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Exchange Rate and Asset Market: the Trilemma for China's Monetary Policy

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Abstract: This paper investigates the trilemma for China's Central Bank based on IS-LM-BP model and Vector Error Correction Models. According to a revised IS-LM-BP model, which incorporates the special monetary supply mechanism of Emerging Market Economies, depreciation restrains the growth of the monetary base in the trilemma. Then the central bank may not catch two goals of monetary independence and exchange rate stability together, even giving up the full capital mobility. The evidence during the 2014-2016 period shows that the severe capital outflow trapped China in a trilemma. In this situation, RMB depreciation negatively and heavily shocked asset price by influencing China's interest rate. Along with the contraction of global monetary cycle and the bubble-like asset price in China, that mechanism might amplify the risk of China's macro economy. According to the empirical analysis, *operation twist* (including asset purchase operations) could guarantee China's monetary policy autonomy and bolster the asset market in the trilemma.

Keywords: Asset price; Exchange rate; Interest rate; Monetary policy; Open-economy Trilemma
JEL Classification: E52, E43, F41, F31

1. Introduction

For emerging market economies (EMEs), the open-economy trilemma is always one of the biggest challenges. According to IMF (1997), when capital outflow was severe during the crisis of 1997, depreciation obviously forced the East Asian EMEs' domestic interest rate to go up. But this imposed more burdens on local economy. Nowadays a similar trilemma seems threatening China.

Since 2014, Renminbi (RMB) ended its 9 years of appreciation against US Dollar (USD), started the depreciation which lasted for 3 years. From 2014 to 2017, China's net capital outflow added up to $2.44 trillion[1]. RMB depreciated by over 14% against USD from Jan. 2014 to Dec. 2016. Then China has tried harder to attract capital inflow and reduce outflow. That temporarily helped stabilizing the exchange rate and capital outflow in 2017.

However, this situation restricts China from using expansionary monetary policy to offset the negative output shock. The even more dangerous thing is the rise of interest rate would shock

[1] The capital flow is calculated according to China Statistical Bureau data about total net export, and China central bank data about foreign exchange reserves.

China's bubble-like asset price, creating tremendous risk to macro economy. The drastic fall of stock market in 2015 is a breakout of this risk.

As the US Federal Reserve Bank (the Fed) is still contracting monetary policy and the US tax reform is also on the road, the incentives for capital outflow from China is still not to be neglected. The risk of trilemma still haunts over China's financial market.

2. Literature Review

The open-economy trilemma (or so called *the eternal trinity*) imposes a trade-off among exchange rates stability, monetary policy autonomy and capital mobility. The theory is rooted in the IS-LM-BP model (Mundell 1961; Fleming 1962).

According to a large body of literature (e.g. Obstfeld and Rogoff, 1995; Shambaugh, 2004; Obstfeld, *et al*., 2005), the opening of capital markets would magnify the weakness of dollar-peg regime and confine the room for monetary policy. The trilemma is usually seen as a main challenge to EMEs (Shambaugh, 2004).

Some scholars argue that China still has restrictions on capital account. This helps relaxing the trilemma. Cheung, *et al*. (2008) find the pass-through effect of the US interest rate to China was week from 1996 to 2006. Reade and Volz (2010) also believe China has relatively isolated its monetary policy from the US by keeping capital control to some extent. It is a kind of so-called *intermediate policy*. That means partially achieving the objects of capital mobility and monetary policy autonomy.

However, the articles above focus only on the interest rate tools. While considering the effect of capital flow on monetary base, we may get a different picture. Glick & Hutchison (2009) and Bordo, *et al*. (2012) find the accumulation of foreign exchange reserves augmented China's monetary base. And the effect of sterilisation was limited. Frankel (2010) find the sterilization of the PBOC wasn't successful after 2007. China's foreign exchange reserves climbed to $2.5 trillion by January 2010. Wolf (2008) even argues that "Ben Bernanke is running the monetary policy of the PBOC".

Kawai and Liu (2015) doubted the effectiveness of China's capital control. They find the errors and omissions in China's balance of payments rose to $10billion–$20billion. That shows the unaccounted capital flow has been huge. And moreover, according to Aizenman and Sengupta (2013), the sterilization doesn't stop China's credit boom. There would be considerable risk of producing non-performing loans.

As mentioned by Frankel (2010), capital flow had more remarkable influence on China's money supply after the *sub-prime crisis* of 2007. Especially after the initiation of the Fed's unconventional monetary operations, China's M2/GDP ratio soared from 1.48 in 2008 to 2.08 in 2016.

Former literatures reflect the inconsistency of different tools in China's monetary operations, especially at the earlier time. Firstly, the reform of interest rate policy progressed gradually in China. The PBOC uses tools of interest rate and money supply control together. And the money supply

control was the principal tool in the first decade of this century[2]. Secondly, the capital inflow is easier for the PBOC to cope with. She can issue debt to sterilize the inflow. But we should keep in mind that the PBOC currently lacks hedging tool for the capital outflow.

The sudden and severe capital outflow is most dangerous for EMEs in the trilemma framework. Calvo and Reinhart (2002) points out a sudden stop for the international capital inflow would push EMEs into insolvency, causing bankruptcies and destructing the local credit channel.

3. Theoretical Analysis

The open-economy trilemma is a fundamental contribution of the IS-LM-BP model. According to the general equilibrium analysis in this model, an open economy may simultaneously catch two, but not all the three policy goals: monetary independence, exchange rate stability, and full capital mobility. So any revision of the trilemma model should also be made in the IS-LM-BP frame.

3.1 Baseline model

We firstly construct an IS-LM-BP model (baseline model) for an EME as the following:

$$IS: y = \alpha - \beta i + \gamma x \tag{1}$$

$$LM: y = \sigma r + \varphi m \tag{2}$$

$$BP: r = \eta y + (r_w - \theta x - \lambda) \tag{3}$$

In the model, y denotes the total output; r denotes the domestic short term interest rate; i denotes the domestic long term interest rate; r_w denotes the global short term interest rate; m denotes the monetary base supply; x denotes the direct quote exchange rate. α, β, γ, σ, φ, η, θ, and λ, are all positive constants. The global short term interest rate is assumed as an exogenous constant.

As demonstrated by Friedman and Clarida (1983), the interest rate indicator in the IS curve here is long term interest rate (capital market interest rate), instead of the short term interest rate (money market interest rate).

In the baseline model, we assume the depreciation doesn't cause a severe capital outflow. So in the BP curve equation, the depreciation causes the increase of foreign exchange inflow from the current account. This setting will be revised for the model in a trilemma situation later. A fully opened capital account isn't a prerequisite of this model, so the BP curve isn't horizontal.

From (2) and (3) we know,

$$\sigma\eta r + \varphi\eta m = r - r_w + \theta x + \lambda$$

$$r = F_r(x, m) \tag{4}$$

From (1) and (3) we know,

$$\alpha\eta - \beta\eta i + \gamma\eta x = r - r_w + \theta x + \lambda$$

$$i = F_i(x, r) = F_i(x, m) \tag{5}$$

[2] Until June 2012, the PBOC didn't allow the credit interest rate of commercial bank being lower than the 0.8 times of the official benchmark rate.

From (4) and (5) we know, the function of *x, r, i* equals to a function of *m*.

$$e(x,r,i) = e(m) \tag{6}$$

After a depreciation, the IS curve moves to the right. The central banks in EMEs basically issue monetary base by purchasing foreign exchange. Since the depreciation causes the increase of foreign exchange inflow here, the central bank has the freedom of adjusting the monetary base. So the function of e(*x, r, i*) is not fixed. The central bank could have the LM curve move to the right. And the BP curve also moves to the right according to equation (3). The model could realize a new equilibrium with a lower interest rate and a higher output. It is a non-trilemma scenario.

3.2 Revised model

While the EME faces a negative output shock, the return for international investment declines. Then depreciation could cause a severe capital outflow, exceeding the foreign exchange gained from net export. So in the revised model, the BP equation is rewritten as the following:

$$BP: r = \eta y + (r_w + \theta x - \lambda) \tag{7}$$

The severe capital outflow restrains the growth of *m*. And when a negative output shock is approaching, contracting the monetary supply is not a choice on the table.

So *m* is almost fixed here. Then the function e(*x, r, i*) is almost fixed. This EME now faces a trilemma in a depreciation situation. After the IS curve moves to the right due to depreciation, the LM curve couldn't move. And the BP curve is forced to move to the left according to equation (7). The interest rates were forced to rise for stopping the capital outflow. As shown in figure 1, the new equilibrium is at point A'. The rise of the interest rates brings more hazards to asset market. It is just the trilemma for the East Asian EMEs in the crisis of 1997. And it might be what threatens China currently.

According to the revised model in trilemma, depreciation restrains the growth of the monetary base. Then the central bank has to raise interest rate to avoid capital outflow. In reality, EMEs do this not only for the macro equilibrium, but also for some other benefits[3]. That means an open EME may not catch two goals of monetary independence and exchange rate stability together in trilemma, even giving up the full capital mobility.

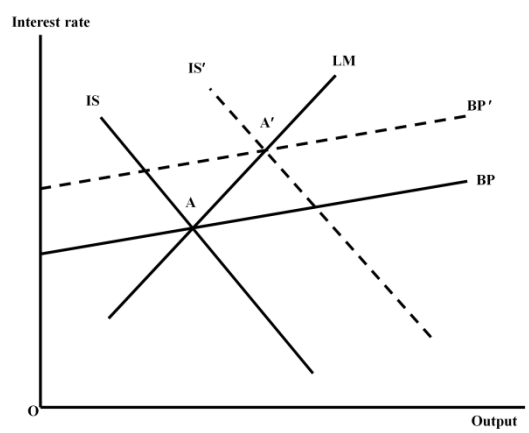

Figure 1. Revised IS-LM-BP Model

[3] The benefits include making up for domestic capital market shortage, gaining the experience about investment and management, exploiting overseas market (linked to foreign investors) and so on.

4. Empirical Analysis

In this part, the shock of exchange rate to China's asset market is empirically analyzed based on the theoretical model above.

4.1 Variables and data sample

According to equation (6), when *m* series is stationary[4], the series of exchange rate, short term interest rate and long term interest rate have a cointegrated relationship. We can construct the endogenous vector using these three variables together with asset price.

The contemporaneous monetary base is an exogenous controlling variable. According to the theoretical model, the change of monetary base is the key factor which defines whether China is in the trilemma situation. China's monetary base is controlled by the PBOC. Although other factors impose restrictions on the monetary base supply, the PBOC decide the supply finally.

Other exogenous controlling variables include the 1-period lagged output and 1-period lagged inflation rate. All the endogenous variables are affected by the behaviour of central bank and financial market investors. The previous output and inflation are the main reference indicators for the monetary policy according to central banks' common guideline. And they also influence the expectations and decisions of investors.

The exchange rate indicator is RMB exchange rate against USD (defined as *x*), which is published by Agriculture Bank of China. Shanghai A-stock composite index (as *s*) is Chinese representative asset price index, which is released by the Shanghai Securities Exchange. Theoretically the price of various assets is the discount value of future income, while taking long term interest rate as the discount rate. So the influencing mechanisms for stock and for other assets are similar. When there is no other representative asset price index in China, the stock index is our best choice.

The short term interest rate indicator is the 7-day repo rate (as *r*) released by China Foreign Exchange Trade System. It is also a main indicator of China's monetary policy rate. The YTM[5] of government bond is usually the indicator of long term interest rate. However China is very cautious about issuing government bond. The market for China Development Bank (CDB) bond is much bigger. And the issuing of CDB bond is regular. The CDB also shares the sovereign credit rating of Chinese government. So the one-year YTM of CDB bond (as *i*) is used as the indicator of long term interest rate. The YTM is released by China Central Depository & Clearing Company.

The output indicator is industrial PMI (as *g*) [6]. The inflation indicator is year on year CPI index (as *p*). They are taken as exogenous controlling variables together with the monetary base (as *m*). The variables of *g*, *p*, and *m* are released by China Statistical Bureau and the PBOC. All the series above are converted into natural logarithms.

The reform of China's exchange rate regime progressed gradually. Before May 2012, the daily fluctuation range of RMB exchange rate against USD is restricted in 1%. This hard peg regime

[4] That means *m* is steady without a tendency of growth.

[5] YTM here means the yield to maturity.

[6] GDP is the usual indicator of output. However it's released quarterly. The quarterly indicator is not enough to lead the monthly operation of the central bank. The industrial PMI is another main indicator for China's real economy. So it is used to control the effect of output.

constrained the influence of market factors on exchange rate. Also as mentioned above, before June 2012 market factors also had relatively weak effect on China's long term interest rate. So the sample period of empirical analysis is from May 2012 to October 2017. All the data was at the monthly frequency[7].

RMB mainly depreciated during January 2014 to December 2016. And the monetary base fluctuated around a fixed level during that period. According to the theoretical model in section 3, China might be trapped in trilemma during that period. So the depreciation period is set as a sub sample.

4.2 Unit root tests and methodology

Three kinds of unit root tests are employed including Augmented Dickey-Fuller test (ADF test), DF-GLS test (Elliott, *et al*., 1992) and KPSS test (Kwiatkowski, *et al*., 1992). We can judge whether a series has unit root based on these tests according to a majority rule. As listed in the appendix, all the endogenous variables and the *m* series are I(1) stationary. And other exogenous variables are I(0) stationary during the whole sample.

For the sub sample, most results are similar with the test results for the whole sample. However, *m* series is I(0) stationary. The result accords with the prediction of the theoretical model.

Since the endogenous series are I(1) stationary, the cointegration analysis techniques are appropriate here. There are interdependencies among the endogenous series theoretically. For example, the exchange rate may have simultaneous impact on interest rate and asset price, and the interest rate and asset price may have feedback effect on the subsequent exchange rate.

The single equation cointegration methods, such as the Autoregressive distributed lag model (ARDL), can't capture these interdependencies. That will cause model specification error. So we employ the Vector error correction models (VECM).

Another advantage is the VECM can depict multiple equilibriums among variables according to our theoretical model. The single equation cointegration analysis can only capture one cointegration relation. The IS-LM-BP model depicts the equilibriums among exchange rate, interest rate and other variables. So the VECM is suitable to capture these equilibriums and the correction mechanism for deviations.

Under different conditions of monetary base supply, there are two equilibrium systems consist of exchange rate, interest rates and asset price. So the empirical analysis is divided into two parts: section 4.3 is the analysis based on the baseline model using the whole sample data; and section 4.4 is the analysis based on the revised model using the depreciation period sub sample.

4.3 Analysis for the whole sample (Baseline model)

4.3.1 Cointegration test

During the whole sample period, the empirical analysis is based on the non-trilemma situation model (baseline model). So there shouldn't be a cointegration of x, r and i. However based on related financial theories, these variables might respectively have cointegrated relationships with asset price as the following:

[7] Series including exchange rate, interest rate and asset price have daily values. We take the last trading day value in every month as the value for the month.

$$\begin{cases} e(x,s) = e_1 \\ e(r,s) = e_2 \\ e(i,s) = e_3 \end{cases} \tag{8}$$

So we can assume there might be three cointegrated equations for the endogenous vector *Y*, where *Y*=[*x, r, i, s*]'. Because *m* is I(1) stationary during the whole sample, it should affect only the level of the endogenous vector, but not the difference of the vector. So it's set in the cointegrated equation[8] here. The VECM under the cointegration test is as the following.

$$\Delta Y_t = \phi\{\prod Y_{t-1} + \rho m_{t-1} + \upsilon\} + \Gamma_j \sum_{j=1}^{l} \Delta Y_{t-j} + \delta g_{t-1} + \pi p_{t-1} + u_t \tag{9}$$

where υ is the constant of cointegrated equation, and u_t is the residual vector of VECM. According to equation (9), the Johansen Trace Test (Johansen 1995) is conducted here. The result is listed in table 1.

Table 1. Johansen Trace Test for the whole sample

Null hypothesis	LR stats	p-value	90% critical	95% critical	99% critical
None***	75.63	0.0001	50.50	53.94	60.81
One at most***	43.61	0.0041	32.25	35.07	40.78
Two at most**	23.06	0.0182	17.98	20.16	24.69
Three at most	6.67	0.1493	7.60	9.14	12.53
Sample period	May 2012—October 2017				
lag order	2				

Note: a. Asterisks ***, **, and * indicate significance at the 1%, 5%, and 10% level, respectively.
b. The lag order is the optimal lag order (for levels) selected by AIC criterion.

Following the outcome, there are three cointegration relationships for the vector. This accords with the prediction of equation set (8).

4.3.2 IRFs for the whole sample

The estimates of VECM are shown in the appendix. According to the general criteria, this paper arranges the order of endogenous variables by their exogeneity. The structural VECM (SVEC) is estimated, basically using a Cholesky scheme to impose the recursive restrictions on the contemporaneous relationship.

RMB exchange rate is believed to have the strongest exogeneity. Interest rate influences exchange rate in the long run according to interest rate parity theory. The asset price might also affect exchange rate by influencing international investors' behaviour. However, the effects shouldn't be simultaneous due to the decision & action lag of market participants.

[8] We don't arbitrarily set how the controlling variables affect the endogenous variables. The only principle is: if a controlling variable is I(1) stationary, we set it in the cointegrated equation; if it is I(0) stationary, we set it in the vector error correction model. In this way, we can avoid the pseudo-regression problem.

Short term interest rate is an indicator of monetary policy. According to the "Act of the PBOC", China's monetary operation is mainly referred to the previous output and inflation, while considering the exchange rate. So the exogeneity of r should be the second strongest in the endogenous vector.

Long term interest rate is directly influenced by the short term interest rate. And it directly influences the asset price according to the asset valuation theory. Long term rate's exogeneity should be after the short term rate. The asset price may be influenced by all variables above synchronously. The financial market participants always pay close attentions to the changes of exchange rates and interest rates.

Following the order of endogenous variables, a recursive restriction scheme is used. The contemporaneous effects of the structural errors are initially expressed in a lower triangular matrix B. The structural shocks matrix ε_t is defined as $u_t = B\varepsilon_t$. We can estimate matrix B and eliminate the coefficients which are not significant at 10% level in the matrix[9].

Figure 2 presents the IRFs of the SVEC (including only main findings here). The impulses here are one-standard error shocks. The full lines are IRFs and the dotted lines are 90% confidence intervals for IRFs (based on 500 time bootstrap replications), following the bootstrap simulation method of Hall (1992).

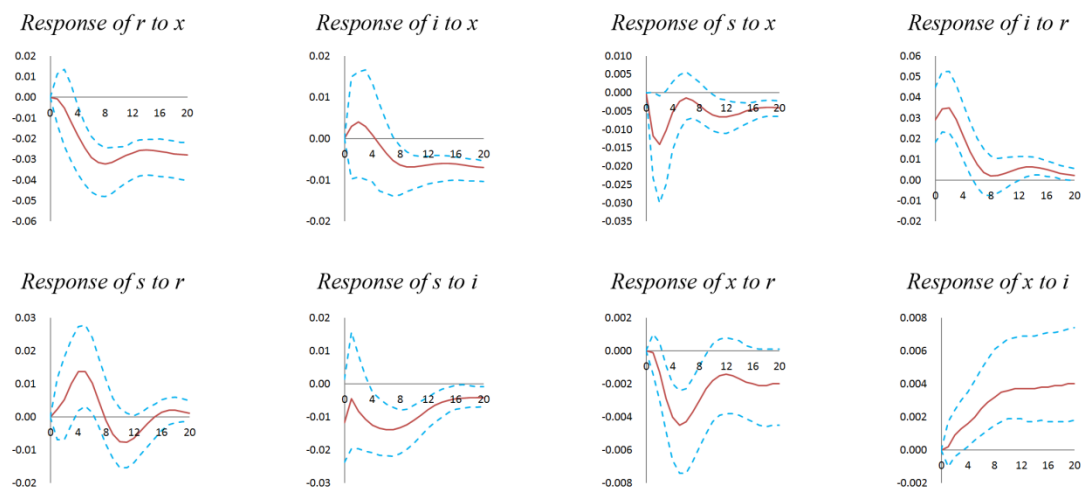

Figure 2. IRFs for the whole sample

Note: The full lines are IRFs. The dotted lines are 90% confidence intervals based on 500 time bootstrap replications. All the impulses are 1-standard error shocks.

The IRFs accord with the mechanism in the baseline model. The depreciation shock of RMB (rise of x) leads to a significant and persistent decline of short term interest rate. The depreciation shock also leads to a significant and persistent decline of long term interest rate after several months. That means in the baseline scenario, PBOC could expand its monetary supply to lower the interest rates.

[9] Keeping the insignificant coefficients doesn't affect IRFs obviously. However eliminating them can avoid irrelevant potential disturbances.

The positive short-term interest rate shock (rise of r) leads to a significant rise of asset price after several months. That is synchronous with its negative effect on the exchange rate (appreciation effect). The rise of short term rate helps to attract international investors, which has positive effects on asset price and domestic currency value.

The positive long-term interest rate shock (rise of i) leads to a significant and persistent decline of asset price. That accords with the asset valuation theory.

4.3.3 Variance decomposition for the whole sample

According to the SVEC, we can decompose the forecast error of asset price (see table 2). 75% of the forecast error is driven by the shock of the asset price itself even after 20 months. The effect of exchange rate seems not to be important.

Table 2. Decomposition of Stock Price Forecast Error (for the whole sample)

Horizon	Forecast error			
	x	***r***	***i***	***s***
5	4%	3%	4%	89%
10	4%	5%	11%	80%
15	5%	6%	13%	76%
20	6%	6%	13%	75%

4.4 Analysis for the sub sample (Revised model)

4.4.1 Cointegration test

During the continuous depreciation period of RMB, *m* is confined around a level. With the surplus of current account, that's mainly due to the capital outflow. According to equation (6), *x, r, i* have a cointegrated relationship. And these three variables have a cointegrated relationship with *s* together. So we can assume there might be two cointegrated equations for the endogenous vector *Y*, where *Y*=[*x, r, i, s*]'. The cointegrated equations are assumed as the following.

$$\begin{cases} e(x,r,i) = e_1 \\ e(i,r,s) = e_2 \end{cases} \tag{10}$$

Since *m* is I(0) stationary during depreciation period, it is set in the error correction model here. So the VECM model under cointegration test is as the following:

$$\Delta Y_t = \phi\{\prod Y_{t-1} + \upsilon\} + \Gamma_j \sum_{j=1}^{l} \Delta Y_{t-j} + \rho m_t + \delta g_{t-1} + \pi p_{t-1} + u_t \tag{11}$$

Table 3. Johansen Trace Test for the sub sample

Null hypothesis	LR stats	p-value	90% critical	95% critical	99% critical
None***	66.92	0.0019	50.50	53.94	60.81
One at most**	37.77	0.0241	32.25	35.07	40.78
Two at most	16.24	0.1660	17.98	20.16	24.69
Three at most	1.09	0.9241	7.60	9.14	12.53
Sample period	January 2014—December 2016				
lag order *k*	2				

Note: a. Asterisks ***, **, and * indicate significance at the 1%, 5%, and 10% level, respectively.
b. The lag order is the optimal lag order (for levels) selected by AIC criterion.

According to equation (11) above, the result of Johansen Trace Test is listed in table 3. The outcome shows there are two cointegration relationships for the vector. This accords with the assumption of equation set (10).

4.4.2 IRFs for the sub sample

The estimates of the depreciation period VECM are shown in the appendix. The same restriction scheme as in the section 4.3 is used. Figure 3 presents the IRFs of the depreciation period SVEC. The IRFs accord with the mechanism in the revised IS-LM-BP model (as in figure 1). While the PBOC couldn't expand monetary base supply, the economy was trapped in the trilemma.

Under the transmission mechanism here, the depreciation shock leads to significantly persistent rise of the short-term and long-term interest rates. And the positive long-term rate shock leads to a significant and persistent decline of asset price. The negative effect of the depreciation shock on asset price is more intensive compared to the whole sample SVEC.

The positive short-term rate shock has an appreciation effect which is not significant. That means in the trilemma situation, the attraction of rising interest rate declines relatively.

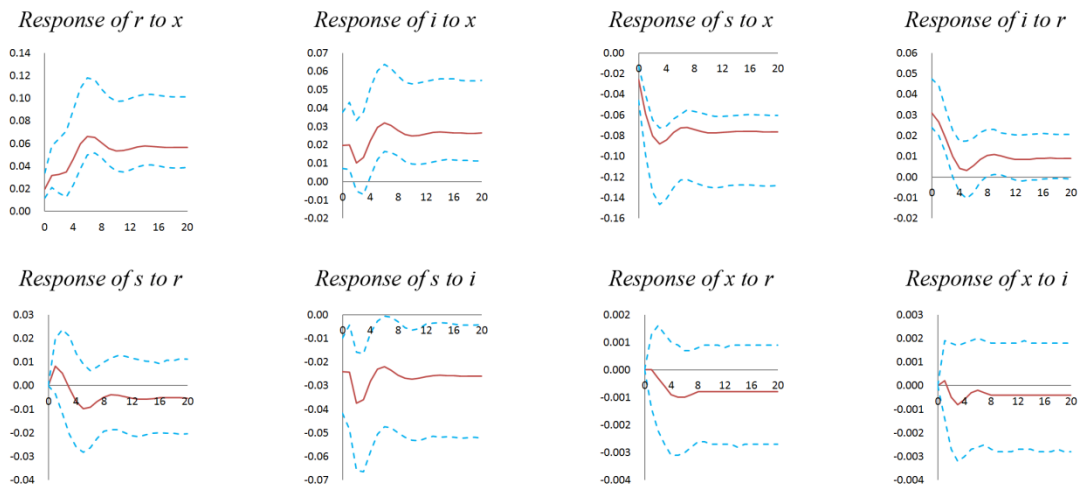

Figure 3. IRFs for the sub sample

Note: The full lines are IRFs. The dotted lines are 90% confidence intervals based on 500 time bootstrap replications. All the impulses are 1-standard error shocks.

4.4.3 Variance decomposition for the sub sample

The decomposition of the asset price forecast error is listed in table 4. In the trilemma situation, the influence of exchange rate on asset price fluctuation is much bigger compared to the whole sample SVEC. After 20 months, 65% of the asset price forecast error is driven by the depreciation shock.

In the trilemma situation, the shock of long term interest rate is a derivative effect of the exchange rate. The exchange rate and the long-term interest rate work together to drive totally 73% of the asset price forecast error after 20 months. So they have tremendous impact on asset market fluctuations.

Table 4. Decomposition of stock price forecast error (for the sub sample)

Horizon	Forecast error			
	x	***r***	***i***	***s***
5	57%	1%	10%	32%
10	62%	1%	9%	28%
15	64%	1%	8%	27%
20	65%	1%	8%	26%

5. Conclusions

Now we have two main findings: **Firstly, China was trapped in the trilemma during the continuous capital outflow and depreciation.** The evidences show depreciation of RMB significantly impacts asset price by influencing long term interest rate in the trilemma situation. This mechanism has considerable influence on the fluctuation of the asset market. This mechanism is theoretically applicable to the real estate market, which has a more dangerous bubble-like feature.

Qifan Huang, the vice chairman of China's "Finance and Economics Commission of the National People's Congress", recently acknowledged there are imbalances in Chinese real estate market [10]. Moreover, the pricing pattern of real estate is self-strengthening. The soaring price of real estate gives the investors and developers superfluous financing which stimulates the price to soar again.

China's current measures[11] to attract capital might not work continuously. Although the USA tolerates weak dollar to balance its trade account nowadays, the contraction of Fed's monetary policy continues. The USA tax reform and infrastructure construction plan are also on the road. All the reforms increase the USA's attraction for international capital. China's risk of being trapped in trilemma is still high.

For slowing down capital outflow, China is currently employing a strong RMB strategy. However the rising interest rate would press the capital market. The tightening market makes financing harder for enterprises whose profit is going down. Especially once the bubble in real estate market was pricked, the international capital would also rush out.

Secondly, the short term and long term interest rates have different influences on asset price. The empirical results show, long term interest rate has far more severe negative influence on asset price compared to the short term interest rate, no matter in the trilemma or non-trilemma situation. The rise of short term interest rate has much smaller negative effect on asset price in the trilemma situation, and even has significant positive effect on asset price in the non-trilemma situation. And raising short term interest rate is the main way for China to avoid capital outflow. That leaves a room for *operation twist* to relax the trilemma.

Operation twist is a combination of monetary policy tools which has short term and long term interest rates move in different directions.

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[10] See Qifan Huang's speech at Fudan University, 2017. (http://finance.ifeng.com/a/20170528/15416398_0.shtml).

[11] The current measures include issuing more dollar bond and encouraging residents to focus on domestic investment.

In the trilemma situation, the PBOC could raise short term interest rate by repo operations. This operation could absorb the short term liquidity glut and attract international capital. At the same time, she may conduct the asset purchase operations to press long term interest rate slightly, as what the Fed did after the sub-prime crisis.

By a proper *operation twist* conducted deliberately, the PBOC would support the asset market without enlarging the asset price bubble. That could guarantee China's monetary policy autonomy and capital market stability.

Asset purchase operations have more benefits for China. When the monetary base supply is confined, these operations provide extra monetary base in the form of long term capital. It would better relax the trilemma. In the non-trilemma situation, rising short term interest rate would have a stronger appreciation effect, according to the whole sample SVEC. It is the most desirable situation for China. Additionally asset purchase operations could act as a substitution mechanism of providing capital once international capital outflow accelerates.

Yuan Chen, the vice chairman of "the Chinese People's Political Consultative Conference", also proposed China should consider operations like the Fed's *Large Scale Asset Purchase*. He believes this could support strong RMB and optimizing China's financial resources allocation[12].

References

[1] Aizenman, J., and Sengupta, R. (2013). "Financial Trilemma in China and a Comparative Analysis with India", *Pacific Economic Review*, 18(2): 123-146.

[2] Bordo M D., Humpage O., Schwartz A J. (2012). "Epilogue: Foreign-exchange-market Operations in the Twenty-first Century", Working Paper, Federal Reserve Bank of Cleveland, No.1207, Cleveland, Ohio.

[3] Calvo, Guillermo A., and Carmen M. Reinhart. (2002). "Fear of Floating", *The Quarterly Journal of Economics*, 107(2): 379-408.

[4] Cheung Y. W., Tam D. C., Yiu M. S. (2008). "Does the Chinese Interest Rate Follow the US Interest Rate?" *International Journal of Finance & Economics*, 13(1): 53-67.

[5] Elliott G., Rothenberg T.J., and Stock J. (1992). "Efficient Tests for an Autoregressive Unit Root", *NBER Technical Working Papers* No.130, 1992.

[6] Fleming, J. Marcus. (1962). "Domestic Financial Policies Under Fixed and Under Floating Exchange Rates", *IMF Staff Papers*, 9(3): 369-380.

[7] Frankel, J. (2010). "China-US Currency", Issues Presentation in Ash Center, [Online] Available at: https://sites.hks.harvard.edu/fs/jfrankel/ChinaUS&Currencies.ppt (June 8, 2010)

[8] Friedman, B. M. and Clarida, R H. (1983). "Why Have Short-Term Interest Rates Been So High?" *Brookings Papers on Economic Activity*, 1983(2): 553-585.

[9] Glick, R. and Hutchison, M. (2009). "Navigating the Trilemma: Capital Flows and Monetary Policy in China", *Journal of Asian Economics*, 20(3): 205-224.

[12] See Chen, Yuan. (2017). *The Inspiration of Bernanke's Magic (written in Chinese)*. "China Finance 40" Forum Working Paper, November 2017 (https://wallstreetcn.com/articles/3041035).

[10] Hall, Peter. (2013). *The Bootstrap and Edgeworth Expansion*. New York: Springer Science & Business Media.

[11] *IMF* Research Department Staff (1997). "Capital Flow Sustainability and Speculative Currency Attacks", *Finance & Development,* December: 8-11.

[12] Johansen, S. (1995). *Likelihood-based Inference in Cointegrated Vector Autoregressive Models*. Oxford: Oxford University Press.

[13] Kawai, M. and Liu, L G. (2015). "Trilemma Challenges for the People's Republic of China", *Asian Development Review*, 32(1): 49-89.

[14] Mundell, Robert A. (1961). "A Theory of Optimum Currency Areas", *The American Economic Review*, 51(4): 657-665.

[15] Obstfeld, M. and Rogoff, K. (1995). "The Mirage of Fixed Exchange Rates", *The Journal of Economic Perspectives*, 9(4): 73-96.

[16] Obstfeld, M., Shambaugh, J. C. and Taylor, A. M. (2005). "The Trilemma in History: Tradeoffs among Exchange Rates, Monetary Policies, and Capital Mobility", *Review of Economics and Statistics*, 87(3): 423-438.

[17] Reade, J. and Volz, U. (2012). "Chinese Monetary Policy and the Dollar Peg", *The Evolving Role of China in the Global Economy*, 265-299.

[18] Shambaugh, Jay C. (2004). "The Effect of Fixed Exchange Rates on Monetary Policy", *The Quarterly Journal of Economics*, 119(1): 301-352.

[19] Wolf, Martin (2008). "How Imbalances Led to both Credit Crunch and Inflation", *Financial Times,* [Online] Available at: https://www.ft.com/content/c8c0cd8e-3c95-11dd-b958-0000779fd2ac (June 24, 2008).

Appendix

This appendix supplements information about the empirical analysis in section 4.

A1. Unit root tests

As listed in table A1, all the endogenous variables and the *m* series are I(1) stationary. And other exogenous variables are I(0) stationary during the whole sample. For the sub sample, most results are similar with the test results for the whole sample. However, *m* series is I(0) stationary. The result accords with the prediction of the theoretical model.

Table A1. Results of Unit Root Tests

Variables	Test Statistics for Whole Sample			Test Statistics for Sub Sample		
	ADF	DF-GLS	KPSS	ADF	DF-GLS	KPSS
x	-0.999	-0.942	0.764***	0.942	0.363	0.668**
Δx	-5.956***	-5.978***	0.191	-5.098***	-4.579***	0.309
r	-1.827	-1.403	0.405*	-2.529	-0.950	0.617**
Δr	-3.457**	-3.037***	0.087	-4.814***	-2.587**	0.240
i	-1.217	-1.259	0.239	-2.052	-1.011	0.633**
Δi	-7.868***	-7.312***	0.148	-5.677***	-4.814***	0.335
s	-1.145	-1.301	0.709**	-1.866	-1.545	0.415*
Δs	-6.355***	-5.221***	0.078	-4.244***	-4.294***	0.152

m	-2.015	-0.054	0.904***	-2.287	-1.831*	0.258
Δ*m*	-5.250***	-2.189**	0.190	—	—	—
g	-3.296**	-1.423	0.184	-1.707	-1.755*	0.250
p	-3.784***	-1.884*	0.340	-3.085**	-2.197**	0.173

Notes: a. Asterisks ***, ** and * indicate significance at the1%, 5% and 10% level, respectively.
b. The null hypothesis of ADF test is the series has a unit root. The null hypothesis of DF-GLS test is the series has a unit root. The null hypothesis of KPSS test is the series is stationary.
c. Δ indicates 1st difference series.
d. All the tests include intercept in test equations, don't include trend. The lag orders of tests are determined by the Schwartz Information Criterion.

A2. Analysis for the whole sample

Because *m* is I(1) stationary during the whole sample, it should be set in the cointegrated equation. The vector error correction model (VECM) for the whole sample is as the following:

$$\Delta Y_t = \phi\{\prod Y_{t-1} + \rho m_{t-1} + \upsilon\} + \Gamma_j \sum_{j=1}^{l} \Delta Y_{t-j} + \delta g_{t-1} + \pi p_{t-1} + u_t$$

where υ is the constant of cointegrated equation, and u_t is the residual vector of VECM. The estimates of VECM are shown in table A2:

Table A2. Estimates of VECM (for the whole sample)

	Δx_t	Δr_t	Δi_t	Δs_t
$e1_{t-1}$	-0.078***	-0.998***	0.049	0.046
	(0.025)	(0.216)	(0.220)	(0.201)
$e2_{t-1}$	-0.025***	-0.184***	0.079	0.066
	(0.007)	(0.063)	(0.064)	(0.058)
$e3_{t-1}$	0.014**	-0.150**	-0.216***	-0.066
	(0.007)	(0.060)	(0.061)	(0.056)
Δx_{t-1}	0.279**	0.894	0.369	-1.676*
	(0.116)	(1.008)	(1.028)	(0.940)
Δr_{t-1}	0.019	0.402***	0.178	-0.097
	(0.014)	(0.119)	(0.121)	(0.111)
Δi_{t-1}	-0.005	0.222*	-0.157	0.211*
	(0.015)	(0.128)	(0.131)	(0.119)
Δs_{t-1}	0.012	-0.014	-0.054	0.314***
	(0.014)	(0.121)	(0.124)	(0.113)
g_{t-1}	0.092	3.523***	3.006***	-1.607**
	(0.079)	(0.685)	(0.699)	(0.639)
p_{t-1}	0.001	-0.138***	-0.007	-0.054*
	(0.004)	(0.034)	(0.034)	(0.031)
Log Likelihood			498.195	
Determinant Residual Covariance			$2.04e^{-12}$	

Note: ***, ** and * mean significance at the 1%, 5%, and 10% level. Data in parentheses are standard errors.

The Estimates of Cointegrated Equations are as the following:

$$e1_{t-1} = x_{t-1} + \underset{(0.422)}{1.701}^{***} \times s_{t-1} - \underset{(1.115)}{4.545}^{***} \times m_{t-1} - \underset{(17.192)}{17.608}$$

$$e2_{t-1} = r_{t-1} - \underset{(1.758)}{6.572}^{***} \times s_{t-1} + \underset{(4.647)}{18.693}^{***} \times m_{t-1} + \underset{(71.685)}{96.276}$$

$$e3_{t-1} = i_{t-1} - \underset{(0.731)}{1.741}^{**} \times s_{t-1} + \underset{(1.933)}{7.001}^{***} \times m_{t-1} + \underset{(29.814)}{68.733}^{**}$$

Note: *** and ** mean significance at the1% and 5% level, respectively. Data in parentheses are standard errors of the estimated coefficients.

The structural shocks matrix ε_t is set as $u_t = B\varepsilon_t$. Matrix B is estimated as the following (eliminating the coefficients which are not significant at 10% level):

$$B = \begin{bmatrix} 0.007^{***} & 0.000 & 0.000 & 0.000 \\ 0.000 & 0.063^{***} & 0.000 & 0.000 \\ 0.000 & 0.029^{***} & 0.057^{***} & 0.000 \\ 0.000 & 0.000 & -0.018^{*} & 0.057^{***} \end{bmatrix}$$

Note: ***, and * mean significance at the 5% and 10% level, respectively. The test value of the over-identification test is 1.564, and the p-value of the Chi-square distribution with 4 degree of freedom is 0.815.

A3. Analysis for the sub sample

Because *m* is I(0) stationary during the sub sample, it should be set in the error correction model. The VECM for the sub sample is as the following:

$$\Delta Y_t = \phi\{\prod Y_{t-1} + \upsilon\} + \Gamma_j \sum_{j=1}^{l} \Delta Y_{t-j} + \rho m_t + \delta g_{t-1} + \pi p_{t-1} + u_t$$

During the continuous depreciation period of RMB, *m* is confined around a level. According to the theoretical model, *x, r, i* should have a cointegrated relationship. So we can assume there might be two cointegrated equations for the endogenous vector. The estimates of VECM are shown in table A3:

Table A3. Estimates of VECM (for the sub sample)

	Δx_t	Δr_t	Δi_t	Δs_t
$e1_{t-1}$	-0.050	-1.200**	-3.419***	-1.206
	(0.109)	(0.609)	(0.818)	(0.920)
$e2_{t-1}$	-0.009	-0.396***	-0.486***	-0.189
	(0.016)	(0.089)	(0.120)	(0.135)
Δx_{t-1}	0.346*	1.417	3.080**	-2.860*
	(0.204)	(1.135)	(1.526)	(1.716)
Δr_{t-1}	-0.009	0.232*	0.019	0.013
	(0.024)	(0.136)	(0.182)	(0.205)

Δi_{t-1}	0.020	0.365**	0.231	0.414*
	(0.028)	(0.156)	(0.209)	(0.235)
Δs_{t-1}	0.015	0.179	0.107	0.318*
	(0.022)	(0.125)	(0.169)	(0.190)
m_t	0.010	1.632***	0.855*	0.659
	(0.071)	(0.396)	(0.532)	(0.598)
g_{t-1}	0.072	0.262	2.014*	-0.127
	(0.148)	(0.828)	(1.113)	(1.252)
p_{t-1}	-0.005	-0.141***	0.023	-0.023
	(0.008)	(0.043)	(0.058)	(0.065)
Log Likelihood			274.067	
Determinant Residual Covariance			$1.17e^{-12}$	

Note: ***, ** and * mean significance at the1%, 5% and 10% level. Data in parentheses are standard errors.

The Estimates of Cointegrated Equations are as the following:

$$e1_{t-1} = x_{t-1} \underset{(0.063)}{-0.424***} \times r_{t-1} \underset{(0.065)}{+0.502***} \times i_{t-1} \underset{(2.925)}{-5.897**}$$

$$e2_{t-1} = s_{t-1} \underset{(0.403)}{+1.951***} \times r_{t-1} \underset{(0.413)}{-1.301***} \times i_{t-1} \underset{(18.577)}{+57.437***}$$

Note: *** and ** mean significance at the1% and 5% level. Data in parentheses are standard errors.

The structural shocks matrix ε_t is set as $u_t = B\varepsilon_t$. Matrix B is estimated as the following (also eliminating the insignificant coefficients):

$$B = \begin{bmatrix} 0.008^{***} & 0.000 & 0.000 & 0.000 \\ 0.020^{***} & 0.042^{***} & 0.000 & 0.000 \\ 0.020^{***} & 0.031^{***} & 0.050^{***} & 0.000 \\ -0.026^{***} & 0.000 & -0.024^{***} & 0.061^{***} \end{bmatrix}$$

Notes: *** indicates statistical significance at the 5% level. The value of the over-identification test is 0.376. The p-value of the Chi-square distribution with 1 degree of freedom is 0.540.