The impact of the Fed's interest rate hike on China's macroeconomy: Based on the TVP-VAR model

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Abstract. This paper employs a Time Varying Parameter-Vector Auto regression (TVP-VAR) model to comprehensively examine the impact of the Federal Reserve's interest rate hikes on China's macroeconomy. The study reveals that the Federal Reserve's interest rate hike policy significantly affects China's interest rates, exchange rates, and capital markets, leading to reduced capital liquidity and increased exchange rate pressures. Additionally, this paper finds that the interest rate hike cycle is highly correlated with fluctuations in China's stock market, increasing market uncertainty and affecting investor confidence and market stability. Finally, the paper proposes policy recommendations such as enhancing monetary policy flexibility, stabilizing exchange rate policies, and strengthening financial market transparency to provide references for policy formulation amid global financial volatility.

Keywords: Federal Reserve interest rate hike; Chinese economy; TVP-VAR model.

1. Introduction

Since the mid-1980s, economic globalization has not only driven international trade and investment but also made national economies more susceptible to global market fluctuations. With the outbreak of the global pandemic, economic activities halted abruptly, leading the Federal Reserve to implement unprecedented easing measures. These included lowering the federal funds rate target range to 0% to 0.25% and implementing unlimited quantitative easing. By 2022, as the Fed phased out its easing policies and raised U.S. Treasury yields, global capital flows shifted, causing a stronger dollar and significant impacts on emerging market economies, particularly China.

Research has extensively studied the relationship between U.S. monetary policy and other countries' economic trends. Scholars like Bluedorn and Bowdler, and Dedola et al. noted the mixed effects of U.S. monetary policy [1-2]. Walerych and Wesołowski analyzed its significant spillover effects on emerging markets using the Panel Bayesian Vector Autoregression (BVAR) model [3]. Coutino and Jarocinski identified the immediate impacts of Fed policies on global financial markets through SVAR and other models [4-5]. Additionally, Arshad et al. used the Quantile-on-Quantile (QQR) method to show that U.S. monetary policy uncertainty significantly harms stock returns in Asian markets [6]. Similarly, Kyriazis et al. analyzed the broad impact of this uncertainty across various financial markets, highlighting its profound effect on market volatility [7].

Despite extensive research, most studies using VAR or SVAR models assume parameter stability throughout the sample period, failing to capture dynamic changes over time. Hanisch suggests that discrepancies in research findings stem from using aggregate analysis rather than country-specific modeling [8]. The Time-Varying Parameter Vector Autoregression (TVP-VAR) model is proposed as more effective for reflecting economic relationship dynamics and analyzing specific impacts of policy changes.

This paper aims to explore the Fed's rate hike policy impact on China's macroeconomy using the TVP-VAR model. This research employs key economic indicators such as the Fed's federal funds rate, Chinese interest rates, and stock market data to analyze the dynamic impacts of Fed rate hikes.

This study will help policymakers in China and other emerging economies understand the mechanisms to respond to external shocks and provide recommendations for enhancing monetary policy flexibility and financial market efficiency.

2. Research Methodology

2.1. TVP-VAR Model

Given that the TVP-VAR model can effectively capture the dynamic responses of macroeconomic variables to external shocks at different periods, it is suitable for analyzing the impact of policy changes on economic variables. Therefore, we apply this model in our study.

The TVP-VAR model is an extension of the traditional Vector Auto regression (VAR) model, in which the model parameters are allowed to vary over time. This flexibility enables the model to better capture the changing interdependencies among macroeconomic variables. The model is generally represented as follows:

$$Y_t = \Phi_0(t) + \Phi_1(t)Y_{t-1} + \ldots + \Phi_p(t)Y_{t-p} + \varepsilon_t \quad (1)$$

Here, $Y_t$is the vector that includes all the variables under study, Φ_t (i = 0,…, p)is the time-varying coefficient matrix, and e_t represents the error term, which is assumed to follow a multivariate normal distribution with a mean of zero and a time-varying covariance matrix.

The parameters of the TVP-VAR model are estimated using Bayesian methods, particularly the Markov Chain Monte Carlo (MCMC) technique. This technique effectively handles the posterior distribution of the parameters, especially when the number of parameters is large and their distribution is difficult to solve directly. The parameter updating process in the model adopts a random walk, ensuring the flexibility and adaptability of the parameter estimation. For the specific parameter estimation, this paper refers to the study by Nakajima [9].

To ensure the reliability of the estimates, the TVP-VAR model employs the Geweke convergence diagnostic to test the convergence of the model parameters. The Geweke test compares the mean differences between different segments of the Markov chain to determine if the stationary distribution of the chain has been achieved. The model is considered to have converged only when the Geweke diagnostic statistics for all key parameters are close to zero.

2.2. Variable Selection and Data Sources

Referring to the existing literature by Deng & Zha [10], this paper selects the following seven variables for analysis: the Federal Reserve's federal funds rate, China's interest rate, China's exchange rate, the Shanghai Composite Index, China's Producer Price Index (PPI), the growth rate of China's money supply, and the interest rate differential between the United States and China. The daily data for these variables are converted into monthly data using arithmetic means. To ensure the stationarity of the data, a first-order differencing process is applied. The study period spans from February 2015 to December 2023. The data for this research are sourced from the National Bureau of Statistics of China and the Wind database. The meanings of the related variables are as follows:

Federal Funds Rate(**Effr**): To study the impact of the Federal Reserve's interest rate policies on the Chinese economy, this paper uses the Federal Reserve's federal funds rate as a proxy variable. An increase in this rate indicates the Federal Reserve has implemented a rate hike policy, while a decrease indicates a rate cut policy.

China's Interest Rate(**Interest**): This paper uses China's interest rate to reflect the changes in interest rates. An increase in the interest rate suggests that the People's Bank of China has adopted a rate hike policy, while a decrease suggests a rate cut policy.

China's Exchange Rate(**Exrate**): The paper uses the real effective exchange rate as a proxy variable to reflect the purchasing power and competitiveness of the Chinese currency in the international market. An increase in the real effective exchange rate represents an appreciation of the

renminbi (RMB) relative to a basket of currencies, indicating a potential decline in the international competitiveness of Chinese products. Conversely, a decrease indicates a depreciation of the RMB, potentially enhancing the competitiveness of export enterprises.

Shanghai Composite Index(**Index**): The Shanghai Composite Index is used as a proxy variable for Chinese stock prices to measure the overall performance of the stock market. An increase in the Shanghai Composite Index typically indicates growing investor confidence in the Chinese economy and good stock market performance, while a decrease may suggest increasing market uncertainty and weakening investor confidence.

China's Producer Price Index (**PPI**): The Producer Price Index is used to measure changes in price levels at the production stage in China. This indicator effectively represents fluctuations in production costs in the macroeconomy.

Growth Rate of China's Money Supply($\mathbf{M_2}$): The growth rate of China's M_2money supply is selected as a proxy variable for monetary policy. Changes in the money supply can be seen as indicators of the central bank's monetary policy stance, either expansionary or contractionary, which directly impacts economic activity and inflation.

Interest Rate Differential between the United States and China(**Interest_diff**): This paper uses the interest rate differential between the United States and China as a proxy variable for the differences in monetary policies between the two countries. The differential is calculated as the difference between the U.S. federal funds target rate and China's one-year benchmark deposit rate. An increase in the U.S.-China interest rate differential generally indicates increased pressure on cross-border capital flows, potentially leading to exchange rate volatility and changes in cross-border investment behavior.

3. Empirical Results Analysis

To study the spillover effects of the Federal Reserve's interest rate hikes on the Chinese economy, this section employs the TVP-VAR model. The federal funds rate is used as the shock variable, and the impact of the United States' contractionary monetary policy on the Chinese economy is analyzed from five aspects: interest rate transmission, exchange rate transmission, price transmission, capital market transmission, and monetary policy transmission.

3.1. Stationarity and Cointegration Tests

3.1.1. Stationarity Test

Before conducting the TVP-VAR model analysis, it is necessary to test the stationarity of the data. To reduce the impact of heteroskedasticity, the natural logarithm of the federal funds rate is taken, and the collected data are subjected to the Augmented Dickey-Fuller (ADF) test. The results show that, except for the Shanghai Composite Index and the Producer Price Index, which can reject the null hypothesis (i.e., the variables are stationary), the other five variables cannot reject the null hypothesis (i.e., the variables are non-stationary). However, after performing a first-order differencing on the selected indicators, all variables can reject the null hypothesis, indicating that all data series are stationary and have no unit roots. The test results are shown in Table 1.

Table 1. Stationarity Test Results.

Index name	Inspection method	Statistic	Probability value	Conclusion
Effr	ADF	-1.6001	0.4836	Non-stationary
⊿Effr	ADF	-6.7701	0.0000	stationary
Interest	ADF	-2.8198	0.0555	Non-stationary
⊿Interest	ADF	-8.1576	0.0000	stationary
Exrate	ADF	-1.9429	0.3121	Non-stationary
⊿Exrate	ADF	-7.2102	0.0000	stationary
Index	ADF	-2.9253	0.04249	stationary
PPI	ADF	-3.6562	0.0048	stationary

M_2	ADF	-1.8474	0.3572	Non-stationary
ΔM_2	ADF	-5.2989	0.0000	stationary
Interest_diff	ADF	-0.6223	0.8659	Non-stationary
ΔInterest_diff	ADF	-7.4807	0.0000	stationary

3.1.2. Cointegration Test

Due to the existence of non-stationary series in the original variable sequences, the Johansen cointegration test was conducted. The test results are shown in Table 2. The results in Table 2 indicate that, because the test statistics for $\mathbf{r \leq 1}$ are greater than the critical values at various confidence levels, the null hypothesis can be rejected, meaning that there are at least two sets of long-term stable relationships among the variables.

Table 2. Johansen Cointegration Test Results.

Cointegration	10pct	5pct	1pct
$r = 0$	126.58	131.70	143.09
$r \leq 1$	97.18	102.14	111.01
$r \leq 2$	71.86	76.07	84.85

3.2. Model Parameter Estimation Results

To better address structural changes and capture the complex dynamic relationships among variables, we establish a TVP-VAR model covering the period from February 2015 to December 2023. Based on the Akaike Information Criterion (AIC) and the Schwarz Criterion (SC), the lag order of the model is set to 2. The number of iterations for the MCMC simulation is set to 10,000. Given that the initial 1,000 iterations may exhibit unstable characteristics as a burn-in phase, this portion of the data is excluded from the final analysis to ensure the stability of the results.

The parameter estimation results of the TVP-VAR model are shown in Table 3. All maximum ineffective factor values are less than 100, and the null hypothesis can be rejected at the 5% significance level. This indicates that the 10,000 MCMC simulation iterations are effective.

Table 3. Stability Test Results of TVP-VAR Model Parameters.

Parameter	Mean	Stdev	95% confidence interval	Geweke	Inef.
sb_1	0.0227	0.0026	[0.0183 , 0.0285]	0.134	8.37
sb_2	0.0224	0.0025	[0.0182 , 0.0280]	0.246	4.42
sa_1	0.0801	0.0332	[0.0418 , 0.1688]	0.581	55.52
sa_2	0.0796	0.0303	[0.0411 , 0.1586]	0.614	36.58
sh_1	0.6475	0.1379	[0.4084 , 0.9512]	0.126	32.82
sh_2	0.5153	0.1414	[0.2807 , 0.8278]	0.378	28.32

3.3. Analysis of Time-Varying Impulse Response Functions

This study uses the federal funds rate as the shock variable and selects the shock points based on the intensity of the rate hikes. The three major rate hike shock points chosen are December 2015, December 2017, and September 2018. We calculate the time-varying impulse response functions of the Federal Reserve's rate hikes on China's interest rate, exchange rate, Shanghai Composite Index, Producer Price Index (PPI), money supply growth rate, and interest rate differential, analyzing and comparing the spillover effects of these three major rate hikes.

Referring to the study by Deng & Zha, the six variables mentioned above are categorized into economic variables and financial variables for research and analysis [10]. Economic variables include the interest rate, exchange rate, and Shanghai Composite Index, while financial variables comprise the Producer Price Index (PPI), money supply growth rate, and the U.S.-China interest rate differential. By distinguishing between economic and financial variables, this study enhances the structural and systematic nature of the research. This allows for a more precise assessment of the sensitivity and response patterns of these variables to policy changes and reveals the interdependencies and transmission mechanisms between the economic and financial sectors.

3.3.1. Analysis of the Impulse Response Functions of Chinese Financial Variables to Federal Reserve Rate Hikes

Fig. 1-3 displays the impulse response curves of China's interest rate, exchange rate, and Shanghai Composite Index from top to bottom. These three graphs illustrate the impact of the Federal Reserve's rate hikes on Chinese financial variables.

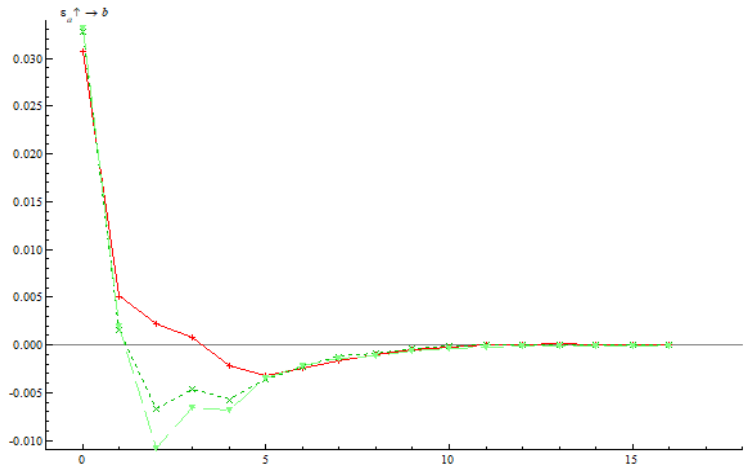

Fig 1. Impulse Response Curve of China's Interest Rate.

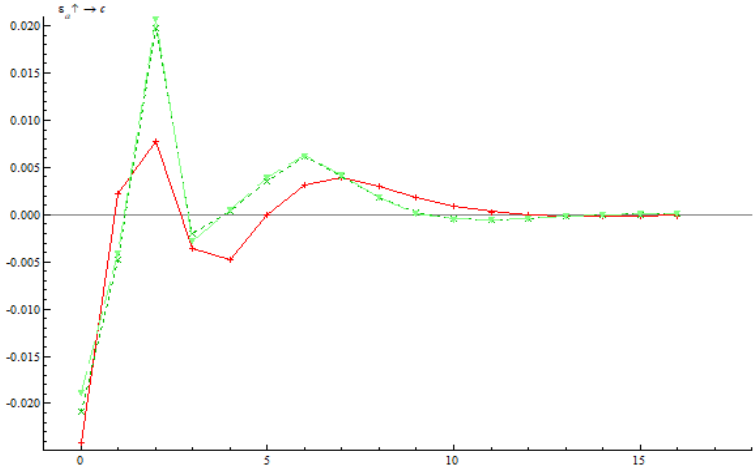

Fig 2. Impulse Response Curve of China's Exchange Rate.

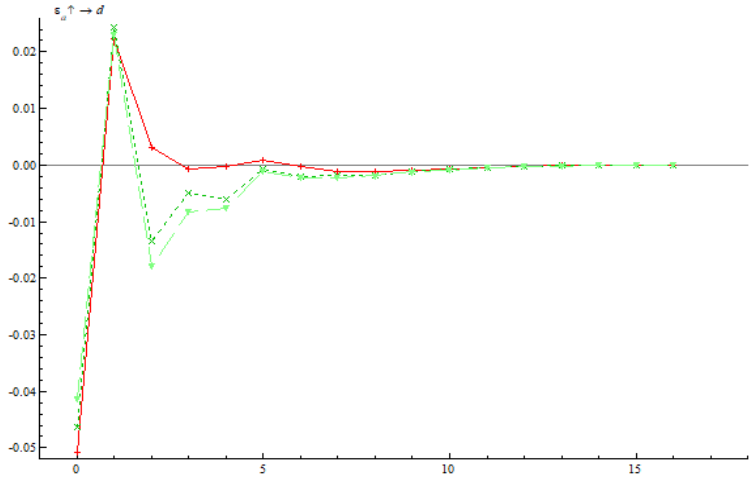

Fig 3. Impulse Response Curve of the Shanghai Composite Index.

The impulse response curve of China's interest rate (Fig. 1) shows that, following the three rate hike points, the short-term response curves of interest rate changes are all above the zero line, indicating that the Federal Reserve's rate hikes have a significant positive impact on China's interest rates, and this impact is swift. This is because the rate hikes by the Federal Reserve lead to a substantial depreciation of the Chinese currency, prompting the People's Bank of China to raise interest rates to maintain currency stability and prevent capital outflows. However, this positive impact trend declines rapidly after one period and falls below the zero line at different times: after 5 periods (December 2015), 2 periods (December 2017), and 1 period (September 2018), indicating a shift to a negative impact. This phenomenon occurs because the central bank implements countermeasures against the rate hikes, and as the market adjusts to the pace and eventual level of the Federal Reserve's rate hikes, the interest rate undergoes a negative adjustment. This negative impact gradually diminishes and approaches zero after 10 periods. Throughout the entire process, the positive impact on interest rates due to the December 2015 rate hike is greater than the other two shock points, especially within the first three periods. Conversely, the negative impact on interest rates from the December 2015 rate hike is significantly less than that of the other two points.

The impulse response curve of China's exchange rate (Fig. 2) shows that the response curve is not stable, indicating that the Federal Reserve's rate hikes have a structural impact on China's exchange rate. The two impulse response curves for the shock points in December 2017 and September 2018 are highly coincident. Initially, the shocks at the three rate hike points bring about a significant negative impact on the exchange rate, peaking in the depreciation of the Chinese currency. After approximately one period, the impact turns positive, reaching its highest value at two periods, suggesting that China quickly intervened with strict foreign exchange controls to temporarily slow the depreciation. However, due to the significant rate hikes by the Federal Reserve, China could not completely offset the spillover effects, and the positive impact gradually decreased, turning negative again between the third and fourth periods, reaching the peak of negative shocks. The impact continues to weaken, returning to positive between the fourth and fifth periods, and the positive impact of the Federal Reserve's rate hikes on the exchange rate diminishes, approaching zero after 10 periods. The multiple crossings of the zero line in the three curves highlight the structural changes in the exchange rate. Additionally, the positive impact on the exchange rate from the rate hikes in December 2017 and September 2018 is significantly higher than that from December 2015, particularly from the first to the seventh periods. This suggests that with multiple rate hikes, the central bank's policy adjustments became quicker, and market participants actively adjusted their investments and asset allocations, resulting in smaller negative impacts on the exchange rate during the latter two rate hikes.

The impulse response curve of the Shanghai Composite Index (Fig. 3) shows that the index is negatively impacted by the selected three rate hikes, and the degree of impact is similar, indicating that the magnitude of the capital outflows is almost the same for each shock. As the negative impact gradually weakens, all three shock curves cross above the zero line at about 0.5 periods, reaching the peak of positive impact at one period. As the positive impact diminishes, the two shock curves for December 2017 and September 2018 cross below the zero line again at approximately 1.7 periods, reaching the peak of negative impact at two periods, then gradually weakening and eventually approaching the zero line. The curve representing the December 2015 shock point falls below the zero line only after 3-4 periods, but the negative impact on the index afterward is very weak and negligible. Overall, the shocks from December 2017 and September 2018 have a more pronounced negative impact on the index compared to the shocks from December 2015. This suggests a more pessimistic outlook on the market, especially the real economy, in recent years.

3.3.2. Analysis of the Impulse Response Functions of Chinese Economic Variables to Federal Reserve Rate Hikes

Fig. 4-6 displays the impulse response curves of China's Producer Price Index (PPI), money supply growth rate, and the U.S.-China interest rate differential from top to bottom. These three graphs illustrate the impact of the Federal Reserve's rate hikes on Chinese economic variables.

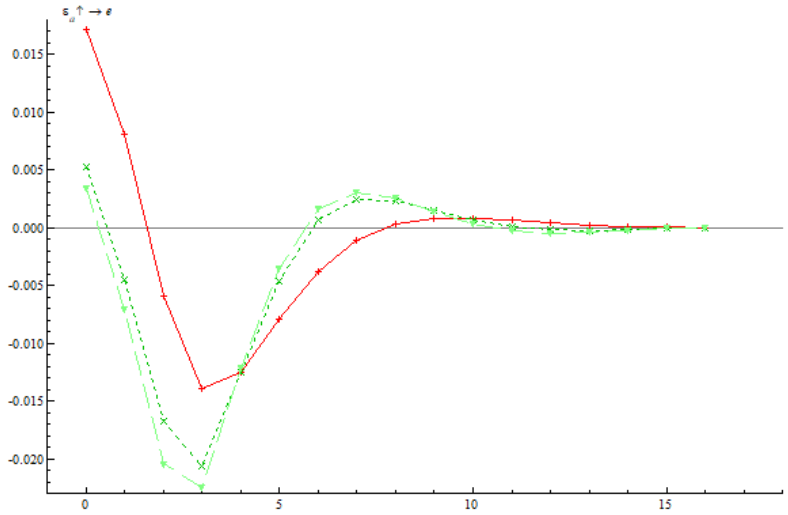

Fig 4. Impulse Response Curve of China's Producer Price Index (PPI).

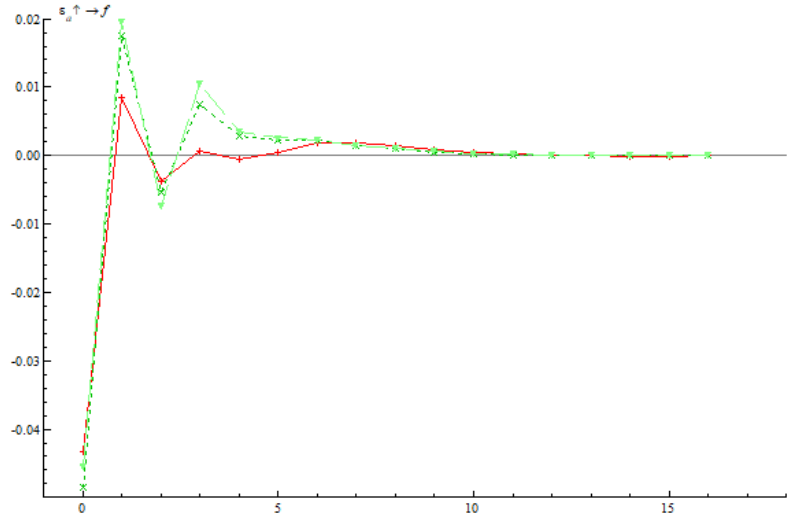

Fig 5. Impulse Response Curve of China's Money Supply Growth Rate.

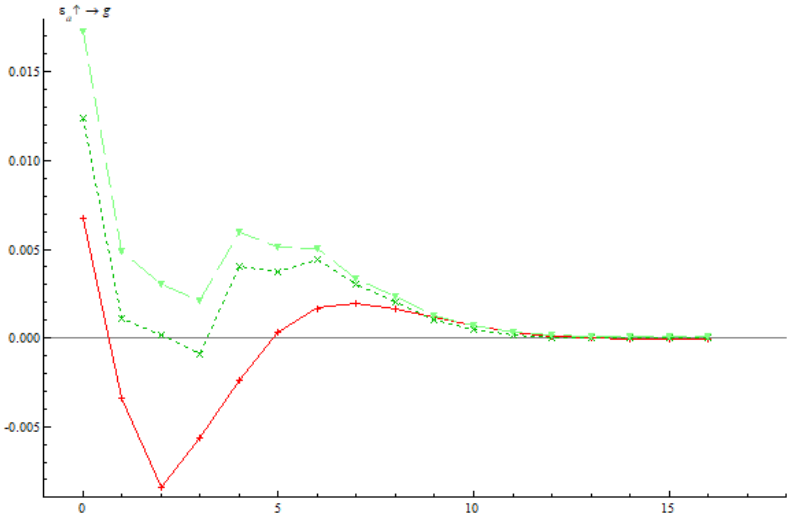

Fig 6. Impulse Response Curve of the U.S.-China Interest Rate Differential.

In the wake of the three selected rate hike shocks, the Federal Reserve's rate hikes may increase global capital costs, impacting the prices and costs of commodities (Fig. 4). Therefore, the PPI shows

a positive shock, with the curve above the zero line. The shock in December 2015 causes an initial rise in the PPI, which falls below the zero line after 1.5 periods. The shocks in December 2017 and September 2018 also lead to a short-term rise in the PPI but fall back to the zero line within 0.5 periods. All three curves reach the peak of negative shocks at 3 periods, after which the impact gradually diminishes. After briefly returning to positive impact in the short term, the curves approach the zero line. Overall, during the observation period, the negative impact on the PPI is predominant after the three shocks, with the December 2017 and September 2018 shocks having a greater impact. During this period, the global economic slowdown deepened, further reducing the demand for goods and services, leading to a decline in the PPI.

The impulse response curves for the money supply growth rate at the shock points of December 2017 and September 2018 are highly coincident (Fig. 5). Following the three shocks, the Federal Reserve's contractionary monetary policy immediately shows a negative impact on the money supply growth rate, with the curves below the zero line. However, towards the end of the first period, the negative impact gradually diminishes and swiftly turns into a positive impact, reaching the highest value of positive shock within the entire period at one period. This indicates that the rate hike shock by the Federal Reserve reduced the short-term money supply gap in China. Subsequently, around the second period, the curves briefly dip below the zero line, bringing positive shocks to the money supply growth rate for the remaining period. During the observation period, the positive shocks on the money supply growth rate dominate, with the shocks in December 2017 and September 2018 having a greater impact. The People's Bank of China's monetary policy coordinates with the Federal Reserve's policy to some extent. The Chinese government may frequently conduct open market operations, foreign exchange interventions, and other measures to mitigate the negative impacts of the Federal Reserve's policy and maintain financial market stability.

The shocks on the interest rate differential exhibit different behaviors at each of the three rate hike points (Fig. 6). Under the December 2015 rate hike, the curve initially shows a positive shock, but the positive impact on the interest rate differential gradually weakens, reaching the peak of negative impact at 2 periods. In the subsequent three periods, the negative impact diminishes, returning to the zero line at 5 periods, then maintaining a weak positive shock and gradually returning to the zero line. The curve representing the December 2017 shock consistently remains above the zero line, maintaining a positive impact throughout but showing a declining trend. The curve for the September 2018 shock is similar to that of December 2017, dipping briefly below the zero line around the third period, but remaining above the zero line for the rest of the time.

4. Discussion on the Impact of Federal Reserve Rate Hikes on China and Other Countries

The Federal Reserve's rate hikes, as a significant event in global financial markets, have profound impacts not only on China but also on other emerging markets and developing countries. Particularly among the other BRICS countries (Brazil, Russia, India, and South Africa), this policy shift has triggered a series of economic responses, making the analysis crucial for helping emerging economies to cope with changes in the global financial environment effectively.

From an interest rate perspective, the Federal Reserve's contractionary monetary policy leads to short-term interest rate hikes, a trend common among the BRICS countries. Although this impact gradually weakens over time, the capital flow trends are significant. A large inflow of capital into the United States increases the depreciation pressure on other countries' currencies, affecting their macroeconomic stability.

In terms of exchange rates, China's response differs from other BRICS countries. During the Federal Reserve's rate hikes, China's exchange rate shows a relatively stable downward trend, partly due to timely policy interventions by the Chinese government. In contrast, other BRICS countries experience more frequent and severe exchange rate fluctuations, reflecting instability in the global financial market. This difference highlights China's strategic and effective adjustments in foreign

exchange policy, particularly in mitigating direct market pressures through RMB to USD policy adjustments.

Regarding the growth rate of money supply, the Federal Reserve's policy changes impact BRICS countries to varying degrees. For example, Brazil sees a reduction in the money supply gap in the short term, likely a direct result of initial capital inflows. Mid-to-long-term observations show a trend of reduced domestic money supply due to capital outflows. Correspondingly, China and Russia also show a reduction in the money supply gap in the short term, but a long-term trend of increasing money supply gaps. This phenomenon is also observed in India and South Africa. The Federal Reserve's rate hikes have sustained impacts on these countries' monetary policies and market expectations.

5. Conclusions and Policy Recommendations

5.1. Conclusions

From the above analysis, it is evident that the Federal Reserve's rate hikes have significantly demonstrated spillover effects on the Chinese economy. These effects vary across different time periods and among different economic and financial variables, reflecting the complexity of China's economic fundamentals and its sensitivity to external shocks. Specifically, the Federal Reserve's policy adjustments have various degrees of impact on China's interest rates, exchange rates, stock markets, and monetary policy, closely related to China's macroeconomic policies at different times.

In terms of interest rates, the Federal Reserve's rate hikes exert upward pressure on China's short-term and long-term interest rates, particularly during periods of significant changes in Federal Reserve policy expectations. This pressure raises domestic capital costs, suppressing corporate investment and household consumption, posing challenges to sustained economic growth.

Regarding exchange rates, the RMB/USD exchange rate is directly affected. After each Federal Reserve rate hike decision, the RMB shows a short-term depreciation trend. Although the People's Bank of China promptly adjusts policies through foreign exchange interventions to stabilize the exchange rate, this increases the pressure on the nation's foreign exchange reserves and highlights the domestic market's sensitivity to external shocks.

In the stock market, the Federal Reserve's policy adjustment cycles are highly correlated with fluctuations in the Chinese stock market. Particularly during Federal Reserve rate hikes, increased market uncertainty leads to capital outflows, adding pressure to the stock market, affecting investor confidence, and market stability.

On monetary policy, the Federal Reserve's contractionary policy forces the People's Bank of China to balance pursuing monetary policy independence and responding to external pressures. As the global capital reallocation induced by U.S. rate hikes affects China's money supply growth rate, the central bank needs to adjust monetary policy to prevent excessive capital outflows and control inflation expectations.

Overall, the spillover effects of the Federal Reserve's rate hikes on Chinese economic variables are more pronounced than on financial variables, significantly impacting real economic activities. This differentiation emphasizes the need for agile adjustments and forward-looking planning of macroeconomic policies to reduce the potential negative impacts of external shocks on the domestic economy.

5.2. Policy Recommendations

1. Enhance Flexibility and Proactivity of Monetary Policy: The People's Bank of China should consider enhancing its ability to respond to external shocks when formulating monetary policies. Implementing more flexible and proactive interest rate adjustment strategies can mitigate the impact of external monetary policy adjustments on the domestic economy.

2. Stabilize Exchange Rate Policy: The Chinese government and regulatory authorities need to take effective measures to stabilize the exchange rate and reduce market volatility caused by Federal

Reserve policy changes. This includes strengthening foreign exchange market regulation to ensure exchange rate stability, thereby protecting exporters from negative impacts.

3. Improve Transparency and Efficiency of Financial Markets: Strengthening the infrastructure of capital markets, improving market transparency, and ensuring effective market operation. By improving the regulatory framework of financial markets, boosting the confidence of market participants, and reducing excessive market volatility.

4. Strengthen the Application of Macroprudential Policy Tools: Enhancing the monitoring of financial system stability, especially cross-border capital flows. Utilizing macroprudential policy tools, such as capital flow management measures, to guard against potential external risks.

5. Promote Domestic Consumption and Investment: Expanding domestic demand, increasing public investment, and promoting domestic consumption to reduce reliance on external economic changes. The government can consider implementing more policies to stimulate domestic demand, such as tax cuts and increased public service spending, to promote economic growth and employment.

Table 3. Abbreviations.

PPI	Producer Price Index
VAR	Vector Auto Regression
SVAR	Structural Vector Auto Regression
BVAR	Bayesian Vector Auto Regression
TVP-VAR	Time Varying Parameter-Vector Auto Regression
TVP-FAVAR	Time Varying Parameter-Factor Augmented Vector Auto Regression
QQR	Quantile-on-Quantile
OECD	Organisation for Economic Co-operation and Development
MCMC	Markov Chain Monte Carlo
ADF test	Augmented Dickey-Fuller Test
AIC	Akaike Information Criterion
SC	Schwarz Criterion

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