

CESifo Venice Summer Institute

19 - 24 July 2010



“THE EVOLVING ROLE OF CHINA IN THE GLOBAL ECONOMY”

to be held on **23 - 24 July 2010**
on the island of San Servolo in the Bay of Venice, Italy

Chinese Monetary Policy and the Dollar Peg

J. James Reade and Ulrich Volz



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Very Preliminary — Please do not Circulate

J. James Reade[†] Ulrich Volz[‡]
University of Birmingham German Development Institute

June 7, 2010

Abstract

In this paper we investigate the impact of China's dollar peg on the conduct of Chinese monetary policy. In particular, we analyse to what extent Chinese monetary policy is constrained by the dollar peg. To this end, we use a cointegration framework to examine whether the Chinese interest rate is driven by the Fed's policy. We find that there is indeed some dependence of Chinese interest rate movements on US rates, but that this relationship is not very strong, suggesting that China has been able to isolate its monetary policy to a certain extent from the US policy. In a second step, we estimate a monetary model for China, in which we include also other monetary policy tools besides the central bank interest rate, namely reserve requirement ratios and open market operations. Although modelling proves difficult (which is not surprising given the complexities of the Chinese monetary and financial system), our results suggest that the interest rate tool has not been effectively made use of, a further indication that monetary dependence on the US is indeed limited. Rather, monetary policy has relied upon open market operations for sterilising foreign exchange intervention and changes in the reserve requirement ratio to affect monetary growth. We therefore conclude that by employing capital controls and relying on other monetary instruments than the interest rate China has been able to exert relatively autonomous monetary policy. Nonetheless, we argue that the People's Bank of China would be able to develop and pursue a more efficient monetary policy mix

*We would like to thank Tamon Asonuma, Anindya Banerjee, John Fender and Ming Zhang for helpful discussions and comments while we were drafting this paper. We also received useful comments from participants of the Macroeconomic and Econometrics Conference at the University of Birmingham and a presentation at the School of Oriental and African Studies of the University of London. All shortcomings are our own.

[†]Address for correspondence: Department of Economics, JG Smith Building, University of Birmingham, Birmingham, B15 2TT, United Kingdom. Email: james.reade@bham.ac.uk. Tel.: +44 121 415 8359, Fax: +44 121 414 7377.

[‡]Address for correspondence: German Development Institute, Tulpenfeld 6, 53113 Bonn, Germany. Email: ulrich.volz@die-gdi.de. Tel.: +49 228 9492 7245, Fax: +49 228 9492 7130.

if it could make effective use of the interest rate tool, which at present is sidelined by the exchange rate peg.

Keywords: Chinese monetary policy; monetary independence; cointegration.
JEL Classification: C32, E52, F33.

1 Introduction

China's reinstatement of its dollar-peg in July 2008 in the wake of the global financial crisis has stirred a heated discussion about China's alleged currency manipulation and beggar-thy-neighbour policy. Proponents of a reform of China's currency regime have argued that the dollar peg not only has negative effects on China's trading partners, but also detrimental effects on the Chinese economy since it impedes an independent monetary policy by the People's Bank of China (PBC), China's central bank (e.g. Roberts and Tyers, 2003; Eichengreen, 2004; Prasad et al., 2005; Goldstein and Lardy, 2006, 2009).

The theoretical implications of a fixed exchange rate peg on the conduct of monetary policy are clear. The "impossible trinity" stipulates that a country is unable to maintain an open capital account, a fixed exchange rate and an independent monetary policy simultaneously. Policymakers are thus obliged to choose between two of the three goals. Since Chinese policymakers have opted for a fixed exchange rate against the dollar and a fairly closed capital account, this policy choice should theoretically provide room for an independent conduct of monetary policy. However, the validity of the impossible trinity hypothesis has been contested. On the one hand, the isolation property of floating exchange rates has been questioned and the empirical evidence has been mixed (e.g. Rose, 1996; Calvo and Reinhart, 2002; Frankel et al., 2004; Shambaugh, 2004; Obstfeld et al., 2005). On the other hand, in practice it is difficult to maintain effective capital controls over time, especially for economies that are open to trade. The empirical evidence suggests that capital controls can be circumvented and that they are not very effective in achieving a higher degree of monetary policy independence (Edwards, 1999).

Surprisingly, there has been relatively little empirical research on the impact of the Chinese dollar peg on the conduct of and constraints on Chinese monetary policy so far. Ma and McCauley (2007) examine price and flow evidence to determine the effectiveness of China's capital controls. Looking at onshore and offshore renminbi yield differentials, as well as gaps in the dollar/renminbi interest rate differentials, they find that China's capital controls remain substantially binding. Although the Chinese capital controls have not been watertight, Ma and McCauley conclude that they have allowed the Chinese authorities to retain some degree of short-term monetary autonomy, despite the fixed exchange rate.

Cheung et al. (2007) focus on the link between US and Chinese interest rates. Using cointegration as well as vector autoregression analysis they investigate the interaction between US and Chinese money market rates. According to their findings, China does not meet the assumptions of a perfect interest rate pass through since the effect of US interest rates on Chinese rates that they find is

rather weak. Like Ma and McCauley, Cheung *et al* conclude that China has had alternative means in place to de-link its interest rates from the US rates.

Glick and Hutchison (2009) scrutinise to what extent China's current account surpluses, foreign direct investment (FDI) inflows and occasionally large non-FDI capital inflows compromise China's monetary policy goal of limiting inflation in the presence of a fixed or tightly managed exchange rate regime. They estimate a vector error correction model that links foreign exchange reserve accumulation to developments in China's reserve money, broad money, real GDP and price level to explore the inflationary implications of different policy scenarios. Under a scenario of limited exchange rate flexibility, rapid foreign exchange reserve accumulation and limited effectiveness of sterilisation operations, their model predicts a rapid increase in inflation. They see a temporary yet limited effect of increasing reserve requirements in dampening inflationary pressures. Glick and Hutchison conclude that as long as China continues to place a higher priority on exchange rate stability than on using monetary policy as a tool for macroeconomic management, China's scope for an autonomous monetary policy is constrained.

Prasad (2008) concurs that, when constrained by a tightly managed exchange rate, monetary policy can at best play a very limited role for China in responding to economic shocks, be they internal or external. However, he points out that although the huge accumulation of foreign exchange reserves — a consequence of Chinese foreign exchange market intervention to counter the appreciation of the yuan — added to the liquidity of the banking system and further complicated the control of credit growth, the PBC was able to sterilise the capital inflows rather well. Unlike in most other emerging market economies, where sterilisation policies usually run into limits quickly, the PBC encounters a great demand for its bills even at relatively low interest rates, a result of both high savings rates in the private and corporate sectors as well as limited diversification alternatives in the closed Chinese capital market. Still, Prasad insists that the PBC's inability to use interest rates as a primary tool of monetary policy implies that monetary growth has to be controlled by blunter and non-market-oriented instruments such as targets or ceilings for credit growth as well as "non-prudential administrative measures".

In this paper we enter the debate on China's monetary and exchange rate policy, trying to address two questions. First, following Cheung *et al.* (2007), we want to know how much monetary policy independence the PBC enjoys — with monetary independence understood in a narrow sense as the PBC's ability to conduct its own interest rate policy without having to follow the Fed's lead. To this end, we use a cointegration framework to examine whether the Chinese interest rates are driven by the Fed's policy. Second, we want to know how effective the PBC's interest rate policy and the other monetary policy tools it has used (namely changes in the reserve requirement ratios and open market operations) have been in managing monetary growth and containing inflation. For this purpose, we estimate a monetary model for China which includes the PBC's policy rate, the required reserve ratio, a measure of the PBC's open market operations as well as macroeconomic indicators that policy might be

expected to respond to, namely inflation, economic activity, growth in broad money and growth in foreign currency reserves.

Our results indicate that although there appears to be some dependence of Chinese interest rate movements on US rates, this relationship is not very strong. This implies that China has been able to isolate its monetary policy to a certain extent from the US policy despite its exchange rate policy. Moreover, our monetary model for China suggests that the interest rate tool has not been effectively made use of, presumably for fear that raising the interest rate would attract ever higher levels of capital inflows that could prove difficult to sterilise. Rather, monetary policy has relied upon open market operations for sterilising foreign exchange intervention and changes in the reserve requirement ratio to affect monetary growth. We therefore conclude that through the maintenance of capital controls and the reliance on monetary instruments other than the interest rate China has been able to exert relatively autonomous monetary policy. We nonetheless believe that the PBC's current monetary policy mix is suboptimal, since the interest rate is not effectively made use of, which arguably is a direct consequence of the constraints resulting from the exchange rate peg.

The remainder of this paper is organised as follows: Section 2 will provide a brief overview of Chinese monetary and exchange rate policy. Section 3 will introduce our econometric methodology and Section 4 introduces the data that we will use. Subsequently, Section 5 presents our econometrics results, with Section 5.1 examining the PBC's monetary policy independence by investigating the relationship between the US and Chinese money market rates and in Section 5.2 a monetary model is estimated for China that examines the relationship between macroeconomic variables and the various policy instruments and the effectiveness of the latter. Section 6 concludes.

2 Brief Overview of China's Monetary and Exchange Rate Policy

The PBC's objective of monetary policy is "to maintain the stability of the value of the currency and thereby promote economic growth".¹ According to the PBC, "[t]he monetary policy instruments applied by the PBC include reserve requirement ratio, central bank base interest rate, rediscounting, central bank lending, open market operation and other policy instruments specified by the State Council".²

In practice, as pointed out by Koivu (2009), the foundations of China's monetary policy have been a fixed exchange rate, strict controls on capital flows and a wide selection of administrative and quantitative policy tools. Figure 1 displays the exchange rate of the Chinese yuan against the US dollar. China fixed its exchange rate at 8.28 yuan to the dollar from 1994 to 21 July 2005, when it abandoned the tight dollar peg and adopted an undisclosed basket exchange

¹<http://www.pbc.gov.cn/english/huobizhengce/objective.asp>

²<http://www.pbc.gov.cn/english/huobizhengce/instruments.asp>

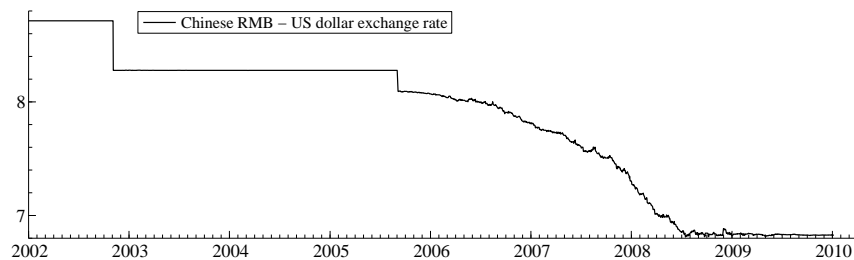


Figure 1: Plot of the exchange rate between the Chinese Renminbi and the US dollar between 2002 and 2010.

rate regime under which it allowed a small and tightly controlled appreciation of the yuan against the dollar. Between July 2005 and July 2008, the yuan appreciated by 21 percent against the dollar. In July 2008, in the face of the global financial crisis, China returned to the tight peg against the dollar, now at 6.8 yuan to the dollar.

Throughout this time, China has administered tight capital controls. According to the Chinn-Ito (2008) index for financial openness, which measures a country's international financial openness on a scale from -2.54 to 2.54 (with -2.54 indicating a completely closed capital account and 2.54 full liberalisation), China's degree of capital account openness has remained unchanged at -1.13 since 1993.³

As noted above, the PBC uses various instruments to achieve its monetary objective. However, as will be shown later in our empirical analysis, not all instruments have been effectively made use of. In particular, several studies observe the absence of a major role for interest rates in the Chinese economy, as compared to advanced economies (Laurens and Maino, 2007; Mehrotra, 2007; Prasad, 2008; Geiger, 2008; Koivu et al., 2008; Koivu, 2009, e.g). Although the PBC sets several interest rates (central bank lending rate, rediscount rate and benchmark rates for different maturities of deposits and loans), in practice, the role of interest rates has been limited in pursuing the objective of monetary policy. Laurens and Maino (2007) maintain that there are several potential obstacles to the effectiveness of interest rates as an operating target for monetary policy conduct in China. First, they point out that some of the characteristics of China's financial sector may limit the effectiveness of the interest rate transmission channel for monetary policy. In particular, the effectiveness of the transmission channel is hampered due to insufficient progress in establishing a commercially driven financial sector as well as market segmentation of the banking sector and money markets.⁴ Moreover, Laurens and Maino argue that

³The index, which was last updated in February 2009, is available on Menzie Chinn's homepage: <http://www.ssc.wisc.edu/mchinn/research.html>.

⁴China has a two-tier commercial banking system which features commercial banks that

the PBC does not yet have in place the monetary framework and instruments to conduct fully-fledged market-based monetary policy.

However, as pointed out by Yi (2008), the PBC's approach to financial macro-management has gradually changed since the 1990s and the PBC has been trying to advance the reform of the interest rate system and strengthen the role of interest rates. For instance, the band of deposit and lending rates has been widened and the lending rate ceiling and deposit rate floor have been abolished. Yi maintains that with this improvement of the central bank interest rate system, the PBC is now better able to guide the market interest rate and that market participants have become more sensitive to interest rate changes. In any case, while the PBC has been generally reluctant to use the interest as a policy tool, it did increase the use of the interest rate instrument when trying to contain accelerating inflation in 2006–2007 (Koivu 2009), and slumping output in the face of the global financial crisis.

While the PBC has been making efforts to shift from direct to indirect control — for example through the abolition of credit ceilings on 1 January 1998 — the transmission mechanism continues to rely on measures affecting the quantity of loans and money supply, instead of prices such as interest rates (Nagai and Wang, 2007). The PBC sets annual intermediate and operational targets for money supply growth (M1 and M2) and base money and in recent years it has also announced a target for credit growth. The money supply is then controlled by setting the reserve requirement ratio and deciding on central bank lending.⁵

Koivu (2009) points out that since summer 2003, expanding capital inflows have increased liquidity in China's financial markets and have made the conduct of domestic monetary policy more complicated. A particular challenge was the growth of reserve money, a consequence of frequent intervention in the foreign exchange market in order to maintain the dollar peg. The PBC responded by raising bank reserve requirements and imposing lending restrictions in an attempt to decouple reserve money growth from broad money growth (Glick and Hutchison 2009). The PBC has also tried to control market liquidity via open market operations (OMO) by selling central bank bills to commercial banks.⁶

are subject to prudential ratios and international standards of portfolio risks as well as policy lending banks which are not subject to similar regulations. The segmentation of the money market is another obstacle to greater reliance on interest rates as policy tools. China's money market consists of three main sub-markets: the interbank market, the interbank bond market and the bond repo market. The segmentation between these markets implies that monetary policy actions of the PBC in the interbank market cannot migrate to the other components of China's money market.

⁵Koivu et al. (2008) use a McCallum rule based on money supply for modelling the implementation of Chinese monetary policy and come to the conclusion that such a rule is reasonably capable of modelling the PBC's focus on monetary aggregates as intermediate policy targets. Although Geiger (2008) maintains that the PBC has often missed its exact targets for monetary growth, Koivu et al. point out that monetary developments have closely followed the major trends in central bank targets and that the ultimate targets of China's monetary policy — low inflation and rapid growth — have been simultaneously achieved since the mid-1990s.

⁶The origin of the OMO traces back to the interbank foreign exchange transactions which were started in 1996 (Nagai and Wang 2007). The OMO had for a long time been centred on government bonds and treasury bonds. However, it became difficult to rely on those securities

According to Yi (2008), the role of OMO has been strengthened in the daily adjustment of base money and they have become a major instrument.

Last but not least, the PBC continues to use administrative policy tools to guide financial market developments. Even after the abolishment of credit plans, which formed the basis of bank lending until the end of 1997, the PBC continues to issue lending guidelines for commercial banks. The so-called window guidance policy, which involves the issuance of direct guidelines and orders to commercial banks, was intensified due to rapid credit growth in 2003 and again in 2007 (Koivu et al. 2008).⁷ With this brief outline of Chinese monetary policy, we now move on to econometrically examine what is driving Chinese interest rates and the role of the various monetary policy instruments in actual Chinese monetary policy making.

3 Econometric Methodology

As is usually the case with empirical macroeconomic analysis, the uncomfortable bridge between static economic theories and a dynamic and persistent economic reality must be breached. The Taylor rule in its original formulation for policy is entirely static despite attempts to incorporate slugging interest rate adjustment and forward-looking expectations. Yet macroeconomic data series display high levels of persistence, and economic relationships exist through time via lag and lead variables. In particular, variables can frequently be described as non-stationary, be it due to structural breaks or extreme persistence expressed through a unit root. The cointegration framework provides a means by which to bridge this gap. Cointegration describes the situation where two or more unit-root non-stationary time series are in combination stationary. In other words, a steady state, or equilibrium, relationship exists between the non-stationary economic variables. Given the prevalence of non-stationary macroeconomic variables and equilibrium macroeconomic theories, the cointegration framework is thus an ideal one to work within for understanding more about economic fluctuations.

We make use of the cointegrated vector-autoregressive (VAR) model of Johansen (1995) in order to investigate Chinese monetary policy and shed more light on it. By using a VAR model, we are able to model macroeconomic variables without *a priori* assuming exogeneity of many of the variables in our model. Given the complex nature of macroeconomies, again this is highly desirable, as we are able to avoid the possibility of endogeneity bias in our estimated model. Furthermore, we can consider the possibility of more than one cointegration, or steady state, relationship. Often there will be numerous equilibrium relationships possible within economic systems; a trivial example would be a de-

because the variety of government bonds was limited and the outstanding amount of treasury bills was small. In April 2003, the PBC began to issue central bank papers as a new tool for OMO.

⁷The window guidance policy is actually carried out by the PBC in conjunction with the China Banking Regulatory Commission (CBRC). See Geiger (2008).

mand relationship and a supply relationship when considering the market for a good.

We specify a $p \times 1$ data vector X_t , which contains p variables measured at time t . The VAR model with K lags is written as:

$$X_t = \Pi_0 + \sum_{k=1}^K \Pi_k X_{t-k} + \varepsilon_t, \quad \varepsilon_t \sim \mathbf{N}(\mathbf{0}, \Sigma) \quad (1)$$

where Π_k are $p \times p$ matrices of regression coefficients, and ε_t is a $p \times 1$ vector of residuals. The data vector is assumed to contain variables that are at most integrated of order one, so have unit roots. Some variables in X_t can be stationary although for this exposition we'll assume that all variables have unit roots hence $X_t \sim \mathbf{I}(1)$.⁸ The VAR model can be reformulated into a vector error-correction form:

$$\Delta X_t = \Pi_0 + \Pi X_{t-1} + \sum_{k=1}^{K-1} \Delta X_t + \varepsilon_t, \quad (2)$$

where Δ is the difference operator such that $\Delta X_t = X_t - X_{t-1}$, and $\Pi = \sum_{k=1}^K \Pi_k - 1$. Because we assume $X_t \sim \mathbf{I}(1)$ then $\Delta X_t \sim \mathbf{I}(0)$ and since the error term ε_t is also assumed stationary, then for (2) to balance we need Π to be of reduced rank. If we denote the reduced rank of Π by r , then there exist two $p \times r$ matrices α and β such that $\Pi = \alpha\beta'$ and so:

$$\Delta X_t = \Pi_0 + \alpha\beta' X_{t-1} + \sum_{k=1}^{K-1} \Delta X_t + \varepsilon_t. \quad (3)$$

In (3), $\beta' X_{t-1}$, which are $r \times 1$ are the r cointegrating vectors, or steady state relationship, implied by the reduced rank r of the economic system.

Our procedure in this paper is that recommended by Johansen (1995) and Juselius (2007), to start general by modelling the VAR model in (1) and ensuring that the model satisfies the independent Normality assumption placed on the error term. From Rahbek and Mosconi (1999) it is known that only autocorrelation and non-Normality in the residuals (so not heteroskedasticity) affect the trace test for cointegrating rank and subsequent coefficient estimates, and hence we focus only on these two tests. Following this we conduct the trace test for cointegration rank to determine r , before imposing the rank and analysing the resulting cointegrating vectors $\beta' X_{t-1}$ and the adjustments of each variable to the cointegrating vectors, described in the α matrix.

Juselius (2007) is also transparent and clear about the difficulties of empirical work. The assumptions we make on our error terms are often violated, which naturally raises the difficult question of what can really be learnt from empirical investigations. This difficulty is all the greater given the object of our empirical interest is China; the potential difficulties of the integrity and quality of data

⁸Simply they will be found to be cointegrating vectors.

collection, allied with the length of time series collected, makes the task yet more difficult. As mentioned, some model misspecifications do not result in problems for subsequent analysis, but others do. Many more subtle misspecifications are often ignored in empirical papers, such as structural uncertainty. Again, given the immense speed at which China is industrialising, the likelihood of structural breaks and instability in the data is multiplied on a grand scale. Our aim in this paper is thus not to present an empirical analysis that we try and push as the definitive insight on how Chinese monetary policy operates: This would be difficult in a more stable, Western-style economy, let alone China. Instead, we simply seek to shed some light on what may be taking place in China, and to some extent present a cautionary note on attempting to read too much into patterns that might be seemingly apparent from the data in that country.

4 Data

Given our description of the econometric techniques to be used in this paper, it will be useful to consider the nature of the data being modelled. All of our data was acquired using Datastream, and the original source of our data was either the PBC or the National Bureau of Statistics in China for our Chinese data, and the Federal Reserve Bank of St. Louis FRED database for the US series.

Figure 2 plots the Chinese monetary policy interest rate (the rediscount rate) alongside its 1-month interbank on the left panel, and on the right panel the US target interest rate (the Federal Funds target rate) alongside both the actual Federal Funds rate and the interbank interest rate.⁹ US market rates remain much closer to the target interest rate than is the case in China. This we suspect is related to the other tools that are used for monetary policy manipulation in China such as the required reserve ratio and open market operations to sterilise reserve accumulation.

For our initial investigation of Chinese monetary independence, we model the daily 1-month interbank interest rates. This follows our previous investigations of monetary policy independence in East Asia (Reade and Volz, 2009*b*), in the Eurozone countries pre-EMU (Reade and Volz, 2009*a*) and in Sweden (Reade and Volz, 2010). Cheung et al. (2007) also make use of interbank interest rates in their analysis of Chinese monetary policy in relation to US policy. The reasoning is that the interbank interest rate reflects money market equilibrium in an economy, the rate at which the demand for money and supply of money are equalised. If this equilibrium interest rate in an economy systematically moves in response to another economy's money market equilibrium (hence interest rate), then this is a clear indication of a lack of monetary independence on the part of that economy. Hence the interbank interest rate is more than appropriate for this purpose, even if it may be the case the interbank rate diverges somewhat from the policy rate, as is the case in China. Additional

⁹As interest rates hit zero in 2008, the Federal Reserve Target rate became a target zone between 0 and 0.25%. We take the target, for the sake of argument, in this period as 0.25%.

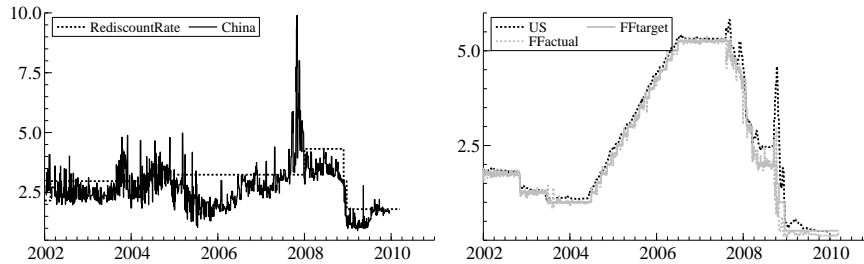


Figure 2: Plot of the monetary policy interest rates in China and the US alongside their respective interbank rates.

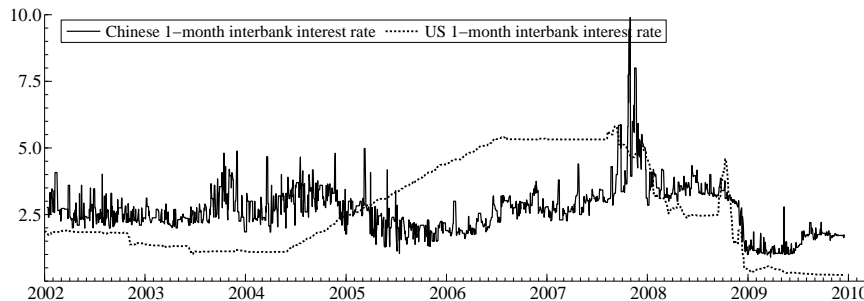


Figure 3: Plot of the Chinese and US 1-month interbank interest rates.

virtues for using the interbank interest rate are that it is available at a much higher frequency than the policy interest rate (daily), and reflects short-term movements in money market equilibrium, something which the policy rate does not do.

Figure 3 plots the 1-month interbank interest rates for China and the US at the daily frequency. These two series are used firstly to consider the possible monetary policy interactions between China and the US. Both series individually would appear to be non-stationary, as they display persistence around particular values, and do not appear to have any constant mean over the time period considered. Interest rates theoretically ought not to be non-stationary, but Juselius (2007) has emphasised the value of modelling data series appropriately given their statistical properties over a given sample. As such, we treat the series as non-stationary and seek to identify any co-movements between them. A brief glance at Figure 3 suggests minimal co-movement, with both series increasing in the latter part of the 2000s, before falling in 2008–09. Any such casual data analysis can only be a precursor to a more formal econometric investigation of co-movements, which follows in the next Section.

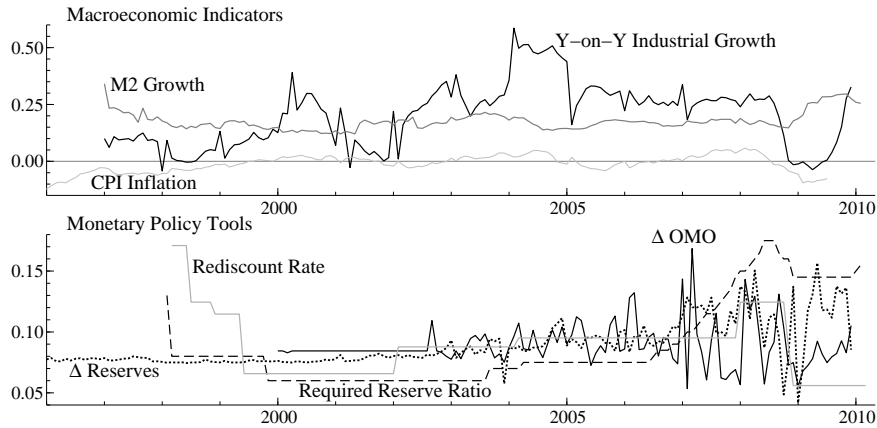


Figure 4: Plot of the data series included in the monetary policy model for China reported in Section 5.2.

The apparent loose co-movement of the interbank interest rate series, and the somewhat different nature of Chinese monetary policy as discussed earlier mean we choose to also model Chinese monetary policy internally in this paper, and Figure 4 plots the various series we use to do this. Due to the types of data series we wish to use, we must use data of a monthly frequency here. On the top panel the macroeconomic indicators we use are plotted: Inflation, output growth (proxied by industrial output growth) and money growth, while on the bottom panel what might be described as monetary policy tools are plotted: The rediscount interest rate, the required reserve ratio, the change in open market operations, and the change in the level of foreign reserves. As can be seen, some of the policy tools have periods with no variation. This makes these variables somewhat akin to dummy variables, which require particular attention when carrying out rank testing, but does not preclude them from our modelling exercise. We are seeking to understand the policy movements and hence policy rates such as the rediscount rate, and the required reserve ratio are more appropriate variables to include here.

5 Econometric Model

Our econometric results are presented in two parts; first we consider possible co-movements and dependencies between Chinese and US interest rates, before developing an econometric model for Chinese monetary policy.

5.1 Interest Rate Parity

We first investigate, using daily data, the possibility of a monetary policy relationship between China and the US. Given the fixed/managed exchange rate policy pursued by China throughout this period, then theoretically China's interest rate ought to have followed the US interest rate very closely in order to defend the fixed exchange rate. Interest parity conditions can be invoked to argue that a parity steady state relationship involving Chinese and US interest rates should exist, something like:

$$r_t = r_t^*, \quad (4)$$

where r_t is the Chinese interest rate and r_t^* the US interest rate, since the fixed exchange rate system ensures that the exchange rate term in either covered or uncovered interest rate parity should cancel. Hence we define our data vector X_t to contain r_t and r_t^* , which constitute the daily 1-month interbank interest rates for China and the US respectively. Our sample period begins January 25 2001, and ends on December 17 2009, yielding 2072 observations.

As the data is at the daily frequency, many lags appear necessary to mop up all residual autocorrelation and hence ensure the rank test provides the appropriate outcome. The more lags that are added, the less cointegration is detectable in the system. If just three lags are included, the largest eigenvalue (which is the correlation between the candidate cointegrating vectors ($\beta' X_{t-1}$) and the data differences and hence indicative of cointegration) is 0.0323, while when 12 lags are modelled that largest eigenvalue has fallen to 0.0086. The clarity of the rank one conclusion is lost with these extra lags as a result; with three lags rank zero is rejected at the 1% level of significance while with 12 lags, it is only rejected with a p-value of 0.079. The rank one conclusion is never rejected.

Despite this loss of strength of cointegration, the actual vector and adjustment patterns remain very similar. This appears to suggest a certain robustness of the results to the lag length, and hence we report here the coefficients for 12 lags. We are able to restrict the US adjustment coefficient in the α matrix to be zero for all lag lengths, while the Chinese adjustment coefficient is significant. That this restriction is acceptable is given by a test of likelihood ratio test over-identifying restrictions; with 12 lags this test statistic is 0.216, which has an associated p-value (probability of false rejection of null hypothesis of over-identifying restrictions) of 64%. The model is, where standard errors are reported in parentheses beneath the coefficient estimates:

$$\begin{pmatrix} \Delta r_t \\ \Delta r_t^* \end{pmatrix} = \begin{pmatrix} -0.047 \\ (0.01) \\ 0 \end{pmatrix} \begin{pmatrix} r_t - 0.207r_t^* - 2.098 \\ (0.108) & (0.345) \end{pmatrix} + \begin{pmatrix} \hat{\varepsilon}_{1,t} \\ \hat{\varepsilon}_{2,t} \end{pmatrix}. \quad (5)$$

In (5) we report on the right-hand side the $\hat{\alpha}$ and $\hat{\beta}X_{t-1}$ matrices, where the latter are the cointegrating relationships and the former the adjustments to those vectors. On the left-hand side is the X_t data matrix in first difference form, indicating that the right-hand side of the equation expresses the nature of the

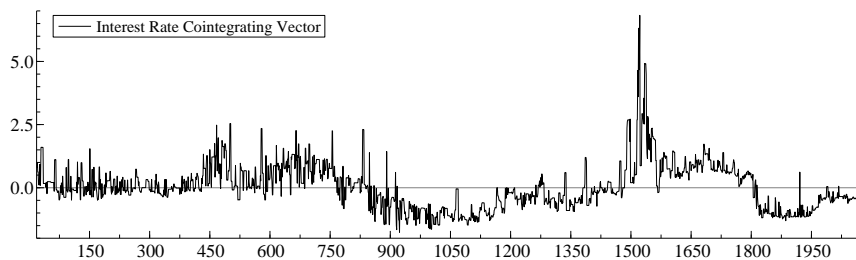


Figure 5: Plot of cointegrating vector from interest rate parity model in (5).

changes, or adjustments to the variables in our data vector each period. In the adjustment matrix $\hat{\alpha}$, the single column contains all the adjustment coefficients to the single cointegrating vector, which each row displays the adjustment for a particular variable in the data matrix X_t , as can be found by tracing across to the X_t matrix on the left-hand side. For example, the first row relates to adjustment to r_t , the domestic interest rate. In (5) we have a system with rank one, and hence a single steady-state relationship between the two interest rates. It is not a parity relationship however, as might be expected from economic theory. China adjusts to this relationship in a correcting manner, while the US does not. Although this is somewhat indicative of a lack of independence for China, this would be something of a strong conclusion. The cointegration is weak as indicated by the eigenvalues reported above, and the steady state relationship is not a parity relationship.

Figure 5 reports the cointegrating vector from this model. This plots the linear combination of variables indicated in (5), and hence is zero in equilibrium. So non-zero values suggest disequilibrium in this plot. While the vector is stationary in the sense that the mean is clearly zero throughout, there are nonetheless long periods of departure from zero, which should not be possible in a fixed exchange rate system in the absence of capital controls. Hence it would appear there is more to investigate when it comes to monetary policy in China.

5.2 Chinese Monetary Policy

As has been described earlier, Chinese monetary policy does not function as in a textbook market economy. The interest rate is not the stated policy tool of the central bank, and nor is there an announced inflation target. We have already established that Chinese monetary policy is able to assert some degree of independence from US monetary policy despite a fixed exchange rate system. In this Section we report a model of Chinese monetary policy considering the various unique factors pertaining to the Chinese monetary system. Required

reserve ratios are one tool the PBC uses in order to attempt to influence the money supply and hence keep inflation under control. The PBC also engages in open market operations (OMOs) to influence the money supply hence inflation and macroeconomic stability. China also operates capital controls in order to maintain a tighter control on financial flows in and out of the economy, hence providing another instrument of monetary policy that might enable the Chinese and US interest rates to diverge for such substantial periods of time as has been noted. Our sample runs from the late 1990s, and we have data on the required reserve ratio the PBC set for banks, the rediscount rate (the PBC's policy rate), the rate of growth of industrial output, CPI inflation and broad money growth (as measured by using M2).

Because of the uniqueness of Chinese monetary policymaking, a simple Taylor rule is highly likely to be an inappropriate characterisation of policy. Given the disparities between the interbank rate for China and the policy rate, as shown in Figure 2, we choose to model the policy rate of interest, which we denote r_t . We also include the required reserve ratio (RRR_t) and a measure of OMOs (OMO_t), notably bonds issues by the PBC. The macroeconomic indicators that policy might be expected to respond to are: Inflation (π_t), economic activity (via industrial output growth, $\Delta_g y_t$) growth in broad money (via the change M2, Δm_t) and growth in foreign currency reserves (via the change in reserves, Δres_t).¹⁰ Hence our data vector X_t is:

$$X_t = \begin{pmatrix} r_t \\ RRR_t \\ OMO_t \\ \pi_t \\ \Delta_g y_t \\ \Delta m_t \\ \Delta res_t \end{pmatrix}. \quad (6)$$

When running the model, we include two lags of all variables, and the model suffers from no autocorrelation problems. A number of the Normality tests fail, but the cause of the failure is fat tailed distributions, and a small number of outliers. It is known (Rahbek and Mosconi, 1999) that non-symmetric distributions affect the rank test (and subsequent coefficient estimates) adversely, but excess kurtosis, which is the problem we have, does not have any untoward effects, and as such we proceed.

However, as might be expected, modelling Chinese monetary policy is fear-somely difficult. In the model we report here, we attempt to draw on the constancies we have discovered during the modelling process, as well as the non-constancies.

A constant conclusion is that of rank three from rank testing. The trace test almost always concludes for a rank of three, and when considering the eigenvalues, there is usually three larger eigenvalues. This could be interpreted as

¹⁰The time series operator Δ_g denotes the percentage growth in a variable, hence $\Delta_g X_t = (X_t - X_{t-12})/X_{t-12}$ for our monthly data.

evidence in favour of a cointegrating relationship for each of the three policy tools considered; however given the nature of the variables another possible interpretation is a money demand and money supply function. We first consider this possible interpretation and then move on to attempt policy-tool identification. The identification strategy makes assumptions regarding what can and cannot enter the different cointegrating vectors. For a rank of r , $r-1$ restrictions must be imposed on each cointegrating vector to achieve identification, hence we must impose two restrictions on each vector in our system. Restrictions need not take the form of excluding variables, but these are the most common type of restriction and it is usually straightforward to motivate an identification strategy based on restricting variables to be zero. Considering the money demand vector, we assume that money demand is a function of output growth (people need money to buy/produce), inflation (people need more money if inflation higher) and the interest rate (people want less money if the opportunity cost of holding it is greater), and hence we restrict the required reserve ratio and open market operations from the vector (because we found rank 3 therefore we only need to impose 2 restrictions to identify each vector). Considering money supply, we assume it is a function of the interest rate (intermediaries wish to create more if the return is greater), the required reserve ratio (since this determines how much can be created by intermediaries given their assets), open market operations (since this directly injects or withdraws money from the system) and reserves (since they constitute money supply), and hence we restrict output growth and inflation from this vector. Finally, we seek to identify the third vector as the required reserve ratio policy tool (on the basis that in our estimations, this was the most constant policy rule found), and hence we restrict the other candidate tools from this vector, so we omit the rediscount rate and open market operations.

The resulting system, without any additional restrictions imposed, is:¹¹

$$\begin{pmatrix} \Delta RRR_t \\ \Delta r_t \\ \Delta^2 OMO_t \\ \Delta \Delta_g y_t \\ \Delta^2 m_t \\ \Delta \pi_t \\ \Delta^2 res_t \end{pmatrix} = \begin{pmatrix} 0.001 & 0.004 & -0.044 \\ (0.000) & (0.001) & (0.009) \\ -0.001 & 0.002 & -0.015 \\ (0.000) & (0.001) & (0.007) \\ -1.488 & 1.913 & -4.675 \\ (0.205) & (0.691) & (4.673) \\ -0.009 & 0.032 & -0.191 \\ (0.011) & (0.037) & (0.250) \\ -0.026 & -1.090 & 5.944 \\ (0.052) & (0.176) & (1.189) \\ -0.001 & -0.005 & 0.030 \\ (0.001) & (0.003) & (0.023) \\ 1.932 & -3.355 & 175.570 \\ (2.001) & (6.728) & (45.533) \end{pmatrix} \begin{pmatrix} \Delta m_t + 8.272RRR_t - 25.421r_t + 0.685OMO_t + 0.039\Delta res_t - 0.026 \\ (3.088) & (12.976) & (0.079) & (0.007) & (0.367) \\ \Delta m_t + 1.227r_t + 0.305\Delta_g y_t - 1.093\pi_t - 0.022\Delta res_t - 0.164 \\ (4.917) & (0.397) & (2.432) & (0.003) & (0.154) \\ RRR_t + 0.104\Delta_g y_t + 0.055\Delta m_t - 1.162\pi_t - 0.004\Delta res_t - 0.061 \\ (0.058) & (0.010) & (0.342) & (0.000) & (0.017) \end{pmatrix}. \quad (7)$$

As with (5), in equation (7) the estimated cointegrating vectors $\hat{\beta}X_{t-1}$ and adjustment matrix $\hat{\alpha}$ are reported, with on the left-hand side the resulting changes in the data vector X_t . Here $\hat{\alpha}$ has three columns, and each column corresponds

¹¹Where, again, standard errors are reported in parentheses beneath the coefficient estimates.

to a row of the $\widehat{\beta}X_{t-1}$ matrix; hence the second column of $\widehat{\alpha}$ contains the adjustments of each variable in the data vector X_t to the second cointegrating vector. Each row of $\widehat{\alpha}$ contains the adjustment of the corresponding variable in the data vector X_t (indicated on the left-hand side of the equation) to each of the cointegrating vectors, hence the second coefficient in the second row of $\widehat{\alpha}$ is the adjustment of the rediscount rate to the second cointegrating vector, the money demand relationship. Each equation in $\widehat{\beta}X_{t-1}$ is a cointegrating vector, or steady-state relationship.

The first vector is the money supply relationship, the second money demand and the third the required reserve ratio rule. Considering each in turn we write them out, rearranging the equations in terms of the variable we normalise on. So for money supply, that is the change in the money supply:

$$\Delta m_t = \underset{(3.088)}{-8.272} RRR_t + \underset{(12.976)}{25.421} r_t - \underset{(0.079)}{0.685} OMO_t + \underset{(0.007)}{0.026} \Delta res_t - \underset{(0.367)}{0.026}. \quad (8)$$

As can be seen, the coefficient signs appear appropriate for a money supply relationship; the increase in the money supply is decreasing in the required reserve ratio, increasing in the interest rate, decreasing in open market operations and increasing in the change in reserves. The small coefficient on reserves suggests there is a considerable sterilization effort on the part of the PBC. Adjustments to this cointegrating vector are found in the alpha matrix, and suggest that: the required reserve ratio weakly corrects (something that would be expected for a policy tool — the idea is the policy tool drives a relationship with money, as we'll come back to when discussing the RRR_t cointegrating vector), the rediscount rate significantly adjusts but in a destabilising manner, and open market operations strongly adjust in a corrective manner. Industrial output and inflation do not significantly adjust to this money supply relationship, and neither does the money supply. This last finding might point towards a more exogenous money supply.

Turning to money demand:

$$\Delta m_t = \underset{(4.917)}{-1.227} r_t - \underset{(0.397)}{0.305} \Delta_g y_t + \underset{(2.432)}{1.093} \pi_t + \underset{(0.003)}{0.022} \Delta res_t + \underset{(0.154)}{0.164}. \quad (9)$$

The money demand relationship is less well defined in the sense that although the interest rate and inflation coefficients are of the right sign, they are insignificant, while the output coefficient is of the wrong sign and insignificant. Nonetheless, the sign of the interest rate coefficient given the identification strategy yields confidence that a money demand relationship has been identified. The only significant coefficient in the relationship is the least sensible, arguably, for a money demand function: The change in the level of reserves. Considering the adjustments in the alpha matrix, the required reserve ratio does adjust significantly (adjusting upwards if demand for money is too high), and the rediscount rate also adjusts in a similarly corrective and significant manner. Open market operations also significantly increase when demand for money is too high, and hence we have that all the candidate tools for monetary policy do react to excess demand for money. In terms of the size of the reactions, it would

appear that open market operations and the required reserve ratio adjust most. Output growth doesn't adjust to the money demand vector, and inflation weakly adjusts in a destabilising manner. Money demand itself, as represented by the Δm_t variable, adjusts significantly and largely to disequilibrium, in a corrective manner. It seems that about all the disequilibrium each period is corrected by the movement in money demand, suggesting it is responsive to the measures of monetary policy used to address monetary disequilibrium. That inflation and output growth do not adjust is thus a little less important given that money demand itself falls back when it is too high, hence suggesting monetary policy is effective.

Finally we consider the policy rule for the reserve ratio requirement:

$$RRR_t = \underset{(0.058)}{-0.104}\Delta_g y_t - \underset{(0.010)}{0.055}\Delta m_t + \underset{(0.342)}{1.162}\pi_t + \underset{(0.000)}{0.004}\Delta res_t + \underset{(0.017)}{0.061}. \quad (10)$$

In this rule, the first coefficient, the response to output growth, is borderline significant and of the wrong sign — perhaps suggesting monetary policy pays less attention to movements in aggregate demand and more attention to inflation. That suggestion is borne out by the inflation coefficient, which is large, significant and greater than unity, all suggesting that the required reserve ratio does respond to higher inflation. Higher reserve accumulation is also significant in this policy rule, suggesting that the proportion of an increase in reserves that isn't sterilized is targetted by the PBC using the reserve requirement instead. The negative coefficient on the change in the money supply reflects more that increases in the required ratio must lead to decreases in the money supply via the reduced ability of banks to create money. Considering the adjustments to this policy rule, the required reserve ratio adjusts strongly and in a corrective manner to this vector, as does the rediscount rate. Inflation adjusts only insignificantly to this rule however, perhaps casting some doubt on the direct effectiveness of this policy tool for monetary policy (not considering the effect on the money supply via the money demand equation). The build-up of foreign reserves, which does not adjust to excess demand or supply of money (the first two cointegrating vectors) does adjust to the required reserves policy rule cointegrating vector, which is a somewhat difficult to interpret finding. It may reflect the fact that the required level of reserve accumulation depends on the stance of monetary policy internally, since excessively expansionary monetary policy in a fixed exchange rate system will lead to downward pressure on the exchange rate, and vice versa.

Overall, this model of Chinese monetary policy provides an interesting insight on to monetary policy in China in the last decade. The breakdown into money supply and money demand provides a glimpse into the conduct of monetary policy, and its effectiveness; as would be expected, money demand is influenced in order to keep inflation in order.

Finally, we can consider plots of the cointegrating vectors themselves (in Figure 6) to get some idea of the nature of the relationships being modelled. The three cointegrating vectors are stationary around zero as expected, but all three display increased volatility around zero during the financial crisis since

2008. We can write our cointegrating vectors in the following stylised manner:

$$\Delta m_t - \Delta m_t^{s*} = 0, \quad (11)$$

$$\Delta m_t - \Delta m_t^{d*} = 0, \quad (12)$$

$$RRR_t - RRR_t^* = 0. \quad (13)$$

Thus, the money demand and supply cointegrating vectors are zero when the actual change in money is equal to the actual change in money demand or supply. If we observe positive values in these vectors, then money has increased more than is necessary to retain equilibrium in demand or supply. In other words, if in the first vector we observe negative values, then the change in money willingly supplied (Δm_t^{d*}) is greater than the actual change in money, in other words willing supply is too high: There is excess supply. Equivalently, if in the second vector we observe negative values then we have an excess supply of money. Considering the policy tool (the interpretation here will apply for all the other policy tool vectors in the next model), then positive values here imply that the actual required reserve ratio observed was higher than its optimal value given the level of output and inflation in the economy: In other words, monetary policy here was tight and was aimed at achieving a different level of output and inflation than those existing at the time. Equivalently, negative values mean that policy was loose: The observed required reserve ratio was too low given what it would optimally be when output and inflation are at the particular values taken at that point.

Hence considering the cointegrating vectors, it appears that in 2007 and the first half of 2008 there was an excess demand for money before a sharp contraction in this in mid-to-late-2008 as the global recession set in. From the third vector for monetary policy, policy appears to have been loose in this boom period before tightening in late 2008 before dramatically loosening in early 2009 in an attempt to respond to the global downturn and attendant drop-off in aggregate demand and money demand. The last observation for monetary policy appears to imply a tightening again of policy as the cointegrating vector has moved positive; this potentially reflects the concern recently expressed by the PBC and other Chinese commentators about rising inflation as the Chinese recovery from the global downturn is already well under way.

As mentioned above, in addition to identifying a money demand and money supply cointegrating vector, we also seek to identify three policy steady-state relationships, or cointegrating vectors. To do so, we restrict the other two policy instruments out of each cointegrating vector, and then consider the model that results. Having done this, we are able to impose zero restrictions on the variables that are statistically insignificant in each of the vectors, hence testing whether simpler forms of policy rules exist as stationary relationships. Restrictions are accepted (or not rejected) if the likelihood ratio test of the (over-identifying) restrictions is not rejected. The final model we arrive at,

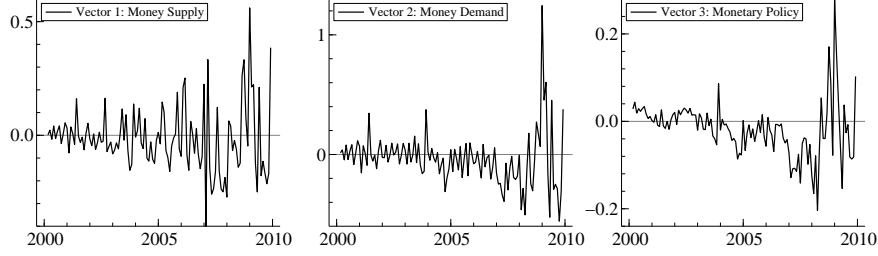


Figure 6: Plots of the three cointegrating vectors from the first monetary policy model reported.

after restricting insignificant variables, is given by:

$$\begin{pmatrix} \Delta RRR_t \\ \Delta r_t \\ \Delta^2 OMO_t \\ \Delta \Delta_g y_t \\ \Delta^2 m_t \\ \Delta \pi_t \\ \Delta^2 res_t \end{pmatrix} = \begin{pmatrix} -0.036 & 0.002 & 0 \\ (0.008) & (0.001) & \\ -0.020 & 0.012 & -0.0005 \\ (0.006) & (0.004) & (0.0001) \\ -14.71 & 22.354 & -0.979 \\ (4.381) & (2.854) & (0.122) \\ 0 & 0 & 0 \\ 5.976 & 0 & 0 \\ (0.906) & & \\ 0 & 0 & 0 \\ 143.3 & -21.835 & 0 \\ (41.45) & (2.935) & \end{pmatrix} \begin{pmatrix} RRR_t - 0.131\Delta m_t - 0.768\pi_t - 0.024 \\ (0.010) & (0.125) & (0.005) \\ r_t - 1.153\Delta m_t + 0.029\Delta res_t \\ (0.157) & (0.003) \\ OMO_t - 24.36\Delta m_t + 0.642\Delta res_t \\ (3.628) & (0.074) \end{pmatrix} \quad (14)$$

The three rows in the further right matrix are the cointegrating vectors. The first vector is for the reserve ratio requirement, the second for the rediscount rate, and the third for open market operations. It is perhaps easier to understand the cointegrating vectors if they are rearranged for the variable they are normalised on. It should be emphasised though that in doing this, no causality is being established. Cointegrating vectors merely reflect the co-movement in economic variables. It is only with the α coefficients that one can begin to investigate which variables lead the relationship, and which variables follow. Nonetheless, writing out the three cointegrating vectors:

$$RRR_t = 0.131\Delta m_t + 0.768\pi_t + 0.024, \quad (15)$$

(0.010) (0.125) (0.005)

$$r_t = 1.153\Delta m_t - 0.029\Delta res_t, \quad (16)$$

(0.157) (0.003)

$$OMO_t = 24.36\Delta m_t - 0.642\Delta res_t. \quad (17)$$

(3.628) (0.074)

Hence it can be seen that all of the policy tools respond positively to the change in the money supply; the required reserve ratio increases, the rediscount rate increases and open market operations (the number of bonds and repos issued)

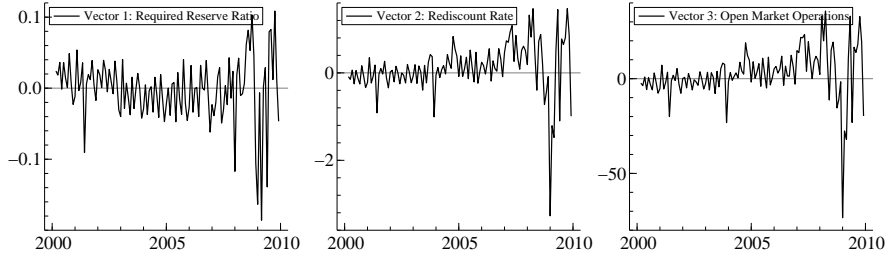


Figure 7: Plots of the three cointegrating vectors from the second monetary policy model reported.

increase. Furthermore, the required reserve ratio does appear to play a useful role in conducting counter-inflationary policy, as it increases in the face of increased inflation: A one percentage point increase in inflation leads to a 0.77 percentage point move in the required reserve ratio. It is hard to think of a Taylor rule or principle for reserve requirements, but the coefficient in all the models we estimated for inflation in the reserve requirements vector was positive and near unity.

This reserve requirement vector is the most constant of the policy rules; the rest we found to be very unstable indeed. In particular, restricting the alpha adjustment coefficient on foreign reserves for the OMO vector led to the signs on Δm_t and Δres_t switching in both the OMO and the rediscount rate equations. The resulting signs of the coefficients seem to suggest somewhat illogical movements in the data series.

Finally, we can again consider plots of the cointegrating vectors (Figure 7), and recall the interpretation of these policy vectors from earlier: Positive values imply a tight policy stance, negative values a looser stance. A brief glance at the figures shows that all three policy tools appear to have been used to operate a distinctly loose policy stance in late 2008 through to the mid-point of 2009 as the Chinese authorities attempted to weather the storm of the global economic downturn. This is represented by a number of observations with large negative values in this period; both the magnitude and persistence of these negative values suggests a concerted policy loosening on the part of the Chinese monetary authorities. Despite this however, it seems clear that the first vector for the required reserve ratio is notably different from the second and third vectors, implying that the required reserve ratio was used to respond to different indicators or for different objectives over the sample period. It seems likely that open market operations respond to the need for sterilisation of foreign reserve flows, and hence respond more to international events affecting the Chinese exchange rate rather than domestic concerns, and perhaps this is reflected in the different profiles of the cointegrating vectors. That the

rediscount rate cointegrating vector most closely resembles the open market operations vector suggests that this policy tool was also more aligned towards correcting external, rather than internal, imbalances.

6 Conclusions

In this paper we address two questions. First, we want to know how much monetary policy independence the PBC enjoys. We understand monetary independence in a narrow sense as the PBC's ability to conduct its own interest rate policy without having to follow the Fed's lead. To this end, we use cointegration analysis to uncover whether the Chinese money market rates are driven by US rates. We find that there is indeed some dependence of Chinese interest rate movements on US rates, but that this relationship is not very strong, suggesting that China has been able to isolate its monetary policy to a certain extent from the US policy.

Second, we want to know how effective the PBC's interest rate policy and the other monetary policy tools it has used have been in managing monetary growth and containing inflation. For this purpose, we estimate a monetary model for China which includes the PBC's policy rate, the required reserve ratio, a measure of the PBC's open market operations as well as macroeconomic indicators that policy might be expected to respond to, namely inflation, economic activity, growth in broad money and growth in foreign currency reserves. Our estimates suggest that the interest rate tool has not been effectively made use of, presumably for fear that raising the interest rate would attract ever higher levels of capital inflows that could prove difficult to sterilise. Rather, monetary policy has relied upon open market operations for sterilising foreign exchange intervention and changes in the reserve requirement ratio to affect monetary growth.

We conclude that through the maintenance of capital controls and the reliance on monetary instruments other than the interest rate China has been able to exert relatively autonomous monetary policy. We nonetheless believe that the PBC's current monetary policy mix is suboptimal, since the interest rate is not effectively made use of, which arguably is a direct consequence of the constraints resulting from the exchange rate peg.

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