

The Shock Effect of International Oil Price Fluctuation on RMB Exchange Rate-Based on the stochastic version of MFD and SVAR models

Yijia Qian #, Yexuan You #, Xinyan Zhou *

Business school, Soochow University, Suzhou, China, 215006

* Corresponding author: yx262425@163.com

#These authors contributed equally.

Abstract. Oil is a basic energy source closely related to finance. With the rapid growth of China's oil consumption and the increasing dependence of China's oil on foreign countries, the impact of international oil price fluctuations on China's macroeconomy has become more and more prominent. Based on the stochastic version of the MFD model, this paper employs the SVAR structural vector autoregressive estimation method to measure the impact effect of international oil price volatility on the RMB exchange rate in the time period of January 2002-December 2022. The study shows that the movement of the RMB exchange rate is basically caused by its own perturbation, and the Granger causality test leads to the conclusion that there is no obvious causality between the international oil price and the RMB exchange rate. The study is of great significance for China to maintain the flexibility of the RMB exchange rate, to further play the role of the exchange rate in regulating the macroeconomy and the automatic stabilizer of the balance of payments, and to improve China's risk-resistant ability. Research on the effect of crude oil prices on currency exchange rate shocks emerged after the 1984 oil crisis.

Keywords: International oil price volatility, RMB exchange rate, shock effect, SVAR model.

1. Introduction

Crude oil is an important basic energy and strategic resource, and the volatility of crude oil prices has a significant impact on the financial markets and international trade of all countries[1]. In recent years, the instability of the world economy has led to frequent fluctuations in oil prices, especially for countries with a high dependence on crude oil, such as China that the impact is more significant[2]. Meanwhile, with the internationalization of RMB, the RMB exchange rate plays an important role in the stability of Chinese economy. In the context, this paper focuses on the shock effect of international crude oil price on RMB exchange rate.

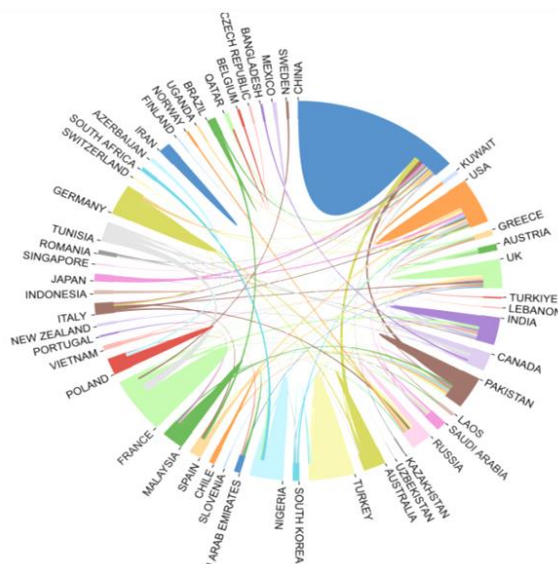


Figure 1. Research country collaborations

Data source: CNKI and WOS Core Collection

Research country collaborations as shown in Figure 1, by analyzing the literature related to "crude oil price" and "exchange rate" in the core collection of WOS, the number of studies in China is higher, which again verifies the necessity of this study. In addition, the close cooperation between countries indicates that the fluctuation of international crude oil price has an impact on exchange rate in the world, and the fluctuation of oil price can be regarded as a common important issue in the world.

By comprehensively analyzing the literature related to "crude oil price" and "exchange rate" in the WOS Core Collection and CNKI, the relevant research topics can be divided into two stages. The period from 1973 to 2015 is the first stage, and most scholars have set their research goal on theoretical model construction. The second stage is after 2016, and most scholars change the research focus to empirical analysis. Lin Weihua analyzed through the GARCH-MIDAS model and the NARDL model, and found that the increase in the international oil price has a greater impact on the RMB exchange rate than the decline, and the spillover effect is significant [3]. Chen Yufeng et al. used the ternary VAR model to study the international crude oil price and found that the RMB exchange rate showed a significant negative response facing the shock from the international crude oil market [4]. Li Jinkun constructed TVP-SV-VAR model and found that the coefficients of the impact of international crude oil prices on the RMB exchange rate showed strong time-varying characteristic relationships in both the direction of action and the degree of impact [5]. Among them, China's international oil price volatility and the RMB exchange rate related research to China's 2015 "8.11 exchange reform" have as a demarcation point [6]. The previous research mainly centered on the international oil price volatility on the RMB exchange rate impact path and the linear correlation between the two to carry out. After the exchange reform, the international oil price on the RMB exchange rate spillover effect of the research have gradually focused on the analysis of dynamic spillover effects [7].

This paper adopts SVAR to analyze the degree of impact that international oil price fluctuations will bring to the RMB exchange rate. While SVAR considers the effects of synchronization and lag between variables on the basis of the structural form of VAR, this kind of model can consider the structural problems of international oil price and RMB exchange rate in real time at the same time simultaneously under the constraint.

2. Research Design

2.1. Theoretical mechanism - stochastic version of the MFD model

This section explores the theoretical framework of the transmission mechanism of exchange rate and other variables induced by oil price shocks. Currently, there are two main paths of transmission generally recognized by research: balance of payments and price impacts[8]. In order to further assess the sources of real and nominal shocks, a stochastic version of the Mundell-Fleming-Dornbusch (MFD) based on an open economy for the economic model is introduced here, variable and notations as shown in Table 1.

Table 1. Variable and notations

Variable	notation
Actual oil prices	o
Capacity output	s
exportation	x
effective exchange rate	e
price level	p
money stock	m
Relative to real GDP	y

Link production and technology to actual oil prices through a Cobb-Douglas long-run production function, and in turn enumerate a traditional money demand function based on transaction demand, a

reflective inflation function based on the price level, and an approximation of the uncovered interest-rate parity under rational expectations (where γ denotes the inverse of elastic energy, assuming that total exports y_x satisfy the incremental function of the real exchange rate within China):

$$\begin{aligned} O_t &= O_{t-1} + \varepsilon^0 \\ y_t^s &= s_t + \gamma O_t \sim [s_t = s_{t-1} + \varepsilon_t^s] \\ y_t^x &= x_t + \Phi e_t \sim [x_t = x_{t-1} + \varepsilon_t^x] \\ m_t &= p_t + ky_t^s - \pi i_t \sim [m_t = m_{t-1} + \varepsilon_t^m] \\ p_t &\sim [p_t = p_{t-1} + \varepsilon_t^p] \\ i_t &= E(e_t) \end{aligned} \quad (1)$$

Solution:

$$\begin{aligned} \Delta O_t &= \varepsilon^0 \\ \Delta y_t &= \gamma \varepsilon^0 + \varepsilon_t^s \\ \Delta e_t &= 1/\Phi(\gamma \varepsilon_t^0 + \varepsilon_t^s - \varepsilon_t^x) \end{aligned} \quad (2)$$

Therefore, the following conclusions come out. Only oil price shocks affect real oil prices in the long run, while relative real GDP will be given by the accumulation of supply and oil price shocks. All other shocks have some lasting effect on the real exchange rate without considering monetary shocks.

2.2. Empirical modeling

2.2.1. Methodological choices

Although most scholars usually use the vector autoregressive (VAR) model to study the impact of oil price volatility on exchange rates, there are some shortcomings in this model, including the inability to accurately reflect the specific form of the relationship between the variables and the inability to account for the estimated parameters of the correlation structure that is potentially in the error term. In view of these shortcomings, this paper extends the VAR model by applying the the SVAR model of Blanchard and Quah.

2.2.2. Selection of variables and data sources

Referring to the previous research, this paper chooses to make some degree of improvement on the basis of Chen tiantian and Li Huiyu[9], choosing the RMB exchange rate as the explanatory variable, the international oil price as the core explanatory variable, and the economic growth, price level, trade balance and monetary policy variables as the rest of the variables, so as to make the model better adapted to the actual situation in China. Among them, the RMB exchange rate EX is expressed in terms of the value of one US dollar to RMB, the oil price OP is expressed in terms of the value of one barrel of West Texas (WTI) crude oil price, the economic growth is changed to the industrial growth index. Oil prices directly affect the PPI, which in turn affects the CPI and CPI also reflects the level of consumer purchasing power and the degree of economic prosperity. Thus, the year-on-year increase in CPI is chosen to indicate the price level. International oil prices are bound to affect imports and exports, and indirectly affect the trade balance. Hence, the year-on-year growth index of exports is selected as a substitute for the trade balance TB. According to previous literature, changes in oil prices affect the monetary authority's decision and the effectiveness of monetary policy, so M2 year-on-year growth is used as a proxy variable for monetary policy MP. The above six data are selected as monthly data from January 2002 to December 2022, with a longer interval to ensure sample adequacy, totaling 252 items from the People's Bank of China, Wind database, National Bureau of Statistics, and the General Administration of Customs to ensure the accuracy and authority of the data.

2.2.3. Model overview

In this paper, SVAR is used to study and analyze the extent of shocks that international oil price fluctuations will bring to the RMB exchange rate. The SVAR model with P-order variables containing k variables is as follows.

$$B_0 Y_t = A_1 \varepsilon_{t-1} + A_2 \varepsilon_{t-2} + \dots + A_p \varepsilon_{t-p} + \mu_t \quad (3)$$

Where B_0 denotes the corresponding coefficient matrix, Y_t is the column vector of n endogenous variables at time t, p denotes the corresponding lag order, A_i denotes the coefficient matrix of the lagged endogenous variables of order i, ε_t denotes the general perturbation vector, and μ_t denotes the structural perturbation vector. For this structural model, there should be $k(k-1)/2$ qualifications assigned to B_0 in order to be eligible.

According to the variables mentioned above there are six in total,

$$B_0^{-1} = \begin{pmatrix} b_{11} & b_{21} & b_{31} & b_{41} & b_{51} & b_{61} \\ b_{12} & b_{22} & b_{32} & b_{42} & b_{52} & b_{62} \\ b_{13} & b_{23} & b_{33} & b_{43} & b_{53} & b_{63} \\ b_{14} & b_{24} & b_{34} & b_{44} & b_{54} & b_{64} \\ b_{15} & b_{25} & b_{35} & b_{45} & b_{55} & b_{65} \\ b_{16} & b_{26} & b_{36} & b_{46} & b_{56} & b_{66} \end{pmatrix}, \quad \varepsilon_t = \begin{pmatrix} \varepsilon_t^{mp} \\ \varepsilon_t^{tb} \\ \varepsilon_t^{pl} \\ \varepsilon_t^{eg} \\ \varepsilon_t^{op} \\ \varepsilon_t^{ex} \end{pmatrix}, \quad \mu_t = \begin{pmatrix} \mu_t^{mp} \\ \mu_t^{tb} \\ \mu_t^{pl} \\ \mu_t^{eg} \\ \mu_t^{op} \\ \mu_t^{ex} \end{pmatrix} \quad (4)$$

Fifteen constraints must be given to this six-element SVAR model. The following constraints are given to the model. (1) Balance of trade, prices, economic growth, international oil prices and RMB exchange rate have no effect on monetary policy, $b_{21}=b_{31}=b_{41}=b_{51}=b_{61}=0$. (2) Prices, economic growth, international oil prices and the RMB exchange rate have no effect on the trade balance, $b_{32}=b_{42}=b_{52}=b_{62}=0$. (3) economic growth, international oil price and RMB exchange rate have no effect on price, $b_{43}=b_{53}=b_{63}=0$. (4) International oil price and RMB exchange rate have no effect on economic growth, $b_{54}=b_{64}=0$. (5) RMB exchange rate does not affect international oil price, $b_{65}=0$. Since the model is based on a sample of monthly data, the stated conditions are short-term. Moreover, there is usually a time lag in the shocks between the variables, so the assumptions stated above are also very reasonable.

3. Empirical Findings

3.1. Descriptive statistics

Analyze descriptive statistics for the monthly data of variables such as RMB exchange rate, international oil price, economic growth, price level, trade balance, and monetary policy etc. from 2002 to 2022. Results of descriptive statistics are shown in Table 2.

From the results of descriptive statistics, the standard deviation of the RMB exchange rate is less than 1, while the standard deviation of the oil price is much larger than 1, indicating that the fluctuation of the international oil price is much larger than the fluctuation of the RMB exchange rate. This is mainly due to the political instability in the Middle East region and other factors that lead to a more dramatic fluctuation of the international oil price[10], whose standard deviation is higher than the standard deviation of the RMB exchange rate. The skewness of each variable is greater than 0, which is right skewed. The kurtosis of the variables EX and OP is less than 3, which indicates that the data of the two are flatter compared to the normal distribution.

Table 2. Results of descriptive statistics

variable	average value	standard deviation	minimum value	maximum value	skewness	kurtosis
EX	7.020782	0.739384	6.0969	8.2775	0.672332	2.015195
OP	66.29643	24.58214	18.84	140.02	0.29056	2.284713
EG	10.75475	6.572638	-25.86705	52.33918	0.408403	11.6634
PL	2.332038	1.929112	-1.8	8.7	0.69068	3.929904
TB	14.72956	19.12804	-40.61	154.28	1.271857	13.0759
MP	14.44976	4.718528	8	29.74	0.865508	3.889414

3.2. Unit root test

In this paper, ADF test is used to analyze the stability of each variable and stability test results are shown in Table 3.

Table 3. Stability test results

variable	ADF statistic	5% critical value	P-value	conclusion
EX	-1.204486	-1.942099	0.2090	uneven
OP	-2.873882	-2.872904	0.0499	stable
EG	-4.027795	-2.872950	0.0015	stable
PL	-3.413271	-2.873440	0.0114	stable
TB	-3.449480	-2.872950	0.0102	stable
MP	-3.601662	-3.428049	0.0317	stable
Δ EX	-3.571733	-1.942147	0.0004	stable
Δ OP	-12.77595	-1.942099	0.0000	stable
Δ EG	-6.437112	-1.942182	0.0000	stable
Δ PL	-5.410025	-1.942170	0.0000	stable
Δ TB	-6.000731	-1.942170	0.0000	stable
Δ MP	-7.058510	-1.942159	0.0000	stable

From Table 3, the ADF statistics of the original series of the variables OP, EG, PL, TB, and MP are less than the corresponding 5% critical values, and the corresponding concomitant probability P-values are 0.0499, 0.0015, 0.0114, 0.0102, and 0.0317, respectively. Thus, the series is stable. Similarly, the ADF statistic of the original series of variable EX is greater than the corresponding 5% critical value and the series is not stable. The ADF statistics of the sequences EX, OP, EG, PL, TB, and MP after first-order differencing are less than the corresponding 5% critical values, so the first-order differenced sequences for each variable are stable.

3.3. Cointegration tests

Results of the trace test as shown in Table 4, it shows that each variable is a first-order single-integrated series, which fulfills the basic conditions of the cointegration test. In order to test whether there is a long-run equilibrium relationship between the variables selected in this paper, Johansen cointegration test is conducted on the variables EX, OP, EG, PL, TB, MP.

Table 4. Results of the trace test

Original hypothesis: number of cointegrating relationships	eigenvalue	trace statistic	5% critical value	P-value
None *	0.166829	122.8084	95.75366	0.0002
At most 1 *	0.119230	77.72683	69.81889	0.0102
At most 2	0.078540	46.36789	47.85613	0.0685
At most 3	0.047798	26.16420	29.79707	0.1239
At most 4	0.031241	14.06673	15.49471	0.0811
At most 5 *	0.024896	6.227142	3.841466	0.0126

From Table 4, at the 5% significance level, we can reject the null hypothesis of "no cointegration relationship", "at most one cointegration relationship", and "at most five cointegration relationships". Hence, there are at least two cointegration relationships between the variables selected in this paper, that is, there is a long-run equilibrium relationship between the variables EX, OP, EG, PL, TB, and MP.

3.4. Granger causality test

Granger causality test results as shown in Table 5, the variables EX, OP, EG, PL, TB, MP are stable and there is a cointegration relationship between the variables, which satisfies the basic requirements for conducting the Granger causality test.

Table 5. Granger causality test results

null hypothesis	F-statistic	P-value	conclusion
OP is not the Granger reason for EX	1.02539	0.4033	accept
EX is not the Granger reason for OP	0.75461	0.5834	accept
EG is not the Granger reason for EX	1.50483	0.1890	accept
EX is not the Granger reason for EG	2.86327	0.0157	reject
PL is not the Granger reason for EX	1.02590	0.4030	accept
EX is not the Granger reason for PL	0.69427	0.6283	accept
TB is not the Granger reason for EX	1.26129	0.2815	accept
EX is not the Granger reason for TB	2.53244	0.0296	reject
MP is not the Granger reason for EX	0.92781	0.4636	accept
EX is not the Granger reason for MP	0.57900	0.7161	accept

From Table 5, at the 5% significance level, international oil prices, economic growth, price level, trade balance, monetary policy are not Granger causes of RMB exchange rate changes. It indicates that there is no statistically significant causality between international oil prices, economic growth, price level, trade balance, monetary policy and RMB exchange rate.

3.5. Determination of the optimal lag order

In this paper, the optimal lag order of the SVAR model is determined according to the LR, FPE, AIC, SC and HQ minimization criteria, and results of variance decomposition are shown in Table 6. Under the LR criterion, the optimal lag order is 8. Under the FPE, AIC criterion, the optimal lag order is 3. Under the SC criterion, the optimal lag order is 1, and under the HQ criterion, the optimal lag order is 2. Therefore, the optimal lag order of SVAR model in this paper should be 3.

Table 6. Results of variance decomposition (own effects have been omitted)

Lag	LogL	LR	FPE	AIC	SC	HQ
0	-4220.883	NA	44871731	34.64658	34.73258	34.68122
1	-2602.226	3144.440	104.2522	21.67398	22.27595*	21.91642
2	-2526.596	143.2007	75.37610	21.34915	22.46709	21.79939*
3	-2488.428	70.39234	74.14383*	21.33137*	22.96530	21.98943
4	-2458.434	53.84020	78.07558	21.38061	23.53051	22.24647
5	-2429.260	50.93580	82.89526	21.43656	24.10243	22.51022
6	-2404.782	41.53240	91.64110	21.53100	24.71285	22.81247
7	-2374.448	49.97571	96.78510	21.57745	25.27527	23.06673
8	-2334.628	63.64716*	94.82868	21.54613	25.75993	23.24322

3.6. Model stability test

After the SVAR model is determined, this paper uses the AR unit root test to ensure whether the constructed SVAR model passes the stability test. The results of the AR unit root test are shown in

Figure 2. The inverse values of the AR unit root of the SVAR model are all in the unit circle, which indicates that the SVAR model constructed in this paper is reasonable and stable.

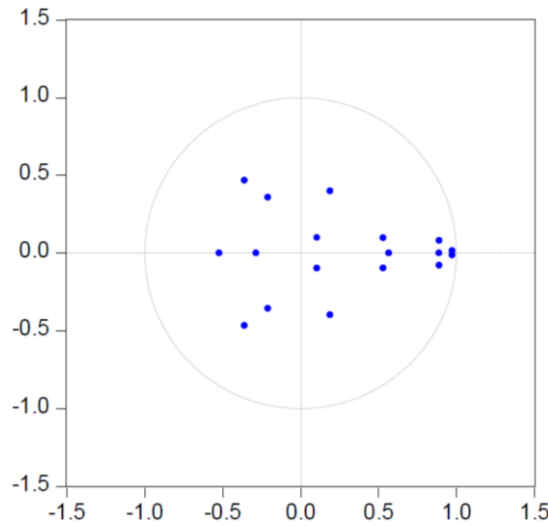


Figure 2. AR unit root test

3.7. Test of SVAR model estimation results

From Figure 2, it shows that the results of the SVAR model in this paper are reasonable and effective. Using the FIML method to estimate the parameters of the SVAR model, the specific results of the SVAR model obtained are as follows:

$$B_0^{-1}\mu_t = \begin{pmatrix} 0.06 & 0 & 0 & 0 & 0 & 0 \\ -0.99 & 6.32 & 0 & 0 & 0 & 0 \\ -0.71 & 0.56 & 4.46 & 0 & 0 & 0 \\ 0.01 & -0.03 & -0.17 & 0.49 & 0 & 0 \\ -0.98 & 0.42 & 6.43 & 1.28 & 9.93 & 0 \\ 0.06 & 0.08 & 0.01 & -0.06 & 0.07 & 0.83 \end{pmatrix} \begin{pmatrix} \mu_t^{mp} \\ \mu_t^{tb} \\ \mu_t^{pl} \\ \mu_t^{eg} \\ \mu_t^{op} \\ \mu_t^{ex} \end{pmatrix} \quad (5)$$

Based on the above SVAR model and coefficient matrix, further impulse response and variance decomposition analyses are carried out in order to study the direction and the degree of the impact of international oil prices, economic growth, price level, trade balance, and monetary policy on the RMB exchange rate.

3.8. Impulse response

The model is stable based on the results of the stability test of the model developed. The parameters in the SVAR model were estimated using the method of great informative likelihood (FIML). The results include $B_0^{-1}\mu_t$ and ε_t combination of linear equations, so as to further analyze the impulse response function of the RMB exchange rate in the SVAR model in response to shocks to oil prices, economic growth, prices, balance of payments, and monetary policy. Impulse response functions play a central role in assessing how and to what extent structural shocks affect the exchange rate, where the horizontal axis represents the number of tracking periods and the vertical axis the degree of response of the dependent variable. Specific results are presented below:

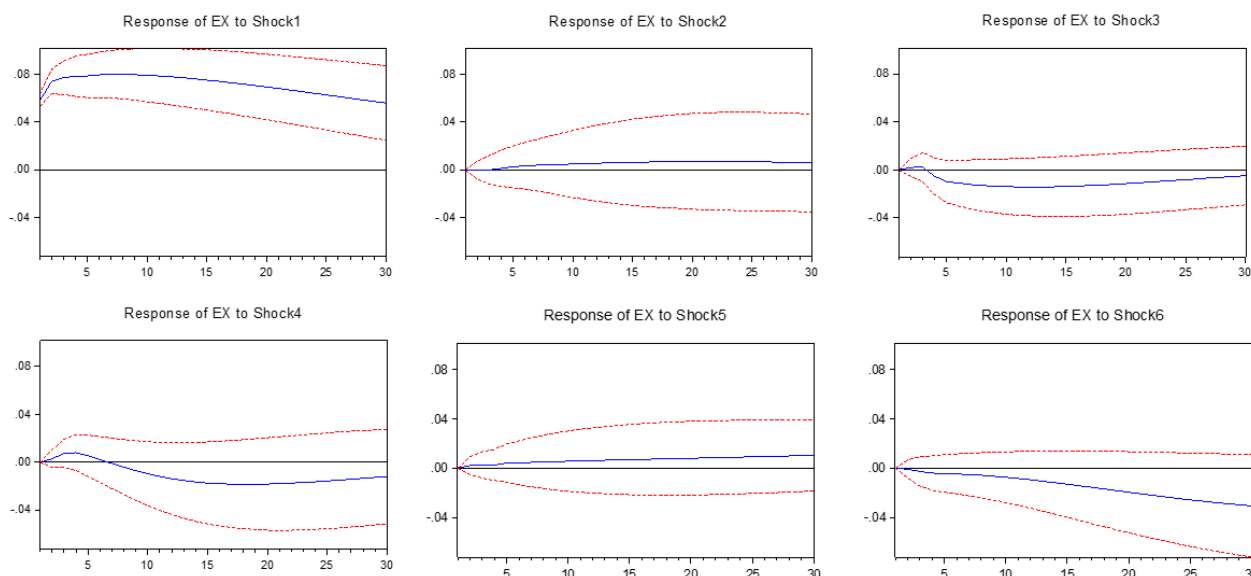


Figure 3. Impulse Response Function

Impulse Response Function as shown in Figure 3, the positive shock impact of RMB exchange rate EX on itself shows that in the first 30 periods, the rise of RMB exchange rate in the previous period will lead to the rise of RMB exchange rate in the current period. In the first 2 periods, the shock impact of RMB exchange rate on itself is incremental, and from the 3rd period onwards, the impact effect is gradually decreasing, but there is still a positive effect. The positive shock impact of RMB exchange rate on OP shows that in the first 30 periods, the increase of international oil price will cause the RMB exchange rate to increase. In the test period, the shock impact is relatively stable and always at a low level. The impact of RMB exchange rate on EG shows that the impact of RMB exchange rate on EG is positive from period 1 to period 3, the impact of economic growth on RMB exchange rate is positive. Since period 4, the shock impact of RMB exchange rate on EG is negative, that is, the impact of economic growth on RMB exchange rate is negative, and the impact effect tends to be 0 gradually with the increase of time. The positive shock impact of the RMB exchange rate to the PL shows that in period 7 and before, the price level has a positive effect on the RMB exchange rate. Starting from period 8, the RMB exchange rate shock impact to the PL is negative, the price level has a negative impact on the RMB exchange rate. The shock impact of RMB exchange rate on TB shows that the impact of RMB exchange rate on trade balance in the first 30 periods is positive, and the impact effect is gradually expanding, that is, there is a facilitating effect of the increase of trade balance on RMB exchange rate. The impact of RMB exchange rate on MP shows that the impact of RMB exchange rate on monetary policy in the first 30 periods is negative, and the impact effect is gradually expanding, that is, the decrease of trade balance can drive the increase of RMB exchange rate.

3.9. Variance decomposition analysis

The extent to which international oil prices, economic growth, price level, trade balance, and monetary policy explain the RMB exchange rate is further measured by conducting variance decomposition.

Table 7. Results of variance decomposition

Period	S.E.	Shock1	Shock2	Shock3	Shock4	Shock5	Shock6
1	0.057878	100.0000	0.000000	0.000000	0.000000	0.000000	0.000000
2	0.093956	99.79949	9.09E-05	0.049496	0.092088	0.051494	0.007344
3	0.121912	99.37619	8.64E-05	0.065792	0.431518	0.074538	0.051878
4	0.145309	99.01100	0.008586	0.176955	0.606953	0.085184	0.111324
5	0.165740	98.63763	0.030730	0.476957	0.572192	0.127699	0.154788
6	0.184344	98.37498	0.058975	0.742139	0.474590	0.159426	0.189894
7	0.201536	98.11865	0.086769	0.980916	0.399714	0.186610	0.227343
8	0.217462	97.82887	0.113743	1.195972	0.379844	0.215376	0.266200
9	0.232321	97.49389	0.139854	1.385095	0.425483	0.242454	0.313224
10	0.246277	97.11188	0.164667	1.552703	0.532005	0.268993	0.369747

Results of variance decomposition as shown in Table 7, the variance of the RMB exchange rate is basically caused by its own perturbation, and the degree of influence of the RMB exchange rate gradually shrinks over time, decreasing from 100% in the first period to 97.11188% in the 10th period. The degree of explanation of the RMB exchange rate by international oil price, economic growth, price level, trade balance, and monetary policy gradually expands over time.

4. Conclusion

This paper uses monthly data from January 2002 to December 2022, and chooses the RMB exchange rate, West Texas light crude oil price, economic growth, prices, trade balance and monetary policy as variables. Through the SVAR model, the paper analyzes the effects of oil price shocks as well as other five shocks on the trend movements of China's real exchange rate, and the following conclusions are obtained:

From the trend of WTI price and RMB exchange rate, there is a spillover effect between the fluctuation of international oil price and the change of RMB exchange rate, but the correlation becomes more complicated over time.

Use Johansen cointegration test to validate the selected sample interval and the results show that there is a long-run cointegration relationship between international oil prices and the RMB exchange rate.

The Granger causality test concludes that there is no statistically significant causal relationship between the international oil price RMB exchange rate.

According to the results of the impulse response function analysis, the shock impact of the RMB exchange rate on its own is positive, the impact on the oil price is positive, the impact on economic growth is negative, the impact on the price level is negative, the impact on the trade balance is positive, and the impact on the monetary policy is negative.

According to the analysis of variance decomposition, the movement of RMB exchange rate is basically caused by its own perturbation.

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