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China's implicit demand for foreign reserves: neutralization and the rise in reserves

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We estimate China's demand for foreign reserves from 1994:1 to 2007:4. Using a monetary model for China's reserve demand, we take into account the People's Bank of China's systematic neutralization policy to reduce inflation. While ultimately inconsistent, this policy has led to a growth in foreign exchange reserves that seems limitless: a neutralization coefficient of 0.57 leading to a "magnification effect" on the increase in reserves of 2.3. That is, a purchase of foreign reserves leads to a contraction of domestic credit of 57% of the foreign exchange purchase, which in turn magnifies the surplus under a stable exchange rate.

Keywords: foreign reserves; monetary approach; vector autoregression; neutralization coefficient; magnification effect

JEL codes: C22, E58, F31

I. Introduction

In the aftermath of the Asian Financial Crisis, China has accumulated large stockpiles of foreign reserves. In 2007, foreign reserves in China topped $1,528 billion, compared to that of $52 billion in 1994. However, as noted by Flood and Marion (2001), China's reserve hoardings cannot be compared through time unless they are scaled in some way, since the economy has also been developing rapidly during the same period. In Table 1, we choose GDP, broad money (M2), imports and foreign debt as the scale variables. The ratios are widely used as rules of thumbs for the central banks to manage their reserves. As is shown in the table, the reserves-to-GDP ratio rises notably from 8.9% in 1994 to 43.6% in 2007, while the reserves-to-M2 ratio increases from 9.5% in 1994 to 26.7% in 2007. Reserves scaled by foreign debt boosts radically from 55.6% to 409% during the same period. In 1994, China's foreign reserve holdings could cover 23 weeks of imports, while in 2007 it is equivalent to 86 weeks of imports. In short, the reserve holdings in China have been surging dramatically even when considered in relative terms.

There were many significant changes in China's foreign exchange system in the 1990s. In 1994, the People's Bank of China (PBC) replaced dual exchange rates with a single exchange rate, i.e. the so-called managed floating exchange based on market supply and demand. In fact, it was actually a pegged exchange rate. The PBC also set up a centralized, automatic price-matching, inter-bank foreign exchange market and implemented the system of foreign exchange settlement and sales, under which companies are required to sell the foreign exchange earned to the central bank. Until now, private Chinese citizens could only buy limited amounts of foreign exchange for travel or education abroad, with the permission

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Table 1. Relative ratios of foreign reserves of China.

	Foreign Reserves (million USD)	F/GDP	F/M2	F/Foreign debt	F (Weeks of imports)
1994	51,620	8.9%	9.5%	55.6%	23
1995	73,579	9.7%	10.1%	69.0%	30
1996	105,029	11.8%	11.5%	90.3%	41
1997	139,890	14.2%	12.7%	106.8%	53
1998	144,959	13.9%	11.5%	99.3%	56
1999	154,675	14.1%	10.7%	101.9%	50
2000	165,574	13.9%	10.2%	113.6%	40
2001	212,165	16.1%	11.1%	114.8%	47
2002	286,407	19.7%	12.8%	153.7%	52
2003	403,251	24.5%	15.1%	193.2%	53
2004	609,932	31.5%	19.9%	246.4%	59
2005	818,872	36.0%	22.5%	291.4%	67
2006	1,066,340	40.6%	24.6%	330.1%	73
2007	1,528,250	43.6%	26.7%	409.0%	86

Source: *International Financial Statistics.*

of the authorities – The State Administered Foreign Exchange (SAFE) system. Since then, China's balance on both the current account and the capital account has been positive, with the exception of a negative capital account in 1998. Under a pegged exchange rate, the PBC has to purchase foreign exchange when there is a surplus at the lower intervention point. At the same time, the purchase of foreign exchange injects base money, normally resulting in a multiplied increase in the money supply. To avoid inflation, the PBC uses many monetary policy tools such as repos, the required reserve rate, a benchmark interest rate, and open market operations, in order to neutralize the increase in money supply. However, the neutralization policy also boosts China's demand for foreign reserves by a multiplier – a magnification effect – determined by the neutralization coefficient of sterilization operations. While ultimately inconsistent, this leads to a continuous growth in foreign exchange reserves.

We use a monetary model for China's demand for foreign reserves that explicitly takes into account neutralization policy. Based on the above reasons, we use quarterly data from 1994 to 2007, the period of rising foreign exchange reserves. According to Chow (1985), when the sample observation is greater than 40, we could have serious time series results. The data are mainly from the International Monetary Fund's International Financial Statistics (IFS), the website of the PBC (http://www.gtaedu.com/teachproduct/database.aspx), the National Bureau of Statistics of China, and China Stock Market Accounting Research (CSMAR) database.

This paper is organized as follows. Section I is the introduction. Section II briefly states the essential elements of the monetary model, and derives the equation to be tested for China's demand for international reserves with neutralization from 1994:1 to 2007:4. Section III reports empirical results for the model. Section IV concludes.

II. A monetary model For China

Following Connolly and Silveira (1979), Obstfeld (1982), Siklos (2000) and Sarno and Taylor (2001), we establish a monetary model for China's demand for foreign reserves.

According to Keynes, there are three distinct motives of holding money balances – the transactions motive, the precautionary motive and portfolio speculative motive. The demand for money is thus a function of real income and the opportunity cost of holding money:

$$L = PY^{\phi_1}e^{-\phi_2 i} \tag{1}$$

where L is the nominal demand for money, P is price level, Y is real income and i is interest rate. The parameters ϕ_1 and ϕ_2 are respectively the income elasticity of demand for money and the semi-elasticity of demand for money with respect to the interest rate.

Second, we specify the money supply process. The money supply equals high-powered money times the money multiplier:

$$M = mH = m(F + D) \tag{2}$$

where M is the money supply, m the money multiplier, H high-powered money, F the stock of international reserves in RMB and D domestic credit respectively.

Third, we assume that purchasing power parity holds for China:

$$P = sP^* \tag{3}$$

where P is the Chinese price index, s the spot price of foreign exchange in terms of RMB, and P^* the world price level. Finally, we assume that money supply adjusts rapidly to the quantity demanded, so that monetary equilibrium holds:

$$M = L \tag{4}$$

Under this simple monetary model, international reserves become endogenous:

$$F = g(P, Y, i, m, D) \tag{5}$$

From the above equations we can see that the domestic credit and foreign exchange reserves are negatively related. A domestic credit contraction by the central bank leads to an inflow of foreign reserves with a stable exchange rate. On the other hand, an expansionary credit policy would be offset by the decrease of foreign reserves.

In general, the change in base money is indicated by:

$$\Delta H_t = \Delta F_t + \Delta D_t \tag{6}$$

When the PBC perfectly neutralizes a purchase in foreign reserves, $\Delta H = 0$, we have:

$$\Delta D = -\Delta F \tag{7}$$

Partial neutralization can be characterized by a sterilization coefficient, θ, representing the fraction of foreign exchange purchases that are neutralized. That is,

$$\Delta D = -\theta \Delta F \quad \text{where} \quad 0 \leq \theta \leq 1 \tag{8}$$

Combining other factors that would influence ΔF, we estimate Equation (9) in the following section:

$$\Delta F = a_0 + a_1 \Delta D_t + a_2 \Delta Y_t + a_3 \Delta P_t + a_4 \Delta DEF_t + a_5 \Delta i_t + \mu_t \quad (9)$$

where ΔF is the change of foreign reserves in billions of RMB. We use the data from IFS. They are converted to RMB at the annual average exchange rate. Following Xu (2003), ΔD is proxied by the changes of currency in circulation. ΔY_t is the change in real GDP. Because the data published by the National Bureau of Statistics of China are not seasonally adjusted, we adjust them using the multiplicative moving average method. We use the Consumer Price Index (CPI) data to measure the inflation rate ΔP_t. ΔDEF_t is the changes of Chinese government deficit, where DEF_t is the difference between fiscal revenue and fiscal expenditure in year t, which comes from the CSMAR database. $\Delta i_t = i_t - i_t^*$ is the difference between the Chinese and American interest rates, where the i_t is the one year lending rate in China, and i_t^* is the US Treasury bill rate percentage per annum from the IFS.

Theoretically, denote $\theta = -\frac{1}{m \times a_1}$, θ is the neutralization coefficient, $0 \le \theta \le 1$. $\theta = 1$ stands for perfect neutralization; $0 \le \theta \le 1$ stands for partial neutralization; when there is no neutralization operation, $\theta = 0$. From the above model we have:

$$\Delta F = \frac{\Delta L}{m} - \Delta D \quad (10)$$

Considering the neutralization policy, $\Delta D = -\theta \Delta F$, we have:

$$\Delta F = \frac{\Delta L}{m(1-\theta)} \quad (11)$$

Because of its foreign exchange management system, the policy of neutralization in China boosts foreign reserve accumulation by a "magnification or multiplier" effect equal to $1/(1 - \theta)$.

III. Empirical results

In literature, there are mainly three ways to estimate the neutralization coefficient: the reduced model, the two-stage least squares regression (2SLS) model, and the vector autoregression (VAR) model. Since there is an endogeneity problem in the OLS method, and a misspecification problem in the 2SLS model (Obstfeld 1982), here we choose the VAR model to estimate Equation (9). VAR modeling is a dynamic system using lagged variables in reduced form. In our estimation, the minimum information criteria will be used to identify the correct lag length of the VAR model. Misspecification tests will be applied including lag length. The individual *F-statistic* value and log likelihood (AIC and SIC) of the system will be considered when choosing the appropriate model. Since the individual coefficients in the VAR model are difficult to interpret, the impulse respond function (IRF) is used to test the theory's predictions. The IRF traces out the response of the dependent variable in the VAR system to the shock in the error terms. The IRF is constructed using the estimated coefficients, so it reports the confidence level.

As is shown in Appendix B, results from the augmented Dickey-Fuller (ADF) unit root tests show that all the variables are stationary at the 5% level. The lag length tests show the minimum information value to be three quarterly lags. The estimation results estimate the R^2 value for the reserve demand equation to be approximately 0.63. The IRF using VAR(3) is reported in Figure 1.

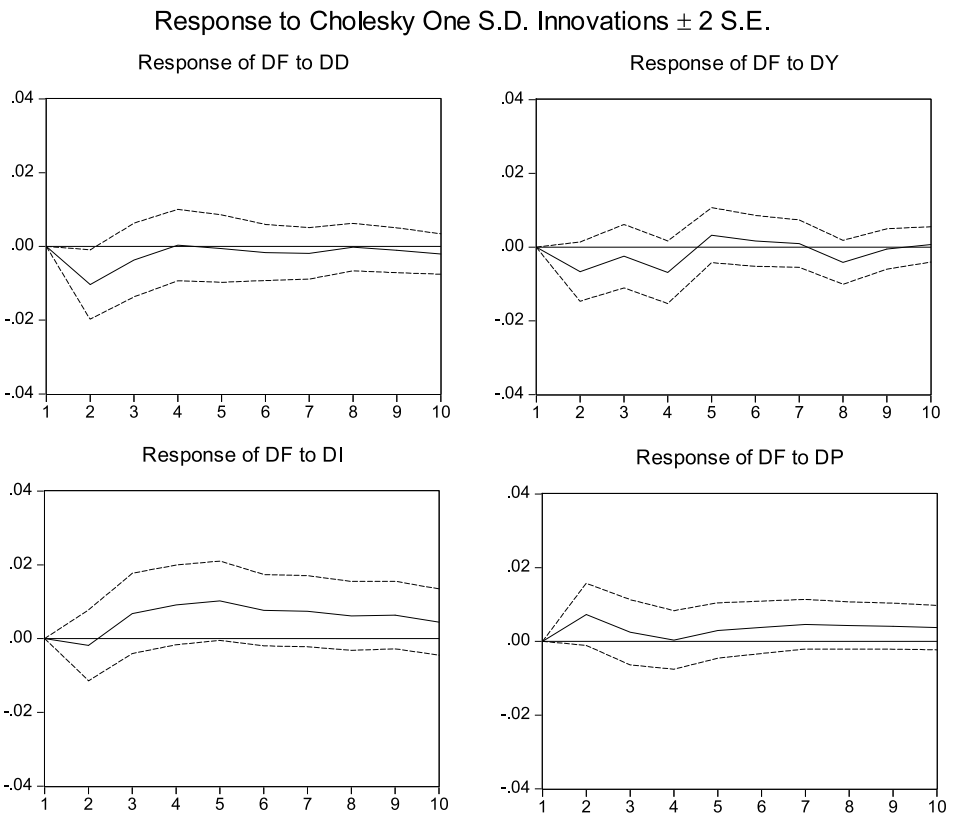

Figure 1. Impulse response function of China's foreign reserve changes to changes of domestic credit, real income, interest rate and price level.

According to the theoretic model, the IRF shows domestic credit has a negative relationship with foreign reserves with a coefficient of 0.73, as the theory of monetary approach expected. The significant negative effect lasts until the 10th quarterly lag. Since the average money multiplier for the sample period is approximately 2.43, according to our theoretical model, we have a neutralization coefficient of approximately 0.57. According to Ouyang *et al.* (2007), since December 2002 net domestic assets of PBC's balance sheet have remained low, if not negative. Open market operations and raising reserve requirements are often used by the PBC to control domestic credit and money supply. As the theory suggests, the neutralization policy contracts domestic credit and leads to a further increase in foreign reserve accumulation. The magnification effect, $1/(1- \theta)$, equals 2.23.

As shown in Figure 1, the empirical evidence on price level and interest rate is also consistent with the monetary model. The price level is positively related to foreign reserves, while foreign reserves respond negatively to the interest rate, at least initially. However, the results indicate that real income has a negative relationship to foreign reserves, which supports the prediction of the Keynesian school. It suggests that when income increases, spending will increase also, thus leading to reserve outflow. The response of the fiscal deficit is economically insignificant.

Another useful tool to analyze the results generated by the VAR model is variance decomposition. It gives the relative importance of each shock to the variables in the VAR. The variance decomposition for ΔF shows its variance can be explained by the innovations

of itself and other variables in the model, especially domestic credit and interest rate shocks. The variance decomposition for ΔD indicates that in the forecast period, the variance of domestic credit changes are mainly influenced by the innovations of itself and foreign reserve changes. These results are consistent with the monetary approach, which states that foreign reserves and domestic credit are negatively related in an open economy with a stable exchange rate.

IV. Conclusion

Because of China's unique foreign exchange system and its neutralization policy, contraction in domestic credit boosts foreign reserve accumulation by a "magnification or multiplier" effect equal to approximately 2.3 times the purchase of foreign exchange by the PBC due to a neutralization coefficient of 0.57. While ultimately inconsistent, the neutralization policy leads to growth in foreign exchange reserves that seems limitless.

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Appendix A: Data Sources

Data used in this paper are from the website of the National Bureau of Statistics of China; *the Statistical Year Book of China*; the website of State Administration of Foreign Exchange; *the Financial Year Book of China,* PBC, the *International Financial Statistics, IMF* and the China Stock Market Accounting Research (CSMAR) database.

Appendix B: Augmented Dickey-Fuller unit root tests

Table B1. Augmented Dickey-Fuller unit root tests (1994:1–2007:4).

Variable	Features	Test Statistics	P-Value
ΔF	(C,0,0)	–3.338887	0.0178
ΔD	(C,0,4)	–3.035300	0.0384
ΔY	(C,0,0)	–6.690985	0.0000
ΔP	(C,t,7)	–4.655358	0.0023
ΔDEF	(C,t,2)	–66.72543	0.0001
Δi	(C,0,1)	–3.366511	0.0167