THE INFLUENCE OF INTERNATIONAL CAPITAL FLOW ON THE EFFECTIVENESS OF CHINESE MONETARY POLICY

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Abstract

The effectiveness of the monetary policy in open economies could be impaired during periods of large capital inflows. This paper innovatively examines the different impacts of international capital flows for both long-term and short-term on the effectiveness of monetary policy by using a TVP-VAR model from the time-varying perspective. In addition, we provide a modified offset coefficient model and measure the offset effects for both long-term and short-term international capital flows. The impact of short-term international capital flows on the effectiveness of monetary policy is positive and much more significant than that of long-term international capital flows. In the dynamic process, we find the offset coefficient of short-term international capital flows has a more violent fluctuation than that of the long-term international capital flows. Implications are explored from three aspects: establishing effective financial supervision, perfecting monetary policy transmission mechanism and developing new monetary sterilization tools.

Keywords: capital mobility; monetary policy; time-varying volatility; TVP-VAR model; the offset effect

JEL Classification: E50; F30

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1. Introduction

International capital flow is a concentrated expression of globalization. Since 1990s, China has been stockpiling international reserves at an extremely rapid pace. The rapid accumulation of reserves has generated several controversies. Currently, China’s exchange rate system is a managed floating system with reference mainly to the U.S. dollar. When foreign capital inflows, the central bank must intervene in the foreign exchange market to prevent exchange rate appreciation, which leads the international capital inflow into the central bank’s foreign exchange reserves. The reserve accumulations make the central bank create more basic money, which leads to the increase in the money supply and weakens the effectiveness of the monetary policy. Meanwhile, China has relaxed market access restrictions in accordance with the basic principles of the WTO, granted national treatment to foreign financial institutions and improved market transparency. These measures have reduced the barriers to international capital inflows, and led to higher foreign exchange reserves year by year. In the forth quarter of 2016 China Monetary Report, a moderate and neutral monetary policy was first proposed, which may be seen as the government’s determination of a relatively tight policy. However, the monetary policy and the international capital flows are not completely independent. To judge the effectiveness of China’s monetary policy, we should not only measure the response of monetary policy to international capital flows, but also calculate the response of the international capital flows to the monetary policy. Whether the impact of international capital flows on the effectiveness of monetary policy is time-varying? Are the impacts of international capital flows on the effectiveness of monetary policy consistent in different periods? How to measure this impact? Based on the above questions, this paper investigates the impacts of long-term and short-term international capital flows on the effectiveness of monetary policy in China.

2. Literature Review

In the Mundellian Trilemma of an open economy, China has chosen a fixed exchange rate to maintain a more stringent capital control and greater monetary policy independence; that is, sacrificing a small amount of monetary policy independence in exchange for limited capital flows. However, in this case, with the expansion of capital flows, China's monetary policy independence will be gradually lost.

The research about the impact of capital flows on the effectiveness of monetary policy starts relatively early. Mundell (1961) first studied the impact of international capital flows on monetary policy and argued that the exchange rate system played an important role. Argy and Kouri (1974) studied the quantitative relationship between liquidity and monetary policy for the first time. Krugman and Obstfeld (2008) pointed out that it is impossible to have all three of the following at the same time: a fixed foreign exchange rate, free capital movement (absence of capital controls), an independent monetary policy. This is the so-called “the impossible trinity”. Bacchetta et al. (2013) explored the relationship between capital flows and monetary policy, pointing out that under the influence of positive monetary policy, the increase in international capital flows limited the effect of monetary policy. By contrast, negative monetary policy reduces the ability of maintaining the counter-cyclical stability, making it more vulnerable to international factors. Jain-Chandra and Unsal (2014) used the dynamic factor model and the structural vector autoregressive model to study the effectiveness of monetary policy under international capital flows, suggesting that the monetary policy transmission mechanism is still valid in Asia. Chang et al. (2015)
investigated China's optimal monetary policy under capital flow control by using the DSGE model. Rey (2016) pointed out that the global financial cycle is a challenge for the validity of the Mundellian trilemma. U.S. monetary policy shocks are transmitted internationally and affect financial conditions even in inflation-targeting economies with large financial markets. Hence, flexible exchange rates are not enough to guarantee monetary autonomy in a world of large capital flows.

The research about the effect of the international capital flow on the monetary policy starts relatively late in China. Tian and Xu (2008) analyzed the offset effect of international capital flows on the monetary policy of the host country, suggesting that the offset effect is related to the form of international capital flows. The implementation process of international debt capital flows on domestic monetary policy is mainly controlled by the offset effect, while the implementation process of international equity capital flows on domestic monetary policy is mainly controlled by promoting effect. Zhang (2010) proposed that short-term capital flows based on profit-seeking factors may weaken the independence of monetary policy, increase its passivity, and even lead to the offset effect between monetary policy and other policies. Yuan and Fan (2012) applied the modified offset coefficient model using China's annual data from 1983 to 2010 to examine the offset effect of different forms of international capital on China's monetary policy. Song and Qiao (2014) used VAR model and impulsive effect function to analyze the influence of international short-term capital flow on the effectiveness of monetary policy, suggesting that there is a long-term stable equilibrium between money supply, interest rate and international short-term capital flows, while interest rate and money supply always change in opposite directions. Shi (2015) revealed the influence of foreign exchange occupation on monetary policy using a delayed P-order VAR model. The results showed that the adjustment of foreign exchange reserves will not affect the inflation.

Much work so far has investigated the impact of international capital flows on the effectiveness of monetary policy at the overall level or focused on the short-term capital flows. However, the generally applied VAR model has its own limitation, in which all parameters are time-invariant. We novelly examine the impact of international capital flows for both long-term and short-term on the effectiveness of monetary policy using a TVP-VAR model from the time-varying perspective. Next, we provide a modified offset coefficient model to measure the offsetting effect of the international capital flow to the effectiveness of China's monetary policy. This is helpful to minimize the risks of international capital flows volatility and has a certain theoretical and practical significance to a healthy economic environment.

### 3. Methodology and Data

#### 3.1 The VAR Model Setting

The basic form of the VAR model is:

\[
A_{t} y_{t} = F_{t} y_{t-1} + \ldots + F_{s} y_{t-s} + \mu_{t}, \quad t = s + 1, \ldots, n
\]

where: \( y_{t} \) is a \( k \times 1 \) dimensional observation vector, \( A, F_{1}, \ldots, F_{s} \) are \( k \times k \) coefficient matrices, and \( \mu_{t} \) is a \( k \times 1 \) structural shock. We specify the simultaneous relations of the structural shock by recursive identification, assuming that \( A \) is lower-triangular.
The equation can be abbreviated to the following VAR model:

\[ y_t = B_1 y_{t-1} + \ldots + B_s y_{t-s} + A \sum \varepsilon_t, \quad \varepsilon_t \sim N(0, \mathbf{I}_k) \]  

where: 

\[ B_i = A^{-1} F_i, \quad i = 1, \ldots, s \], and

\[ \sum = \begin{bmatrix} \sigma_1 & 0 & \ldots & 0 \\ 0 & \ddots & \ddots & \vdots \\ \vdots & \ddots & \ddots & 0 \\ 0 & \ldots & 0 & \sigma_k \end{bmatrix} \]

The \( \sigma_i (i = 1, \ldots, k) \) is the standard deviation of the structural shock. Stacking the elements in the rows of the \( B_i \)'s to form \( \beta(k^2 s \times 1 \text{ vector}) \), and defining \( X_t = I_k \otimes (y_{t-1}, \ldots, y_{t-k}) \), the model can be written as:

\[ y_t = X_t \beta_t + A^{-1} \sum \varepsilon_t \]  

All parameters in the VAR model are time-invariant. We construct the time-varying model in the next section.

### 3.2 The TVP-VAR Model Setting

The time-varying parameter structural vector auto-regression (TVP-VAR) model, with stochastic volatility, in both methodology and empirical applications, enables us to capture possible changes in underlying structure of the economy in a flexible and robust manner (Nakajima et al., 2011). It is a multivariate time series model in which the covariance matrix of coefficients and shocks are time-varying. Time-varying coefficients can capture the time-varying characteristics and possible nonlinear characteristics of the model hysteresis structure, while the multivariate stochastic volatility can capture the non-linear characteristics of the possible heteroscedasticity and the model variables. The advantage that both the coefficient and the covariance matrix are time-varying is that we get the time-varying characteristic of the linear structure during empirical analysis whenever there is change in the pulse or in the response. The TVP-VAR model is as follows:

\[ y_t = X_t \beta_t + A_i^{-1} \sum \varepsilon_t, \quad t = s + 1, \ldots, n \]
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where: the coefficient $\beta_t$, the parameter $A_t$ and $\sum_t$ are time-varying. Let $\alpha_i$ be a tacked vector of the lower-triangular elements in $A_t$ and $h_t = (h_{ij}, ..., h_{ik})$ with $h_{ij} = \log \sigma_{ij}$, for $j=1,...,k$, and $t=s+1,...,n$. In addition, we also assume that the parameters in Equation (4) subject to the following random walk:

$$
\begin{align*}
\beta_{t+1} &= \beta_t + \mu_{\beta_i} \\
\alpha_{t+1} &= \alpha_t + \mu_{\alpha_i} \\
h_{t+1} &= h_t + \mu_h
\end{align*}
$$

for $t = s + 1, ..., n$, where $\beta_{S+1} \sim N(\mu_{\beta_i}, \Sigma_{\beta})$, $\alpha_{S+1} \sim N(\mu_{\alpha_i}, \Sigma_{\alpha})$ and $h_{S+1} \sim N(\mu_h, \Sigma_h)$. The shocks to the innovations of the time-varying parameters are assumed uncorrelated among the parameters $\beta_i$, $\alpha_i$ and $h$. We then assume that $\Sigma_{\beta}$, $\Sigma_{\alpha}$ and $\Sigma_h$ are all diagonal matrices. The drifting coefficients and parameters are modeled to fully capture possible changes of the VAR structure over time. The log of variance $\sigma_t^2$ for the structural shocks follows random walk, which belongs to the class of stochastic volatility (Shephard, 2005). The log volatility ($h_t$) is often formulated to follow a stationary process, e.g. the first-order autoregressive process. The random walk process is non-stationary and it would be undesirable to analyze long series behavior of market products such as financial daily data. The random-walk assumption can capture possible gradual (or sudden) structural change in stochastic volatility (Primiceri, 2005).

3.3 The Offset Coefficient Model Framework

3.3.1 The Basic Offset Coefficient Model

The offsetting coefficient model was first proposed by Arg and Kouri (1974), and their "offset coefficient" model is as follows:

$$
\Delta NFA = \alpha_0 + \alpha_1 \Delta NDA + X \alpha_2 + \mu_i
$$

while $\Delta NFA$ is change in the net foreign asset, which equates in some studies with international capital flow. $\Delta NDA$ is the change in the net domestic asset, and reflects the change of the monetary policy. $X$ represents other explanatory variables that might influence a monetary authority’s reaction. The offset coefficient of $\alpha_i = -1$ represents free movement of international capital flow and its max offset effect to monetary policy, which suggests monetary policy is invalid. When $\alpha_i = 0$, it means the international capital is totally controlled by the central bank, and monetary policy is fully effective.

3.3.2 The BGT Model Setting

The disadvantages of above approach are the lack of explicit micro foundations for inclusion or exclusion of control variables. Therefore, Brissimis Gibson and Tsakalotos (2002) modified the original offset coefficient model, deriving the offset coefficients from the loss function of the authorities, while at the same time providing a means of identifying the
resulting semi-reduced-form equations. The change in net foreign assets (ΔNFA), change in
net domestic asset (ΔNDA) and other control variables are introduced into the loss function
of the central bank as constraint conditions, and according to the principle of “minimization
of the central bank loss function”. The derivatives of ΔNFA and ΔNDA are obtained for the
equations, and the offset coefficient model with strict theoretical framework is constructed,
which is also called “BGT model”:

\[ \Delta NFA_t = \alpha_0 + \alpha_1 \Delta NDA_t + \alpha_2 \Delta P_t + \alpha_3 \Delta m_t + \alpha_4 \Delta Y_t + \alpha_5 \Delta E_t \]  

(6)

ΔNFA\(_t\) is the change of net foreign assets, which represents the change of international
capital. ΔNDA\(_t\) is the change of net domestic assets. ΔP\(_t\) is the change of price, and Δm\(_t\)
is the change of M2 money multiplier. ΔY\(_t\) is the change of output; ΔEt is the change of
exchange rate. The model also shows the degree of influence of other variables which affect
the effectiveness of monetary policy under international capital flows: output, price,
exchange rate and money supply.

3.3.3 Modified Offset Model Construction

According to the international balance reaction function in both offset coefficient model
(Equation 7) and sterilization coefficient model (Equation 8), we divide the international
capital flow (ΔNFA\(_t\)) into current account balance (CA), long-term capital flow (C1) and short-
term capital flow (C2), (Equation 9).

\[ \Delta NFA_t = C1_t + C2_t + CA_t \]  

(9)

where: x\(_1\) and x\(_2\) are the control variables, and \(\alpha_1\) and \(\beta_1\) are the coefficient vectors of
the control variables. \(\alpha_1\) is the offset coefficient, indicating the extent to which net
domestic asset changes are offset by the international capital flows. In general, the
higher the degree of capital flows, the greater the offset effect of international capital
flows on monetary policy and the lower the effectiveness of central bank monetary
policy. \(\beta_1\) is the sterilization coefficient, which indicates the reaction of net domestic
assets to changes in net foreign assets, or the degree of monetary sterilization of the
central bank to the increase in foreign exchange reserves.

Equation (7) equals to Equation (9), which is

\[ C1_t + C2_t + CA_t = \alpha_0 + \alpha_1 \Delta NDA_t + x_1 \alpha_2 + \mu_t \]  

(10)

Therefore,

\[ C1_t = \alpha_0 + \alpha_1 \Delta NDA_t - C2_t + x_1 \alpha_2 - CA_t + \mu_t \]

\[ C2_t = \alpha_0 + \alpha_1 \Delta NDA_t - C1_t + x_1 \alpha_2 - CA_t + \mu_t \]

Subscript has no practical meaning, so Equation (7) and (8) can be rewritten as follows:

\[ C1_t = \alpha_3 + \alpha_4 \Delta NDA_t + \alpha_5 C2_t + x_1 \alpha_6 + \alpha_7 CA_t + \mu_t \]  

(10)

\[ C2_t = \alpha_3 + \alpha_4 \Delta NDA_t + \alpha_5 C1_t + x_1 \alpha_6 + \alpha_7 CA_t + \mu_t \]  

(11)
while \( \alpha_0 = \alpha_3, \alpha_1 = \alpha_4, \alpha_5 = -1, \alpha_2 = \alpha_6, \alpha_7 = -1. \)

The offset coefficient \( \alpha_4 \) reflects the offset effect of the international capital flow on the monetary policy. The closer \( \alpha_4 \) approaches to -1, the greater is the offset effect.

Based on the central bank objective function (Brissimis, 2002; Ouyang et al., 2010), the offset coefficient model (Equation 7), and sterilization coefficient model (Equation 8), the setup of the model captures all the commonly concerned factors that People’s Bank of China use in the monetary policy in China. The offset coefficient model for long-term capital flow (Equation 12) and short-term capital flow (Equation 13) are derived as follows:

\[
C_1 = \alpha_0 + \alpha_2 CA + \alpha_3 C2 + \sum_{i=0}^{n} \alpha_{4i} \Delta NDA_i^* + \sum_{i=0}^{n} \alpha_{5i} \Delta \text{gapt}_i + \sum_{i=0}^{n} \alpha_{6i} \Delta \text{mm}_i + \sum_{i=0}^{n} \alpha_{7i} \Delta \text{reer}_i + \epsilon_i
\]

\[
C_2 = \alpha_0 + \alpha_2 CA + \alpha_3 C2 + \sum_{i=0}^{n} \alpha_{4i} \Delta NDA_i^* + \sum_{i=0}^{n} \alpha_{5i} \Delta \text{gapt}_i + \sum_{i=0}^{n} \alpha_{6i} \Delta \text{mm}_i + \sum_{i=0}^{n} \alpha_{7i} \Delta \text{reer}_i + \epsilon_i
\]

For \( t-i \) settings in Equations 12 and Equation 13, we use a VAR model to estimate the lagged effects of NDA and NFA with reference to Ouyang et al. (2010), where: \( i = 0, 1, ... , n \).

C1 is the long-term capital flow, C2 is the short-term capital flow. Since only monthly data of current account balances is available, CA is replaced by import and export data, \( \Delta NDA \) is the annualized monthly change in the adjusted net domestic asset scaled by the GDP, \( \Delta \text{mm} \) is the annualized monthly change in money multiplier for M2. \( \Delta \text{gapt} \) indicates the real output gap. \( \Delta p \) denotes the annualized monthly change in inflation, as measured by CPI. \( \Delta \text{reer} \) is the cyclical fiscal deficit scaled by GDP. \( \Delta \text{in} \) is the annualized monthly change in foreign interest rates, as measured by the yield on America undefined three-month Treasury bonds. \( \Delta \text{reer} \) is the annualized monthly change in the real effective exchange rate. \( \Delta \text{eet} \) is a change in the nominal expected exchange rate, assuming the public has a perfect expectation of the exchange rate, and the expected exchange rate is the next real exchange rate.

A rising in the M2 money multiplier will increase broad money, lower the interest rates and reduce capital inflows. The increased inflation will promote devaluation of capital and cause capital flight. Higher real output can worsen the current account, cutting down the foreign reserve accumulation. The increased fiscal deficit may lead to broad money increase, which cause inflation. Once serious inflation occurs, investors will convert domestic assets into foreign assets to reduce losses. International capital flows can also occur if a country has a fiscal deficit that is compensated by selling bonds or borrowing from abroad. The increased expected exchange rate will reduce the current account and reduce the accumulation of foreign reserves.

### 3.4 Indices Selection and Variable Construction

In this study, we devise the international capital flows into long-term and short-term. The long-term international capital flows (C1) reflects the flow of capital with an undefined repayment period or repayment period of more than one year, which is measured by the foreign direct investment. The short-term international capital flows (C2) mainly reflects the status of capital flows with a fixed period of maturity or a repayment period of less than one
year. We use the World Bank's definition for reference, short-term international capital flows = increase in foreign exchange reserves - trade surplus - foreign direct investment.

As for the selection of relevant indicators of monetary policy, previous studies show that international capital flows mainly affect the money supply through foreign exchange, thus affecting the effectiveness of monetary policy. Money supply is the most important intermediate target of China's monetary policy. We believe that one of the ultimate goals of China's monetary policy nowadays is the currency stability, that is, the overall price stability. Therefore, this paper chooses the consumer price index (CPI) and the money multiplier for M2 to measure the effectiveness of monetary policy.

According to the balance sheet of People's Bank of China, MB = NFA + NDA, where MB is the monetary base. NDA is the net domestic assets of the central bank. NFA is the net foreign assets of the central bank. In order to exclude the asset revaluation and asset income effects, we need to adjust NFA and NDA. Assuming all foreign exchange assets are denominated in US dollars and are invested in US Treasury bonds, the adjustment in NFA and NDA are in Equation (14) and (15).

\[
\Delta NFA_{t}^* = NFA_{t} - NFA_{t-1} \left( \frac{e_{t-1}}{e_{t}} \right) - NFA_{t-1} \times r_{t-1} \tag{14}
\]

\[
\Delta NDA_{t}^* = \frac{\Delta MB_{t}}{GDP_{t}} - \Delta NFA_{t}^* \tag{15}
\]

where: e represents the US dollar against the RMB exchange rate (indirect quotation), and r is the yield of the one-year US treasury bill.

As monthly data are used, a monthly dummy variable (dM12) is added. For all Decembers, the value is 1, otherwise, the value is 0. In China, commercial banks increase the bank reserves in December to cope with the consumption boom and large-scale of cash extraction during the Chinese New Year. Therefore, a significant increase of the central bank's domestic net assets arise, but the foreign net assets are not affected.

During 2000 to the first half of 2014, China faced surplus in both current account and capital account. Large scale of international capital flowed into the Chinese market and foreign exchange reserves were on the rise. RMB was facing great pressure for appreciation and goals of the monetary policy were challenged. Therefore, we choose this period of time for our study. All data are collected from International Monetary Fund, People's Bank of China, the State Administration of Foreign Exchange and the China Statistical Yearbooks. Data of International capital flows, money multiplier for M2 etc. are monthly data, with time interval from January 2000 to December 2014. The monthly GDP data is obtained by splitting the quarterly GDP based on the ratio of the industrial added value of that month to the industrial added value of that quarter (unified for 100 million yuan).

### 3.5 The Descriptive Statistics and Econometrics Test

The descriptive statistics are shown in Table A1, A2 and A3 of the Appendix. The average long-term capital flows is 66.7196, the maximum is 144.1700, and the minimum is 18.3. The average short-term capital flows is 23.117, the maximum is 1275.58, the minimum is -1210.78, which indicates that the short term capital flow has greater variational amplitude. Using ratio or Logarithmic transformation as de-dimension makes the variables easy to compare and explain (Table A2 and Table A3).

We prepare the empirical data using seasonal adjustment, Hodrick-Prescott (HP) method and standardization. The seasonal adjustment is to remove the seasonal factors in the
quarterly data series. The HP method is to decompose the trend and the fluctuation. The standardized treatment is to eliminate the difference of the data dimension.

To check for stationarity, we applied the standard ADF unit root test to each of the variables and found all variables to be stationary at the 1% significant levels with the exception of the money multiplier for M2, which passed the test after a first differencing (Table A4).

Granger causality test is applied to the long-term capital flow (C1), the short-term capital flow (C2), CPI and D(M2). From Table A5, we can tell that at 5% significant level, C1 and C2 are Granger causes of D(M2) and CPI, but D(M2) and CPI fail in the Granger causality test for C1 and C2. At 10% significant level, C2 and CPI have two-way causality (Table A5).

4. The impact of International Capital Flow on the Effectiveness of China’s Monetary Policy

4.1 Analysis of the Impact of International Capital Flows from the Time-varying Perspective

In this paper, the VAR model is combined, and then the variation of parameters is introduced. The time-varying coefficients follow the first-order random walk process which allows both temporary and permanent shifts in the coefficients. The drifting coefficient can capture a possible nonlinearity, such as a gradual change or a structural break. We assume the time-varying coefficients stationary to avoid overfit issue. According to the AIC and SC criteria, the optimal delay order is selected. Therefore, the second order delay order is used in the establishment of the time-varying parameter vector autoregressive (TVP-VAR) model.

According to the covariance matrix in Equation 4, and the random walk process of parameter in Equation 4, combining with VAR model, the variation of parameters is introduced into TVP-VAR model, which is constructed with four variables, long-term capital flow, short-term capital flow, money supply and price level (Equation 16)

\[
\begin{pmatrix}
C_{1t} \\
C_{2t} \\
M_{2t}^{*} \\
CPI_t
\end{pmatrix} =
\begin{pmatrix}
a_{1t} & a_{2t} & a_{3t} & a_{4t}
\end{pmatrix}
\begin{pmatrix}
C_{1t-1} \\
C_{2t-1} \\
M_{2t-1}^{*} \\
CPI_{t-1}
\end{pmatrix} +
\begin{pmatrix}
b_{1t} & b_{2t} & b_{3t} & b_{4t}
\end{pmatrix}
\begin{pmatrix}
C_{1t-2} \\
C_{2t-2} \\
M_{2t-3}^{*} \\
CPI_{t-2}
\end{pmatrix} +
\begin{pmatrix}
\mu_{1t} \\
\mu_{2t} \\
\mu_{3t} \\
\mu_{4t}
\end{pmatrix}
\]

Among them, \((a_{1t}, a_{2t}, a_{3t}, a_{4t})\) and \((b_{1t}, b_{2t}, b_{3t}, b_{4t})\) are time-varying coefficients.

4.1.1 Parameter Setting and Stability Test

We take a Bayesian approach using the Markov Chain Monte Carlo (MCMC) algorithm for a precise and efficient estimation of the TVP regression model. The goal is to assess the joint posterior distribution of parameters of interest under a certain prior probability density that we set beforehand. Given data we repeatedly sample a Markov chain and the MCMC algorithm proceeds by sampling recursively the conditional posterior distribution where the most recent values of the conditioning parameters are used in the simulation. To compute the posterior estimates, we draw 10,000 samples after the initial 1,000 samples are discarded. Table 1 reports the estimation results for selected parameters of the TVP-VAR model for the variable set with the computed results of the estimates for posterior means, standard deviation, the 95 percent credible intervals, the convergence diagnostics (CD) and the inefficiency factors.
We can accept the assumption that the parameters converge to the posterior distribution if the CD statistics are at 95 confidence interval. It also shows that the MCMC can be presimulated with 1000 samples, and the level of inefficiency factor is low. These statistics show that the Markov Chain Monte Carlo (MCMC) algorithm can effectively obtain the posterior sampling.

Table 1

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Mean</th>
<th>Std. Dev.</th>
<th>95 confidence interval</th>
<th>CD</th>
<th>Inefficincy</th>
</tr>
</thead>
<tbody>
<tr>
<td>sb1</td>
<td>0.0230</td>
<td>0.0026</td>
<td>[0.0185,0.0286]</td>
<td>0.5400</td>
<td>9.20</td>
</tr>
<tr>
<td>sb2</td>
<td>0.0226</td>
<td>0.0026</td>
<td>[0.0183,0.0286]</td>
<td>0.2570</td>
<td>12.62</td>
</tr>
<tr>
<td>sa1</td>
<td>0.0593</td>
<td>0.0145</td>
<td>[0.0373,0.0939]</td>
<td>0.9680</td>
<td>39.60</td>
</tr>
<tr>
<td>sa2</td>
<td>0.0586</td>
<td>0.0150</td>
<td>[0.0363,0.0955]</td>
<td>0.1150</td>
<td>41.61</td>
</tr>
<tr>
<td>sh1</td>
<td>0.5192</td>
<td>0.1390</td>
<td>[0.2935,0.8182]</td>
<td>0.2300</td>
<td>68.53</td>
</tr>
<tr>
<td>sh2</td>
<td>0.4258</td>
<td>0.0638</td>
<td>[0.3182,0.5683]</td>
<td>0.4030</td>
<td>25.37</td>
</tr>
</tbody>
</table>

Figure 1 shows the sample autocorrelation (top line) and the sample path (bottom) for the selected parameters. By discarding the initial 1000 samples, we see that the autocorrelation falls stably, and the sample path appears stable, suggesting that the sampling method efficiently produces the samples with low autocorrelation.

4.1.2 Analysis of Time-varying Impulse Response

Compared with the basic VAR model, the TVP-VAR model not only solves the problem of simultaneous correlation between structural model variables and lag between variables, but
also is a multivariate time series model and can be used to analysis the impulse reponse in a time-varying aspect. We analyze the time-varying impulse response from two aspects: equidistant impulse response and time-point impulse response.

(1) The analysis of the equidistant impulse response function
The lagged effect of monetary policy refers to the period needed to achieve the impact of a specific policy on the basis of the implementation of a specific policy by the relevant institutions. It has a huge impact on the effectiveness of a monetary policy. The response of monetary policy to an equidistant impulse in C1 and C2 vary.

Figure 2 illustrates the equidistant impulse responses of money multiplier for M2 and CPI to international capital flow with time lags of three-month, six-month and twelve-month respectively. We find that money multiplier for M2 responses differently to the long-term capital flows (C1) and short-term capital flows (C2). The trend of money multiplier for M2 influenced by short-term capital flow (C2) is generally consistent with all three time lags. The impulse response is positive from 2000 to 2014 and peaks around 2007. The impulse response of the money multiplier for M2 to long-term capital flow (C1) volatility is positive for the most of the time, and bigger under the six-month and three-month lags, comparing with the twelve-month lag. In addition, we find that the impact of short-term capital flow (C2) on the money multiplier for M2 excels the long-term capital flow (C1) in the case of a six-month lag and twelve-month lag.

Before the U.S. subprime mortgage crisis and the international financial crisis, China's economy has experienced a rapid growth for many years. There is an expectation on the long-term appreciation of RMB, which leads to a price booming of RMB assets in the real estate and stock market. As a result, China experienced an influx of international capital, and a wave of strong international hot money. After the financial crisis, the central bank strengthened the control of capital projects and the monetary sterilization policy played a big role, the impact of international capital flows showed a downward trend. Similar findings on the impact of frequent international capital flow are supported by Agosin and Huaita (2012).

The impulse responses of price fluctuation (CPI) to the long-term capital flows (C1) and the short-term capital flows (C2) are different. In the time lag of three-month and six-month, the trends of the impulse response of CPI to the long-term capital flows (C1) and short-term capital flows (C2) are roughly the same, but in twelve-month lag, the response is slightly smaller. Compared with the long-term capital flow (C1), the short-term capital flows (C2) influences CPI more. The impulse response reached its peak in 2008. The effect of international capital flows on price level ascend first and then descend, with 2008 as the turing point. This may be because of the stimulative policies after the financial crisis, and foreign investment gradually lost their influence on price. This Similar findings about the effect of international capital flow on price level and interest rate are supported by Berument et al. (2015).
(2) The analysis of the time-point impulse response function
We illustrate the unit standard deviation impulse responses of money multiplier of M2 and CPI to international capital flow in Figure 3. We choose three time points: before the financial crisis (November 2002), during the financial crisis (September 2008) and after the financial crisis (June 2012). We found that the impact of short-term capital flows (C2) on money multiplier of M2 and CPI has not changed, no matter it was before, during or after the financial crisis. However, the changes of impact of the long-term capital (C1) is prominent. Before the financial crisis, the impact of C1 to money multiplier of M2 and CPI is relatively small. It can be concluded that there is no structural change in the response of M2 or CPI to C2 in the full sample case, while their responses to C1 has changed. Although the central bank strengthened its regulation of international capital flows after 2008, the sterilization was not enough. The sharp decline in international capital flows after 2008, the sterilization was not enough. The sharp decline in international capital flows, especially the long-term international capital flows, still had a significant impact on currency supply and price volatility. When the international financial crisis broke out, many international financial institutions faced capital chain breaks, therefore, short-term capital returned to the rescue market. Meanwhile, the US dollar assets become a global "safe haven", a large number of short-term international capital flew back to the U.S., causing enormous impact.
The Influence of International Capital Flow on the Effectiveness

Figure 3

The Time-point Impulse Response Function

Note: Time-point Impulse Response Results (before, during and after the 2008 financial crisis)

Figure 3 shows an obvious lower position of the time-point impulse response curve in June 2012, indicating that the impact of the international capital flows on money multiplier of M2 and CPI declined after the financial crisis. The duration reduced, so did the amplitude. Since the second half of 2011, China's economy adhered to a steady progress, and the macroeconomic environment was good. The liberalization of exchange rate policy and better market conditions attracted the international capital inflows, suggesting the monetary sterilization effective to some extent, but not prominent in the whole picture.

4.2 Analysis of the Offsetting Effect of International Capital Flow on the Monetary Policy

4.2.1 The Estimation of the Offset Function

We use the two-stage least-squares regression on Equation (12) and (13) to obtain the long-term capital flow offset equation and the short-term capital flow offset equation. The results are shown in Table 2.

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Each model is fit properly (goodness of fitting is above 0.75). According to the capital flow offset equation, the offset coefficient of long-term capital flow is -0.109, which means long-term capital flows offset 10.9% of any change in monetary policy. The offset coefficient of short-term capital flow is -0.588, which means short-term capital flows offset 58.8% of any change in monetary policy. This suggested that even under the strict capital control of the central bank, the international capital still has a certain liquidity, and the capital flow reduced the effectiveness of monetary policy through foreign exchange account.

The coefficient of currency multiplier, cyclical income and fiscal deficit are negative, indicating that the central bank monetary policy will increase the money multiplier, cyclical income and the fiscal deficit by choosing the opposite direction. Although the interest rate fluctuation variable is not significant, but the model coefficients are negative, indicating that the central bank uses a reverse operation to stabilize the market interest rate. The expected coefficient of RMB exchange rate is big and positive, indicating that the appreciation of the RMB is expected to have a very important impact on foreign capital inflows. Short-term capital flows have a greater impact on the expected appreciation of the RMB. Since 2005, under the expectation of RMB appreciation, a large amount of speculative capital flows flew into China to obtain the benefit from the appreciation of the RMB.

### 4.2.2 The Robustness Test of the Results

In order to test the robustness of the estimated results, we applied the data of the net foreign assets and the net domestic assets, which are not adjusted in the central bank’s balance sheet, in the model. The results suggested that the offset coefficient of long-term capital flow and short-term capital are about -0.11 and -0.59. The coefficients of the main variable are also significant. The goodness of fitting is above 0.8, indicating that the established model structure is robust. If the increase of income of foreign exchange assets is greater than the depreciation of the foreign exchange assets, the inflow of international capital will be overestimated in the balance sheet of the central bank, and the response of the monetary policy will be underestimated, causing a larger offset coefficient, vice versa.

### 4.2.3 The Recursive Results

The recursive coefficient estimation method was originally used to test the robustness of the estimated equation. In this paper, the recursive coefficient method is applied to estimate the recursive offset coefficient (blue line in Figure 4).

Figure 4 takes time as the horizontal axis and the offsetting coefficient of international capital flows as the vertical axis, showing the offsetting effects of long-term and short-term capital flows on monetary policy from 2003 to 2014.
Figure 4

The Dynamic Change of the Offset Coefficient

Note: The dynamic change of offset coefficient of long-term capital flow (left) and short-term capital flow (right).

Generally, the offset coefficient of international capital flows has been at a high level, indicating great pressure to the RMB money supply. The main driving forces of capital flows are the pleasing economic growth of China, the domestic and foreign interest margin of the U.S. and China's managed floating exchange rate regime.

The offset coefficient of long-term capital flows from 2003 to 2005 shows an upward trend, and a slow decline after 2005. The amplitude of variation is relatively small. After China's exchange rate reform in 2005, the one-time appreciation of the RMB weakened the pressure of capital inflows.

The offset coefficient of short-term capital flows from 2003 to 2014 shows a rising trend, but with an increasing volatility. The short-term capital is very sensitive and responses quickly to the change of interest rate and foreign exchange rate. Although the central bank has recognized that international capital flows have had a negative impact on the effectiveness of monetary policy in China and have taken relevant measures of sterilization, the operations is mainly limited in raising the deposit reserve ratio, issuing central bank bills, conducting open market operations. In fact, the short-term capital flows are in a variety of forms, and single sterilization policy has been proved inefficient to cope with the complexing and volatile international capital inflows. The volatility in the offset coefficient of short-term capital flows is consistent with observation from Fernald et al. (2014) using different approach, and Wang et al. (2018).

4. Conclusions and Suggestions

This paper examines the impact of international capital flows on the effectiveness of China's monetary policy. Different from previous research, we devide the international capital flow into long-term and short-term, and study how they influence monetary policy seperately from a time-varying aspect. The TVP-VAR model examines the impact of international long-term
capital flows and short-term capital flows on the effectiveness of monetary policy from a time-varying perspective, which overcomes the limitations of the ordinary VAR model. Besides, a modified offset coefficient model, which is suitable for China, is constructed to measure the impact of international capital volatility on the effectiveness of monetary policy. We obtain several novel results via a theoretical analysis and numerical simulation:

The impact of short-term international capital flows on money multiplier of M2 is positive and more significant than that of long-term international capital flows. And the impact of short-term capital flows has a greater impact on price level, comparing with the long-term capital flows. Both long-term and short-term international capital flows have a time-varying influence on China’s monetary policy.

In the adjusted offset coefficient model, we measured the offset coefficient of both long-term and short-term international capital flows on to the effectiveness of China’s monetary policy. Results suggest that short-term capital flows offset 58.8% of any change in monetary policy while long-term capital flows offset 10.9% of any change in monetary policy. In the dynamic process, we find the offset coefficient of long-term international capital flow rising in 2003-2005, declining mildly after 2005. By contrast, the offset coefficient of short-term international capital flow kept a upward trend in 2003-2014 with violent fluctuation.

The implications are explored and proposed from three aspects based on our conclusions:

(1) Increase financial supervision over short-term capital flows. In order to reduce informal international capital flows under the current account, we suggest a tighter regulation on the international trade. In addition, the use of funds in the frequent transfer of residents should be examined strictly, and the quota should be set according to the usage to control international capital inflows, which is often hidden in the frequent transfer.

(2) Strengthen supervision over long-term capital flows, especially for FDI. The imbalance of international payments caused by the backflow of FDI and the increasing scale of FDI have a great negative impact on the China’s economy in the long run. Moreover, there are also some informal capital flows in the FDI. Therefore, we should control and guide the scale and direction of FDI properly, and strengthen the supervision of the informal capital flow doped in FDI to reduce the impact of international capital flow on China's macro-control.

(3) Use various sterilization operations. The effectiveness of China’s monetary policy is greatly offset by international capital flow. Various sterilization operations should be used according to different situations. In addition, new monetary sterilization operation tools should be developed, such as issuing bonds from central bank, or adjusting liquidity through employee reserve funds, transfer government and employee reserve funds deposits from the banking system to a special account of the central bank, or some similar operations on postal savings and endowment insurance.

Our study has several limitations that need to be addressed. Firstly, the theoretical analysis of the conduction mechanism of monetary policy is not enough, and the impact on the effectiveness of the conduction mechanism needs further quantitative analysis. Secondly, this paper analyzes from a macro perspective, and the impact of international capital flows on the effectiveness of monetary policy from a micro perspective needs further discussion. Finally, an interesting issue to address in future work is introducing the dynamic stochastic general equilibrium (DSGE) model in the open economy.
Acknowledgements

This work was supported by Shandong Social Science Planning Fund Program (17DJJJ03), the National Social Science Fund Major Projects (14ZDB151), and the Fundamental Research Funds for the Central Universities (201413044).

References


### Table A1

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