2. 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

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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 form 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 capitical flow to the effectiveness of China's monetary policy. This is helpful to minimize the risks of international capital flows volitality and has a certain theoretical and practical significance to a healthy economic envirement.

3. Methodology and Data

3.1 The VAR Model Setting

The basic form of the VAR model is:

$$Ay_t = F_1 y_{t-1} + ... + F_s y_{t-s} + \mu_t,\ \ t = s+1,...,n \qquad (1)$$

where: y_t is a k × 1 dimensional observation vecto, $A, F_1....F_s$ are k × k coefficient matrices, and μ_t is a k × 1 structural shock. We specify the simultaneous relations of the structural shock by recursive identification, assuming that A is lower-triangular.

$$A=\begin{bmatrix} 1 & 0 & \cdots & 0 \\ \alpha_{21} & \ddots & \ddots & \vdots \\ \vdots & \ddots & \ddots & 0 \\ \alpha_{k1} & \cdots & \alpha_{k,k-1} & 1 \end{bmatrix}$$

The equation can be abbreviated to the following VAR model:

$$\mathrm{y_t}=\mathrm{B}_1 y_{t-1}+....+\mathrm{B}_s y_{t-s}+A^{-1}\sum \varepsilon_\mathrm{t},\quad \varepsilon_\mathrm{t}\sim \mathrm{N}\ (0,\ I_\mathrm{k}) \tag{2}$$

where: $\mathrm{B}_i = A^{-1}F_i,\quad \mathrm{i}=1,\ldots,s$, and

$$\sum=\begin{bmatrix} \sigma_1 & 0 & \cdots & 0 \\ 0 & \ddots & \ddots & \vdots \\ \vdots & \ddots & \ddots & 0 \\ 0 & \cdots & 0 & \sigma_k \end{bmatrix}$$

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

$$\mathrm{y_t} = X_\mathrm{t}\beta_\mathrm{t} + A^{-1}\sum \varepsilon_\mathrm{t} \tag{3}$$

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 stochastiv 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:

$$\mathrm{y_t}=X_\mathrm{t}\beta_\mathrm{t}+A_\mathrm{t}^{-1}\sum{}_t\varepsilon_\mathrm{t},\quad \mathrm{t}=\mathrm{s}+1,\ldots,n \tag{4}$$

where: the coefficient β_t, the parameter A_t and $\sum_t$ are time-varying. Let α_t be a tacked vector of the lower-triangular elements in A_t and $h_t = (h_{1t}, \dots, h_{kt})'$ with $h_{jt} = \log\sigma_{jt}^2$, 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:

$$\begin{aligned} \beta_{t+1} &= \beta_t + \mu_{\beta t} \\ \alpha_{t+1} &= \alpha_t + \mu_{\alpha t}, \\ h_{t+1} &= h_t + \mu_{ht} \end{aligned} \quad \begin{pmatrix} \varepsilon_t \\ \mu_{\beta t} \\ \mu_{at} \\ \mu_{ht} \end{pmatrix} \sim N\left(0, \begin{bmatrix} I & 0 & 0 & 0 \\ 0 & \Sigma_\beta & 0 & 0 \\ 0 & 0 & \Sigma_a & 0 \\ 0 & 0 & 0 & \Sigma_h \end{bmatrix}\right)$$

for $t = s+1, \dots, n$, where $\beta_{S+1} \sim N(\mu_{\beta_0}, \Sigma_{\beta_0})$, $\alpha_{S+1} \sim N(\mu_{\alpha_0}, \Sigma_{\alpha_0})$ and $h_{S+1} \sim N(\mu_{h_0}, \Sigma_{h_0})$. The shocks to the innovations of the time-varying parameters are assumed uncorrelated among the parameters β_t, α_t and h_t. We then assume that Σ_β, Σ_α and Σ_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 σ_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:

$$\Delta NFA = \alpha_0 + \alpha_1 \Delta NDA + X_1' \alpha_2 + \mu_t \tag{5}$$

while ΔNFA is change in the net foreign asset, which equates in some studies with international capital flow. ΔNDA is the change in the net domestic asset, and reflects the change of the monetary policy. X_1 represents other explanatory variables that might influence a monetary authority's reaction. The offset coefficient of $\alpha_1 = -1$ represents free movement of international capital flow and its max offset effect to monetary policy, which suggests monetary policy is invalid. When $\alpha_1 = 0$, 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":

$$\Delta \mathrm{NFA}_t = \alpha_0 + \alpha_1 \Delta \mathrm{NDA}_t + \alpha_2 \Delta \mathrm{P}_t + \alpha_3 \Delta m_t + \alpha_4 \Delta Y_t + \alpha_5 \Delta E_t \tag{6}$$

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; ΔE_t 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).

$$\Delta \mathrm{NFA}_t = \alpha_0 + \alpha_1 \Delta \mathrm{NDA}_t + \mathrm{x}_1^{'} \alpha_2 + \mu_t \tag{7}$$

$$\Delta \mathrm{NDA}_t = \beta_0 + \beta_1 \Delta \mathrm{NFA}_t + \mathrm{x}_2^{'} \beta_2 + \nu_t \tag{8}$$

$$\Delta \mathrm{NFA}_t = \mathrm{C1}_t + \mathrm{C2}_t + \mathrm{CA}_t \tag{9}$$

where: x_1 and x_2 are the control variables, and α_2 and β_2 are the coefficient vectors of the control variables. α_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. β_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

$$\mathrm{C1}_t + \mathrm{C2}_t + \mathrm{CA}_t = \alpha_0 + \alpha_1 \Delta \mathrm{NDA}_t + \mathrm{x}_1^{'} \alpha_2 + \mu_t .$$

Therefore,

$$\mathrm{C1}_t = \alpha_0 + \alpha_1 \Delta \mathrm{NDA}_t - \mathrm{C2}_t + \mathrm{x}_1^{'} \alpha_2 - \mathrm{CA}_t + \mu_t ,$$

$$\mathrm{C2}_t = \alpha_0 + \alpha_1 \Delta \mathrm{NDA}_t - \mathrm{C1}_t + \mathrm{x}_1^{'} \alpha_2 - \mathrm{CA}_t + \mu_t$$

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

$$C1_t = \alpha_3 + \alpha_4 \Delta \mathrm{NDA}_t + \alpha_5 \mathrm{C2}_t + x_1^{'} \alpha_6 + \alpha_7 \mathrm{CA}_t + \mu_t \tag{10}$$

$$C2_t = \alpha_3 + \alpha_4 \Delta \mathrm{NDA}_t + \alpha_5 \mathrm{C1}_t + x_1^{'} \alpha_6 + \alpha_7 \mathrm{CA}_t + \mu_t \tag{11}$$

while $\alpha_0 = \alpha_3$, $\alpha_1 = \alpha_4$, $\alpha_5 = -1$, $\alpha_2 = \alpha_6$, $\alpha_7 = -1$.

The offset coefficient α_4 reflects the offset effect of the international capital flow on the monetary policy. The closer a_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:

$$\begin{aligned} C1_t = {} & \alpha_0 + \alpha_1 CA_t + \alpha_2 C2_t + \sum_{i=0}^{n}\alpha_{3i}\Delta NDA^{*}_{t-i} + \sum_{i=0}^{n}\alpha_{4i}\Delta p_{t-i} + \sum_{i=0}^{n}\alpha_{5i}\Delta gap_{t-i} + \sum_{i=0}^{n}\alpha_{6i}\Delta mm_{t-i} \\ & + \sum_{i=0}^{n}\alpha_{7i}\Delta G_{t-i} + \sum_{i=0}^{n}\alpha_{8i}\Delta r_{t-i} + \sum_{i=0}^{n}\alpha_{9i}\Delta reer_{t-i} + \sum_{i=0}^{n}\alpha_{10i}\Delta e^{e}_{t-i} + \varepsilon_t \end{aligned} \tag{12}$$

$$\begin{aligned} C2_t = {} & \alpha_0 + \alpha_1 CA_t + \alpha_2 C1_t + \sum_{i=0}^{n}\alpha_{3i}\Delta NDA^{*}_{t-i} + \sum_{i=0}^{n}\alpha_{4i}\Delta p_{t-i} + \sum_{i=0}^{n}\alpha_{5i}\Delta gap_{t-i} + \sum_{i=0}^{n}\alpha_{6i}\Delta mm_{t-i} \\ & + \sum_{i=0}^{n}\alpha_{7i}\Delta G_{t-i} + \sum_{i=0}^{n}\alpha_{8i}\Delta r_{t-i} + \sum_{i=0}^{n}\alpha_{9i}\Delta reer_{t-i} + \sum_{i=0}^{n}\alpha_{10i}\Delta e^{e}_{t-i} + v_t \end{aligned} \tag{13}$$

For t-i settings in Equations 12 and Equation13, we use a VAR model to estimate the lagged effects of NDA_t and NFA_t 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, ΔNDA^* is the annualized monthly change in the adjusted net domestic asset scaled by the GDP.Δmm_t is the annualized monthly change in money multiplier for M2. Δgap_t indicates the real output gap. Δp_t denotes the annualized monthly change in inflation, as measured by CPI. ΔG_t is the cyclical fiscal deficit scaled by GDP. Δr_t is the annualized monthly change in foreign interest rates, as measured by the yield on America undefined three-month Treasury bonds. $\Delta reer_t$ is the annualized monthly change in the real effective exchange rate. Δe^e_t 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 devide 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, privious 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 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).

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

$$\Delta NDA_t^* = \frac{\Delta MB_t}{GDP_t} - \Delta NFA_t^* \tag{15}$$

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 flew into the Chinese market and foreign exchange reserves were on the rise. RMB was facing great preasure for appreciation and goals of the monetary policy were chanllanged. 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 spliting 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 varibales 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 dererencing (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 issure. 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)

$$\begin{pmatrix} C1_t \\ C2_t \\ M2_t \\ CPI_t \end{pmatrix} = \begin{pmatrix} a_{1t} & a_{2t} & a_{3t} & a_{4t} \end{pmatrix} \begin{pmatrix} C1_{t-1} \\ C2_{t-1} \\ M2_{t-1} \\ CPI_{t-1} \end{pmatrix} + \begin{pmatrix} b_{1t} & b_{2t} & b_{3t} & b_{4t} \end{pmatrix} \begin{pmatrix} C1_{t-2} \\ C2_{t-2} \\ M2_{t-3} \\ CPI_{t-4} \end{pmatrix} + \begin{pmatrix} \mu_{1t} \\ \mu_{2t} \\ \mu_{3t} \\ \mu_{4t} \end{pmatrix} \quad (16)$$

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 repeatly 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 posteriori 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.

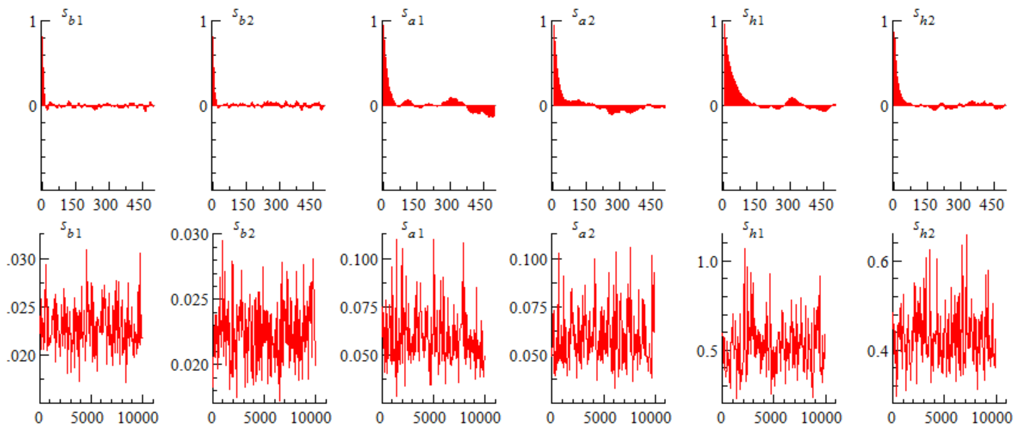
Table 1

The Estimation Results of Selected Parameters in the TVP-VAR Model

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

Figure 1

Estimation Results of Selected Parameters in the TVP-VAR Model. Sample Autocorrelations (Top) and Sample Paths (Bottom)



Graphics show the sample autocorrelations and dynamic simulation path of selected parameters.

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 a equidistant impulse in C1 and C2 vary.

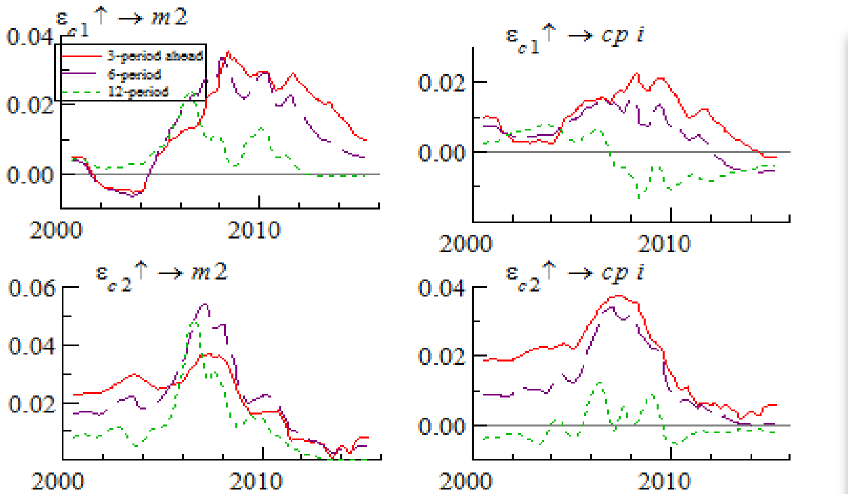
Figure 2 illustrates the equidistant impulse responses of money multiplier for M2 and CPI to international capital flow with time lags of three-month, six-month and twelve-month respectively. We find that money multiplier for M2 responses differently to the long-term capital flows (C1) and short-term 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 influnce 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).

Figure 2

The Equidistant Impulse Response Function



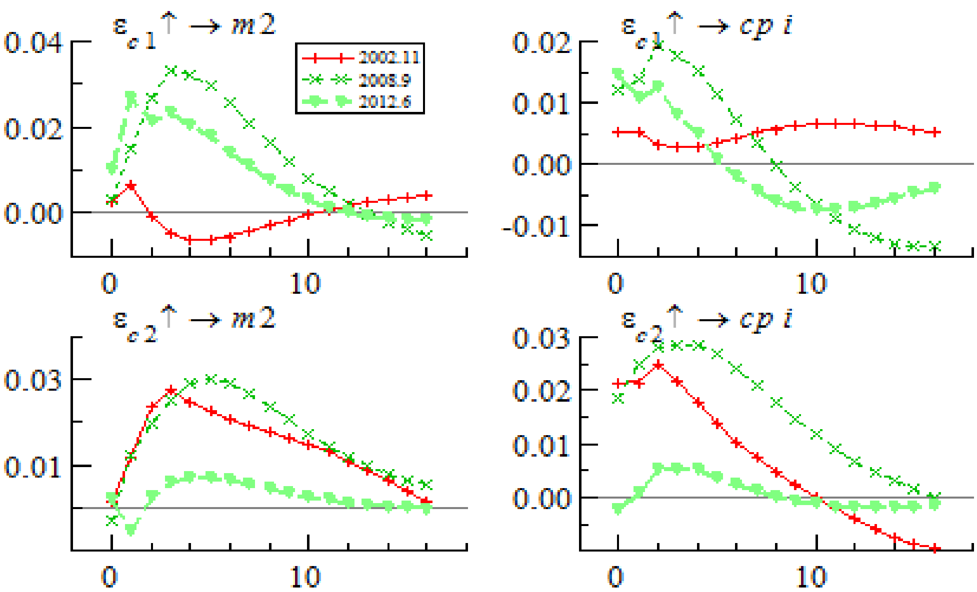
Note: *Equal-interval Impulse Response Results for three-month lag (red line), six-month lag (purple line) and twelve-month lag (green dash line).*

(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, 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.

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 inTable .

Table 2

Estimation Results of the Offset Function

	Long-term capital flow offset equation		Short-term capital flow offset equation	
Variables	Coefficient	Probability	Coefficient	Probability
CA_t	-0.023	0.588	-0.942	0.000
ΔNDA^*_t	-0.109	0.000	-0.588	0.000
gap_{t-1}	0.613	0.000	0.840	0.006
Δp_t	-0.635	0.009	-0.739	0.113
ΔG_t	-0.006	0.583	-0.056	0.207

	Long-term capital flow offset equation		Short-term capital flow offset equation	
r_s	-0.055	0.776	-0.412	0.310
$\Delta reer_{t-1}$	0.288	0.001	0.041	0.235
Δe^e_t	0.102	0.001	0.444	0.000
Δmm_t	-0.044	0.074	-0.544	0.000
$dm12_t$	0.032	0.150	0.045	0.223
R^2	0.769		0.774	

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 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.

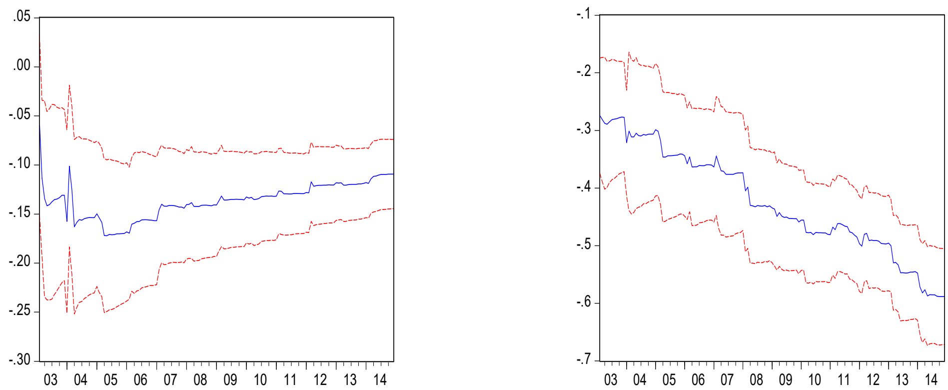
4.2.3 The Recursive Results

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 influnce 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 volitility 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 influnce on China's monetary policy.

In the adjusted offset coeficient 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 offseted 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.

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Appendix

Table A1

The Basic Statistical Description 1

	C1	C2	CPI	M2
Mean	66.720	23.111	102.771	498035.486
Median	62.465	20.810	100.059	380858.515
Maximum	144.170	1275.580	124.649	1228374.807
Minimum	18.300	-1210.780	86.510	121220.400
Std. Dev.	27.250	332.477	12.347	336653.230
Skewness	0.611	-0.325	0.364	0.718
Kurtosis	2.881	6.147	1.711	2.203
Jarque-Bera	11.311	77.419	16.443	20.182
Probability	0.004	0.000	0.000	0.000
Observations	180.000	180.000	180.000	180.000

Table A2

The Basic Statistical Description 2

	$C1_t$'	$C2_t$'	CA_t'	ΔNDA_t*
Mean	0.000	0.000	0.000	0.005
Median	0.000	0.000	0.000	0.007
Maximum	0.008	0.050	0.026	0.095
Minimum	-0.014	-0.071	-0.032	-0.087
Std. Dev.	0.004	0.015	0.007	0.029
Skewness	-1.087	-0.338	-0.440	-0.549
Kurtosis	5.891	6.722	9.758	4.087
Jarque-Bera	91.057	99.604	323.184	16.600
Probability	0.000	0.000	0.000	0.000
Observations	180.000	180.000	180.000	180.000

Table A3

The Basic Statistical Description China Data (Jan. 2000-Dec. 2014)

	Δmm_t	gap_t	Δp_t	ΔGt	r_t	$\Delta reer_t$
Mean	0.000	0.000	0.000	0.000	0.000	0.001
Median	0.003	0.000	0.000	0.004	0.000	0.002
Maximum	0.040	0.053	0.008	0.083	0.002	0.018
Minimum	-0.052	-0.011	-0.011	-0.114	-0.004	-0.015
Std. Dev.	0.016	0.005	0.003	0.024	0.001	0.006
Skewness	-0.629	8.860	-0.366	-1.566	-1.588	-0.247
Kurtosis	3.837	101.932	4.320	8.811	6.641	2.882
Jarque-Bera	15.889	70288.980	15.854	303.227	162.442	1.794
Probability	0.000	0.000	0.000	0.000	0.000	0.408
Observations	180.000	180.000	180.000	180.000	180.000	180.000

Table A4

ADF Unit Roots Test for China Data (Jan. 2000-Dec. 2014)

Variables	t-Statistics	5% level	10% level	ADF test statistic (P value)
C1	-8.151416	-3.004861	-2.642242	0.0000
C2	-5.125356	-3.012363	-2.646119	0.0005
CPI	-3.7928	-2.8775	-2.5753	0.0036
D(M2)	13.4548	-2.8776	-2.5754	0.0000
CA	-3.651841	-3.690814	-3.286909	0.0536
ΔNDA	-4.283232	-3.690814	-3.286909	0.0171
Δmm	-4.620215	-3.673616	-3.277364	0.0084
gap	-3.271658	-3.644963	-3.261452	0.0982
Δp	-4.279252	-3.658446	-3.268973	0.0154
ΔG	-5.815146	-3.644963	-3.261452	0.0006
rs	-6.542304	-3.004861	-2.642242	0.0000
Δreer	-4.320905	-3.012363	-2.646119	0.0031
Δee	-5.378019	-3.020686	-2.650413	0.0003

Table A5

Granger Causality test for China Data (Jan. 2000-Dec. 2014)

H_0	F-Statistic	Prob.
CPI does not Granger Cause DM2	1.48405	0.2296
DM2 does not Granger Cause CPI	6.86826	0.0013
C2 does not Granger Cause DM2	4.62728	0.0110
DM2 does not Granger Cause C2	1.62061	0.2008
C1 does not Granger Cause DM2	6.58554	0.0018
DM2 does not Granger Cause C1	1.90290	0.1523
C2 does not Granger Cause CPI	2.60371	0.0769
CPI does not Granger Cause C2	3.14357	0.0456
C1 does not Granger Cause CPI	5.51741	0.0048
CPI does not Granger Cause C1	0.78257	0.4588