoWin database

Figure 2: Recursive Trace test

a. Forward Trace test



b. Backward Trace test

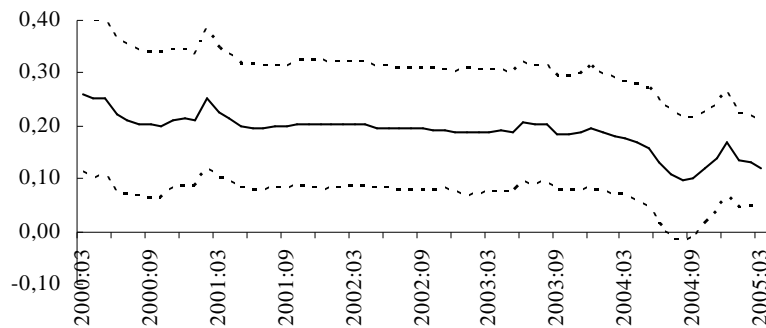


Note 1: Trace i : the trace statistic for i cointegrating relation(s) ; Trace ic : the corrected trace statistic for i cointegrating relation(s) ; X% CV: the X% critical value.

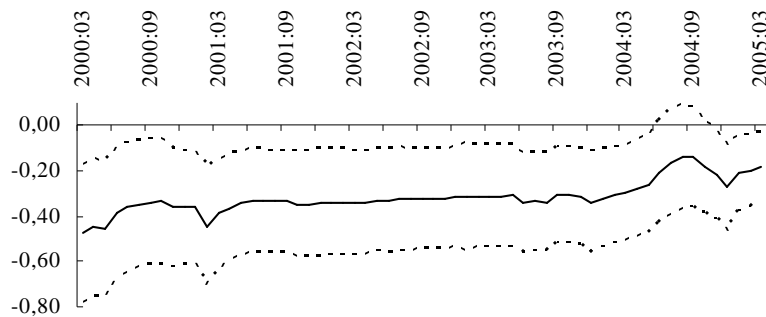
Note 2: the backward recursive trace test checks the cointegrating rank constancy in the baseline sample. Figure 4b has therefore to be read from the right side to the left side. In addition, a constant cointegrating relation should display an rising curve insofar as the trace statistic depend on the sample size.

Figure 3: β recursive estimation

a- Domestic credit



b- GDP



c- US interest rate

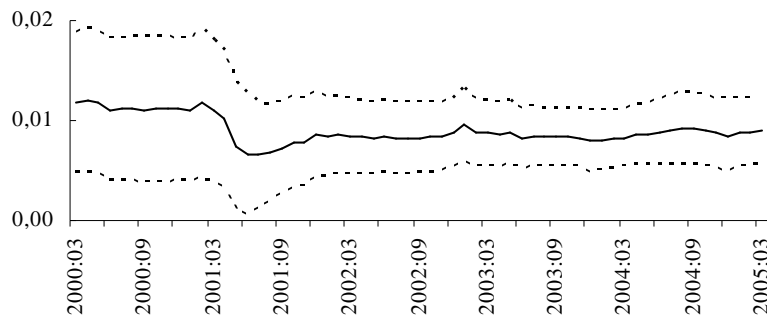


Figure 4: Recursive LR test

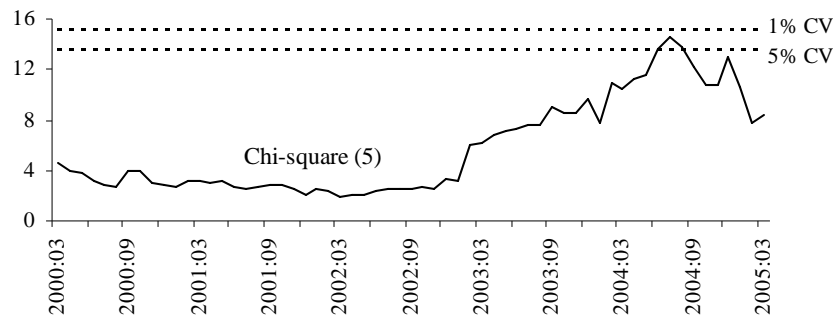
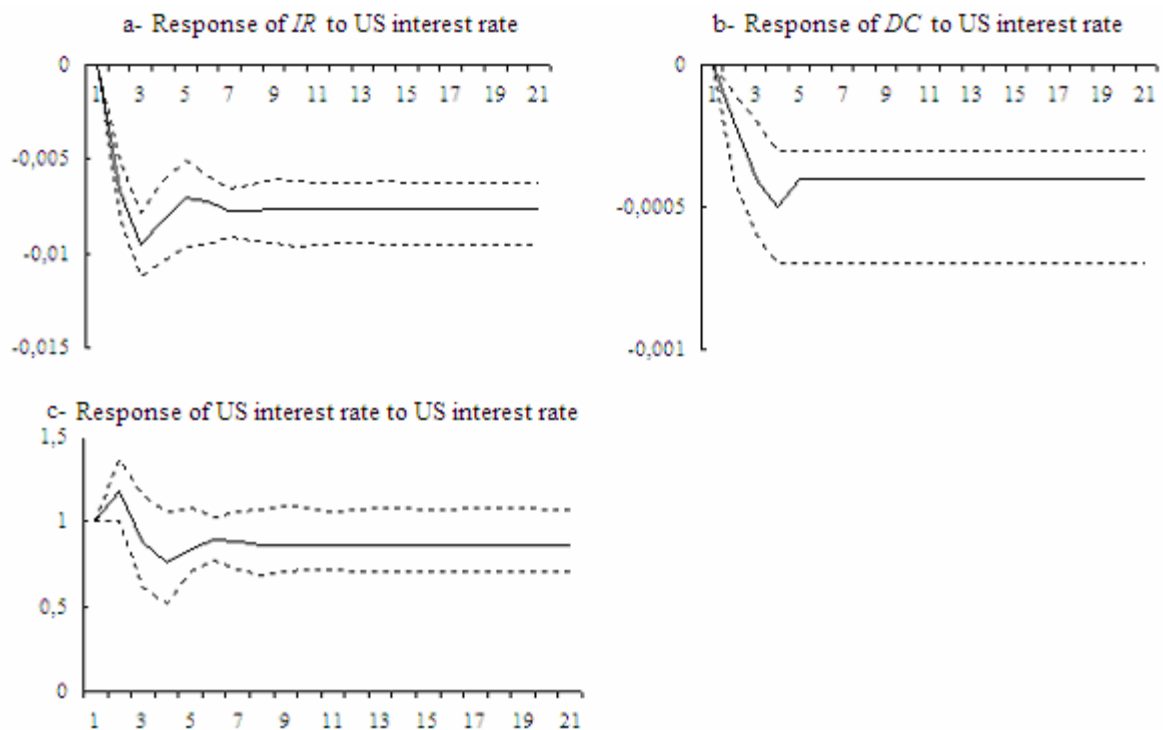
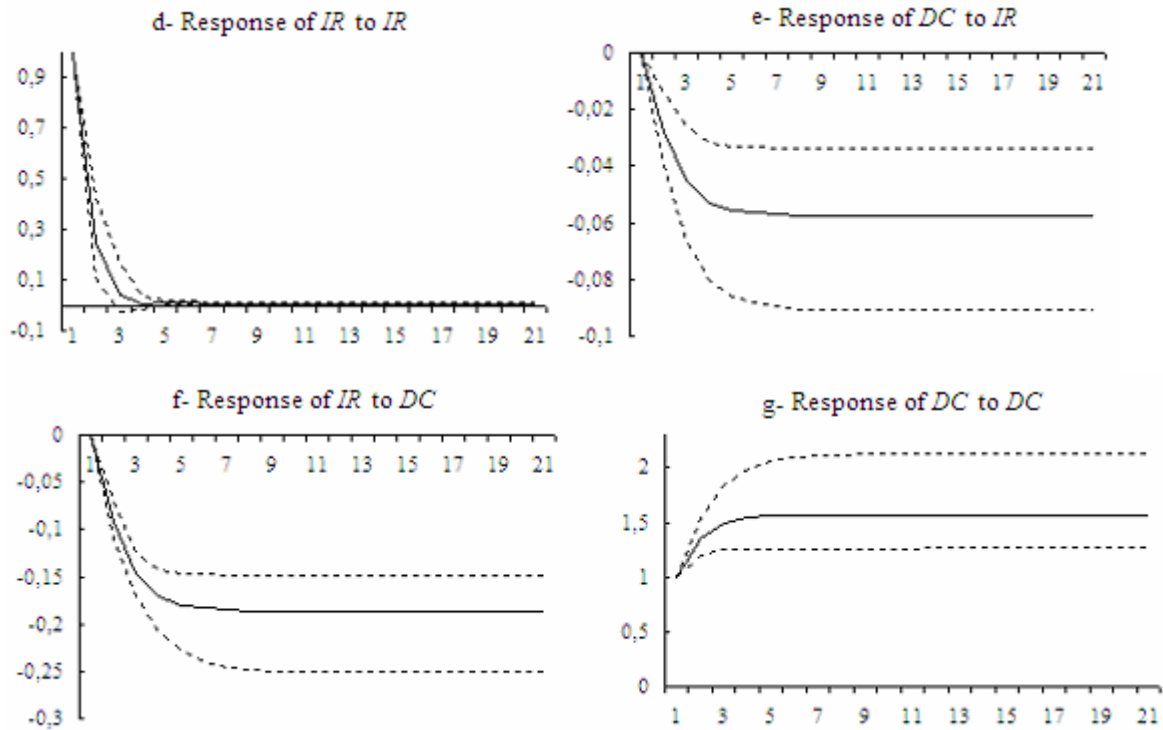


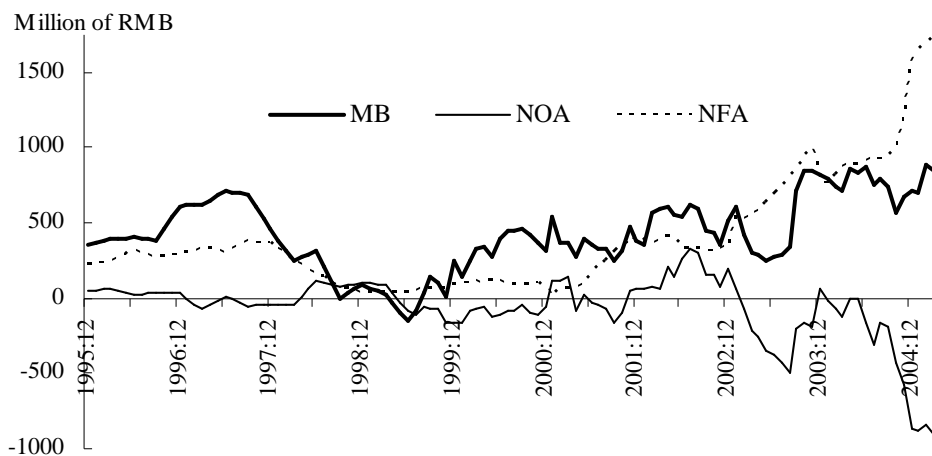
Figure 5: VECM forecast error impulse responses





Note: Confident intervals represent the 95% studentized Hall intervals based on 2000 bootstrap replications and 50 replications for estimating the variance in each of the outer replication rounds. These impulse responses are computed with JMulti 4.02 (Lütkepohl and Krätzig, 2004)

Figure 6: Year on year variation in the PBC balance sheet

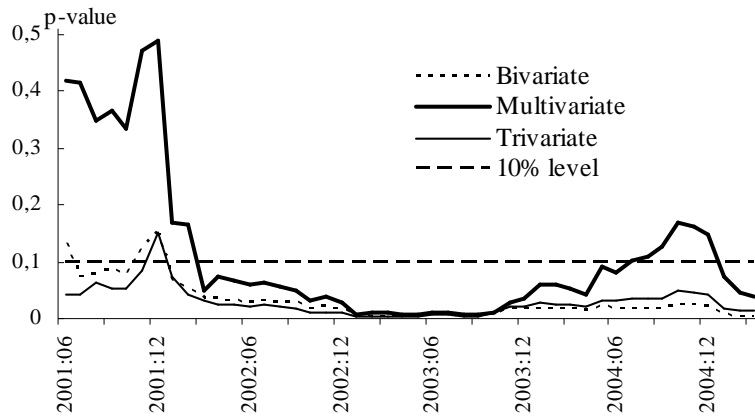


Note: $MB = NFA + NDA + NOA$

NDA variations are quite small since 2001, so there are not represented on the figure to clarify it.

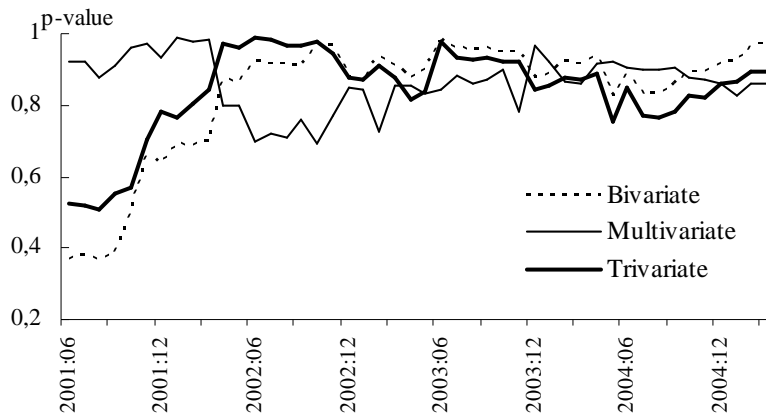
Source: IMF IFS database

Figure 7: Forward recursive causality test from *NFOA* to *M2*



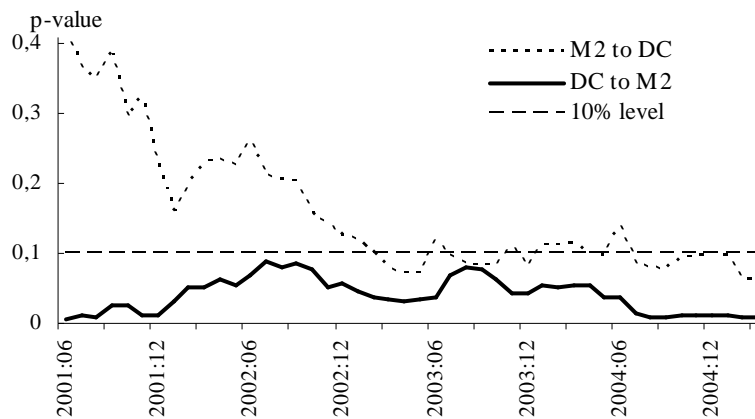
Note: H_0 : *NFOA* do not Granger cause *M2*.

Figure 8: Forward recursive causality test from *NFOA* to *DC*



Note: H_0 : *NFOA* do not Granger cause *DC*.

Figure 9: Forward recursive causality test between *M2* and *DC*



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