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Research Article

Liquidity, Asset Price Volatility, and Monetary Policy Choices: Empirical Evidence from China

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This article effectively identifies the high and low volatility state of asset prices in China by constructing the MS-AR model, and further investigates the relationship between different dimensions of liquidity and asset price volatility. Moreover, we try to incorporate liquidity into the analytical framework and adopt the TVP-SV-VAR model to study the time-varying characteristics between monetary policy, liquidity, asset price volatility and macroeconomy. The results are as follows: firstly, it shows that the high or low volatility state of China's stock market and real estate market can be clearly divided, and display the consistency with the trend of asset price volatility. Secondly, liquidity has a strong ability to explain the high and low volatility state of asset prices, but it shows some hysteresis effects. Thirdly, the time-varying results reveal that monetary policy has a regulating effect on liquidity, and the response cycle of quantitative monetary policy is relatively short, which reflects the effects of macroeconomy precisely. However, price-based monetary policy has a longer response cycle and plays a vital role in the anticipatory adjustment and fine-tuning of asset price volatility. These conclusions can provide an explanation for the attention to asset price bubbles and potential financial risks, and offer decision-making references for the central bank to implement differentiated and dynamic monetary policy choices.

1. Introduction

In recent years, the global economy has shown the characteristics of periodicity and volatility. The most direct reflection is the sensitivity of asset prices; especially, the condition of asset prices dominated by the stock market and real estate market should be attracted more attention, which has different effects on financial stability and regional development. Generally, liquidity plays a vital role in the main factors that drive the fluctuations in asset prices [1, 2], it is not only the vitality of financial markets but also the blood carrier of financial allocation resources. Its different trends will eventually be transmitted to capital markets through various channels [3, 4], which can affect asset prices in -different fields and lead to sharp fluctuations in asset prices. The actual performance of the systemic financial crisis and debt crisis in all countries of the world has demonstrated that the deleveraging process is accelerated, which can lead to the obvious trend of liquidity tightening [5]. By contrast, the past decade has witnessed the rapid growth of credit scale and money supply in China, which exacerbate the excess liquidity. The volatility of asset prices such as the stock market and real estate market may frequently lead to risks. If the liquidity problem is not handled properly, it will directly affect capital market and national economic growth [6, 7]. On the one hand, it can intensify the accumulation of economic risks and increase the possibility of financial crises, such as the real estate bubble and the "subprime crisis" in the United States. On the other hand, it can restrict the rational decision-making of microsubjects and interfere with normal economic operations, such as the "lost twenty years" and the phenomenon of balance sheet recession in Japan.

With the rapid development of China's capital market, asset prices are increasingly closely linked to the stability of

the financial system, the real economy, and monetary policy. Liquidity has been attracted more attention by the markets, government departments, and monetary authorities in China. Previous studies show that liquidity has a strong ability to explain asset price volatility, especially when there is speculative trading in the market, which may strengthen the positive feedback spiral effects between asset price volatility and liquidity [1], thus inducing abnormal asset price fluctuations. However, the tightness of liquidity needs to be dynamically adjusted according to the actual situation of the markets. It is worth mentioning that monetary policy plays a driving role in the regulation of liquidity and has significant impacts on asset price volatility through liquidity transmission [8]. Expansionary monetary policy can stimulate the economy when economic activity is depressed, but excessive money chasing limited financial assets may lead to a rapid rise in asset prices such as the real estate, stock market and bulk commodities, which will give rise to asset bubbles. In order to prevent the economic crisis caused by the sudden bursting of asset bubbles, the central bank often adopts a prudent monetary policy and gradually reduces the amount of money to prevent the bubbles from further enlarging. In the face of downturn economy and increased financial risks, monetary policy is the key to the steady progress of reforms [9, 10], especially how to better guide monetary policy to keep a reasonable, sufficient, and effective liquidity is particularly important [11]. The liquidity of medium-sized banks and nonbank institutions has recently been under pressure, but the overall liquidity of China's financial market is still in a reasonable range. The shift of monetary policy to easing in many countries around the world also creates much more space for China's monetary policy adjustment. Moreover, as an vital monetary policy transmission channel in China, asset prices are increasingly closely linked with financial stability and the real economy, which will profoundly affect macroeconomy such as output and inflation, and imply some information needed for monetary policy choices [12, 13]. Therefore, the specific choices of monetary policy still need to be studied in depth, which plays an important role in regulating liquidity to deal with asset price volatility [14].

Hence, monetary policy should pay attention to the liquidity characteristics of asset price cycle and the implied information of asset price volatility, which maintains the dual goals of financial and price stability. So we try to investigate the feedback mechanisms among liquidity, asset price volatility and monetary policy, and relevant hypotheses can be proposed to further empirically test. On the one hand, from the perspective of liquidity, currency liquidity can affect asset price volatility through banking system liquidity and market liquidity, and shows the spiral effect of the actual impact on asset prices. When liquidity is affected by external shocks, market liquidity interacts with banking system liquidity to form downward or upward liquidity spiral, accompanied by continuous decline of asset prices or accumulation of asset bubbles [15–17]. Therefore, this paper puts forward the first key hypothesis, that is, liquidity of different dimensions can affect asset price volatility through various channels, and has obvious time-varying characteristics. On the other hand, from the perspective of monetary policy choices, quantitative and price-based monetary policy regulation in China can reflect liquidity conditions in different dimensions, and act on the economic and financial system by adjusting money supply and interest rate respectively [18]. Quantitative monetary policy is more favorable to monetary liquidity regulation, but may easily form the real estate bubbles. The transmission mechanism of price-based monetary policy is more market-oriented and flexible, which is more sensitive to the adjustment of banking system liquidity and market liquidity. It is conducive to the development of stock and bond markets, and can effectively improve the negative impact of quantitative transmission [19]. Moreover, as the process of interest rate liberalization in China still needs to be advanced, the transmission mechanism of monetary policy may have a certain lag [20, 21]. Monetary policy choices may steadily step up discretionary and counter-cyclical adjustment to better maintain liquidity and continue to ease economic structural problems. Therefore, the second key hypothesis is proposed in this paper, that is, the effectiveness of the main transmission channel of monetary policy determines its implementation effects, which plays a key role in adjusting liquidity of different dimensions to cope with asset price volatility and maintain macroeconomic stability in the long run.

More importantly, under the impact of "black swans" such as the COVID-19 pandemic and plummeting oil prices, global asset prices have experienced rapid fluctuations in early 2020, which has caused a significant impact on the world economy, especially in emerging economies. Based on the above, this paper focuses on the state transition mechanism of asset price volatility, and analyses the relationship between liquidity and asset price volatility. Furthermore, the main marginal contributions of this paper try to further improve the academic understanding of the relationship between monetary policy choices and asset price volatility under the framework of liquidity, providing micro explanation and theoretical basis for deepening the regulatory system. Specifically, existing literature shows that liquidity plays a vital role in asset price volatility. However, the intensity of liquidity in different dimensions is ignored. Hence, different dimensions of liquidity including currency liquidity, banking system liquidity, and market liquidity, are firstly used to study its inherent linkage effects between asset price volatility and monetary policy choices. This makes up for the previous literature that only uses a single indicator of liquidity to carry out relevant studies, which could furhter deepen the understanding of liquidity spiral effects. Secondly, this paper clearly identifies the high and low volatility state of asset prices in China by constructing the Markov Switching Auto Regression model (MS-AR), and uses the relational parameter diagram to further analyse the nonlinear transformation of asset prices with liquidity changes in different volatility states, which can provide more information on whether monetary policy is necessary to focus on it. Lastly, we investigate the important influence of liquidity on monetary policy regulation channels and its mechanism, and adopt the Time Varying Parameter

Stochastic Volatility Vector Auto Regression model (TVP-SV-VAR) to compare and analyse the regulating effects and dynamic evolution of quantitative and price-based monetary policy choices based on dynamic time-varying information framework, which can capture the changing characteristics of China's monetary policy orientation in different periods. Moreover, it can provide the necessary decision-making references and beneficial policy enlightenments for the central banks to deal with asset price volatility and macroeconomic fluctuations.

The rest of the study is structured as follows. A related literature review is clearly presented in Section 2. Section 3 discusses the empirical methodology. Then Section 4 describes the data and empirical results. Section 5 finally concludes the study.

2. Literature Review

Many factors can drive asset price volatility, and the transmission mechanisms are different. The existing literature has studied the relationship between bank credit and asset prices. The theory was proposed by Fisher [22], which systematically explained the logical relationship between excessive debt and deflation, and investigated the impacts of the debt scale on asset prices. It also can be found from Collyns and Senhadji [23] that banks are more inclined to provide asset-related loans when asset prices are relatively high, which can intensify capital inflows from domestic banks and have a certain impact on the financial market. As the transmission medium of monetary policy, commercial banks are inevitably the main reservoir of liquidity, and the leading cause of the drastic asset price fluctuations is the substantial expansion of bank credit [24–26]. With the continuous release of liquidity and the promotion of bank credit by policies, it is further transmitted to asset prices and the macroeconomic market. Therefore, the credit-driven asset price bubbles in the real estate market and stock market are more harmful than others [27].

There also exists extensive literature on the relationship between liquidity and asset prices. Baks and Kramer [28] relatively early found that the influences between currency liquidity and asset prices were significant. Allen and Gale [29] effectively pointed out that negative external liquidity shocks could cause banks to sell large amounts of their risky assets to obtain sufficient liquidity, which might lead to a sharp drop in asset prices and aggravate financial system risks. Furthermore, the excess liquidity can cause real estate prices to skyrocket [16, 30], especially individual consumers with stochastic liquidity demand are very vulnerable to asset price volatility if they directly hold assets. A recent study such as Hu et al. [31] have argued that liquidity can influence risk transfers between commodity and stock markets when using a composite liquidity index and five different types of liquidity measures. Moreover, Nusret and Adam [32] further use multinational data to find that liquidity strongly influences the stock value of listed firms. In addition, liquidity can be roughly divided into the following: currency liquidity, banking system liquidity and market liquidity, and different dimensions of liquidity have disparate impacts on asset prices. Some studies have explored its negative impact on bond yields based on the explanation of market liquidity in different countries [8]. However, traditional monetarism holds that the substantial increase of money supply will increase the demand for assets and thus promote the rise of major asset prices. This view mainly considers the driving effect of currency liquidity on asset prices [28, 33], which can be further verified after the U.S. financial crisis. Nevertheless, Machado and Sousa [34] showed that banking system liquidity could have more significant impacts on asset prices compared with currency liquidity. More importantly, market liquidity can be measured by the speed of balance sheet expansion, and the size of the balance sheet may have a direct impact on the price of assets with higher liquidity [35, 36]. However, a few studies believe that liquidity is not closely related to asset price fluctuations [37].

Moreover, the studies on the relationship between asset price volatility and monetary policy regulation are abundant, and it is worth mentioning that whether monetary policy should take asset price fluctuations as the target of regulation has received much attention [38, 39]. Many scholars argue that asset price volatility can be intervened by the monetary policy choices [40–42]. Mishkin [26] also considered that the central bank should choose a strategy that combines early warning indicators with a headwind monetary policy in the event of credit-driven asset price bubbles. Furthermore, different monetary policy choices can respond to different asset price fluctuations, Galí and Gambetti [43], using the TVP-VAR model, clearly found that the responses of stock prices to monetary policy shocks declined in the short term, but continued to rise in the long term. Although the expansionary monetary policy can lead to a substantial increase in housing prices [44] and corporate investment in emerging markets [45], the contractionary monetary policy can trigger a sizeable and persistent decline in stock than housing prices [46]. It also seems to influence the risk premium in stock and bond prices and effectively control the liquidity premium in the economy [47]. In addition to all this, some studies suggest that monetary policy can increase pressure in other asset price such as exchange markets by influencing long-term interest rates [48]. Furthermore, changes of monetary policy in different countries may have spillover effects on emerging economies. The traditional monetary policies of the Federal Reserve and the European Central Bank have played a very important role in driving GDP, asset prices and national capital flows in the emerging market economies of central and eastern Europe [49–51], and China's monetary policy has also played a key role in short-term domestic interest rate adjustment in Nigeria and South Africa [52]. However, some scholars point out that monetary policy is unconnected with asset price volatility, and monetary policy implementations do not need to consider the impacts of asset price volatility [53, 54]. Although asset price bubbles can lead to financial instability, monetary policy should not focus on asset prices, but should remain relatively independent if it is in the absence of serious inflation [55, 56].

It worth noting that previous literature has carried out an empirical analysis on the issue by using different economic

models, especially the studies focusing on the transmission of monetary conditions on asset prices in emerging countries with VAR-type of models should be fully discussed, which can further investigate the implementation of monetary policy on asset price volatility. Specifically, Zhu et al. [19] adopt the VAR model to find that the transmission of monetary policy to exchange rate is relatively ineffective, but the transmission of exchange rate to the ultimate goal of monetary policy is effective. Moreover, the SVAR models are adopted to assess the structural and asymmetric effects of the changes in long-term interest rates and credit conditions on the exchange market pressure index between four emerging countries [48]. To study the international monetary policy spillovers to emerging economies, the GVAR model and multivariate GARCH-in-Mean VAR model can aim to explicitly model economic and financial interdependence at the national and international levels [51, 52]. As the traditional VAR model may have some defects, the panel BVAR model with a hierarchical prior is used to assess monetary policy spillovers [49]. Moreover, in order to consider the time-varying effects, the TVC-VAR model are adopted by Han and Hur [57] to assess how the effects of monetary policy shocks have changed over time; while some researchers such as Gambacorta and Signoretti [58], have introduced the DSGE model into the corporate balance sheet and bank credit mechanism to find that tightening monetary policy can stabilize the macroeconomy when asset prices and bank credit were positively impacted. Recently Paul [59] has developed an estimator to add to the model for structural monetary policy shocks to study how monetary policy jointly affects asset prices and the real economy in the US.

From the above, we can find that the existing literature mostly studies the effect of single liquidity factor, few studies have detailedly subdivided liquidity into different dimensions for research, and the identification of different volatility states of asset prices in China is rarely mentioned. Furthermore, limited studies incorporate liquidity factors into the analytical framework of monetary policy to deal with asset price volatility, which may lead to a certain bias between the estimated results and the actual situation. Moreover, previous studies on asset price volatility by domestic and foreign scholars only focus on single asset prices. However, due to the multiple influences of economic fundamentals, monetary environment and its own characteristics, asset prices with different attributes may have linkage effects. Therefore, the simultaneous comparison of the changes of multiple asset prices should be worthy of in-depth study. More importantly, we try to study the time-varying impacts between liquidity and asset price volatility, and investigate the liquidity characteristics of state conversion period on the basis of different state recognition of China's asset prices, discussing the regulating effects and dynamic evolution of quantitative and price monetary policies from time-varying, short-term and long-term perspectives. Ulteriorly, this paper will conduct a further study of the above deficiencies based on Chinese data, to provide the necessary factual basis for monetary policy choices in emerging economies.

3. Empirical Methodology

3.1. The MS-AR Model. The Markov Switching Auto Regression model (MS-AR) can realize the transition states of time series [60]. This paper uses the MS-AR model to identify the different volatility states of China's asset prices. The MS-AR model in this paper is set up below:

$$\text{Asset}_t = \mu_{s_t} + \sum_{k=1}^{n} \rho_{k,s_t} \text{Asset}_{t-k} + \sigma_{s_t} \varepsilon_t, \varepsilon_t \sim N(0,1), \tag{1}$$

where, $S_t\,(S_t = 1, 2)$ indicates that the state of asset price volatility is in high or low state, and subjects to the first-order Markov chain with a number of finite states. μ_{s_t} represents the intercept of the asset price series Asset_t under S_t, and ρ_{k,s_t} is the estimated parameters of Asset_{t-k}. σ_{s_t} is time-varying standard deviation of residuals, k is the number of lag periods, and n is the order of lag. Assuming that the state variable $S_t\,(S_t = 1, 2)$ follows a strictly stationary first-order Markov process, the transition probability matrix from state $i\,(i = 1, 2)$ in period $t-1$ to state $j\,(j = 1, 2)$ in period t can be expressed as follows:

$$\begin{pmatrix} p_{11} & p_{12} \\ p_{21} & p_{22} \end{pmatrix} = \begin{pmatrix} p_{11} & 1 - p_{11} \\ 1 - p_{22} & p_{22} \end{pmatrix}, \tag{2}$$

where, $p_{i1} + p_{i2} = 1$,and the average duration of the asset prices in the state $i\,(i = 1, 2)$ can be calculated by $1/(1 - p_{ii})$.

The maximum likelihood method can be used to estimate the parameters of the MS-AR model. Let F_{t-1} represents all the information of Asset_t in time $t-1$, and θ represents the parameter vector of the model to be estimated, then the probability density of Asset_t under $S_t = j$ is defined as follows, where μ_j, $\rho_{k,j}$, and σ_j^2 represent constant, lag term coefficient and variance in the state j, respectively.

$$f\left(\text{Asset}_t | S_t = j, F_{t-1}; \theta\right) = \frac{1}{\sqrt{2\pi\sigma_j^2}} \exp\left\{ \frac{\left(\text{Asset}_t - \mu_j - \sum_{k=1}^{n} \rho_{k,j} \text{Asset}_{t-j}\right)^2}{2\sigma_j^2} \right\}. \tag{3}$$

Following iterative algorithm can be adopted to obtain the estimation of parameters.

Step 1. Set the probability of Asset_t in each state at initial time. Assuming the unconditional probability of $S_t = 1$ and $S_t = 2$ as initial probability, we can obtain:

$$\begin{aligned} P\left(S_0 = 1 | F_0\right) &= \frac{1 - p_{11}}{2 - p_{11} - p_{22}}, \\ P\left(S_0 = 2 | F_0\right) &= \frac{1 - p_{22}}{2 - p_{11} - p_{22}}. \end{aligned} \tag{4}$$

Step 2. Calculate the probability of Asset_t in each state at time t according to the information at time $t-1$.

$$P(S_t = j|F_{t-1};\theta) = p_{1j}P(S_{t-1} = 1|F_{t-1};\theta) + p_{2j}P(S_t = 2|F_{t-1};\theta). \tag{5}$$

Step 3. Under the condition that F_{t-1} is known, the probability density function of Asset_t is:

$$f(\text{Asset}_t|F_{t-1};\theta) = \sum_{j=1}^{2} P(S_t = j|F_{t-1};\theta) f(\text{Asset}_t|S_t = j, F_{t-1};\theta). \tag{6}$$

Step 4. After considering the new information at time $t-1$, the filtering probability of Asset_t in each state can be updated as following equation. Using the sample information from the initial time to the time t, we can infer the probability of Asset_t in different states at time t.

$$P(S_t = j|F_t;\theta) = \frac{P(S_t = j|F_{t-1};\theta) f(\text{Asset}_t|S_t = j, F_{t-1};\theta)}{f(\text{Asset}_t|F_{t-1};\theta)}. \tag{7}$$

Step 5. Repeat Step 2 to Step 4 from $t = 1$ to $t = T$ to obtain the filtering probability at each time.

Step 6. Based on the above, the total logarithmic likelihood function can be obtained as following equation, where $\varphi(*)$ is a density function of the standard normal distribution. The parameters can be estimated by maximizing the logarithmic likelihood function.

$$\ln L = \sum_{t=1}^{T} \ln \sum_{j=1}^{2} \varphi\left(\frac{\text{Asset}_t - \mu_j - \sum_{k=1}^{n} \rho_{k,j}\text{Asset}_{t-j}}{\sigma_j}\right)\sigma_j^{-1} P(S_t = j|F_t;\theta). \tag{8}$$

Step 7. Let $t = T-1$, and we can use the information of the full sample to infer the smoothing probability of Asset_t in different states at time t as following equation. And we can use the estimated parameters and Equation (6), (8) and (10) to have a further backward extrapolation, then obtain the smoothing probability at each time from $t = T-1$ to $t = 1$.

$$\begin{aligned} P(S_t = j|F_T;\theta) &= \sum_{j=1}^{2} P(S_t = j, S_{t+1} = i|F_T;\theta) \\ &= P(S_t = j|F_t;\theta) \sum_{i=1}^{2} \frac{p_{ji}P(S_{t+1} = i|F_T;\theta)}{P(S_{t+1} = i|F_t;\theta)}. \end{aligned} \tag{9}$$

3.2. The TVP-SV-VAR Model. The Vector Auto Regression model (VAR) was first proposed by Sims [61], but this model had many limitations that made it inconvenient to use. Since the traditional VAR model assumes that VAR coefficient and variance of disturbance term are constant, this assumption is obviously difficult to match the reality. In fact, the economic system, economic structure, policy preference and other factors change constantly with time, and the model parameters can change accordingly. Hence, the traditional VAR model obviously cannot depict such dynamic characteristics. In addition, the state space model that can describe nonlinear characteristics is limited in use for the reason that it is a one-way equation and cannot show the interaction between multiple variables. In this regard, Primiceri [62] gradually developed the VAR model into the Time Varying Parameter Stochastic Volatility Vector Auto Regression model (TVP-SV-VAR). Subsequently, the TVP-SV-VAR model has been widely used in macroeconomic research [63–65]. Hence, we further adopt the TVP-SV-VAR model to consider the time-varying and nonlinear characteristics between variables. The TVP-SV-VAR model can be expressed as follows:

$$y_t = X_t\beta_t + A_t^{-1}\sum_t \varepsilon_t, t = s+1, \ldots, n, \varepsilon_t \sim N(0, I_k), \tag{10}$$

where y_t is the $k \times 1$ vector of observed variables, β_t is the $k^2 s \times 1$ time-varying coefficient vector, and defining $X_t = I_k \otimes (y_{t-1}', \ldots, y_{t-s}')$.

As suggested by Nakajima et al. [66], we assume that A_t is the lower triangular matrix which can guarantee the recursive recognition of the VAR system and reduce the number of estimated parameters, A_t and Σ_t are as follows:

$$A_t = \begin{pmatrix} 1 & 0 & \cdots & 0 \\ a_{21,t} & 1 & \cdots & \vdots \\ \vdots & \vdots & \ddots & 0 \\ a_{k1,t} & \cdots & a_{kk-1,t} & 1 \end{pmatrix}, \sum_t = \begin{pmatrix} \sigma_{1,t} & 0 & \cdots & 0 \\ 0 & \sigma_{2,t} & \cdots & \vdots \\ \vdots & \vdots & \ddots & 0 \\ 0 & \cdots & 0 & \sigma_{k,t} \end{pmatrix}. \tag{11}$$

The coefficients β_t, the parameters A_t, and Σ_t are all time-varying. The time-varying matrix A_t means that the impact of the variable i on the variable j varies with time, and $h_t = (h_{1t}, \ldots, h_{kt})'$ is the logarithmic random volatility matrix with $h_{jt} = \log\sigma_{jt}^2$ for $j = 1, \ldots, k, t = s+1, \ldots, n$. As suggested by Primiceri [62], we assume that the parameters in equation (11) follow a random-walk process as follows:

$$\begin{aligned} &\beta_{t+1} = \beta_t + u_{\beta_t}, a_{t+1} = a_t + u_{a_t}, h_{t+1} \\ &= h_t + u_{h_t}, \begin{pmatrix} \varepsilon_t \\ u_{\beta_t} \\ u_{a_t} \\ u_{h_t} \end{pmatrix} \sim N\left(0, \begin{pmatrix} I & 0 & 0 & 0 \\ 0 & \sum_\beta & 0 & 0 \\ 0 & 0 & \sum_a & 0 \\ 0 & 0 & 0 & \sum_h \end{pmatrix}\right), \end{aligned} \tag{12}$$

where, $\beta_{s+1} \sim N(\mu_{\beta_o}, \sum_{\beta_0}), \alpha_{s+1} \sim N(\mu_{a_o}, \sum_{a_0})$ and $h_{s+1} \sim N(\mu_{h_o}, \sum_{h_0})$. It is assumed that the shocks to the innovations of time-varying parameters are uncorrelated among β_t, a_t and h_t. We further assume that $\sum_\beta$, $\sum_a$, and $\sum_h$ are all diagonal matrices. And this paper mainly uses the Markov Monte Carlo algorithm (MCMC) proposed by Nakajima et al. [66] under the framework of Bayesian statistical inference to estimate the model.

Table 1: Descriptive statistics of the main variables.

Classifications	Variables	N	Mean	Median	Std. Dev.	Skewness	Kurtosis
Asset price volatility	SP	168	13.6198	0.4050	51.4067	1.9663	7.1568
	HP	168	7.7762	7.3788	5.7710	0.2483	3.0319
Liquidity	LC	168	0.3139	0.3068	0.0316	0.2692	1.7443
	LB	168	3.0598	3.1741	0.9495	0.4643	4.7869
	LM	168	−4.8247	0.6637	31.9942	−0.6278	3.0640
Monetary policy	M2	168	14.1606	13.3500	5.0737	1.1856	4.3151
	R	168	2.8398	2.7016	0.9422	0.7830	4.7956
Macroeconomy	GDP	168	11.6973	10.2100	5.8310	0.3130	3.1829
	CPI	168	2.7514	2.3600	1.9844	0.6028	3.8277

4. Data and Results

4.1. Data. Asset price volatility. Combining the research purposes of this paper and referring to the existing literature [67], we mainly select the year-on-year growth rate of the closing price of Shanghai Composite Index (SP) and the year-on-year growth rate of the average sales price of commercial housing in China (HP) to reflect the asset price volatility in the stock market and the real estate market. Since there may be trend items in the time series of asset price volatility, Hodrick and Prescott filtering method is used in this paper to process the data [68, 69].

Liquidity. This paper refers to the study of Peking University in 2008 and divides liquidity into three dimensions (it is worth noting that currency liquidity refers to the degree of money abundance, banking system liquidity refers to the expansion of the overall assets of commercial banks, and market liquidity refers to the difficulty of asset realization in the financial market. They represent the macro, medium, and micro dimensions of liquidity, respectively): currency liquidity (LC), banking system liquidity (LB), and market liquidity (LM). Combining China's actual situation and the availability of relevant data, this paper selects relevant indicators to represent liquidity in different dimensions. Firstly, M1/M2,that is, the ratio of narrow and broad money supply, can be considered to measure currency liquidity because it could better reflect the structure of currency liquidity. If M1/M2 is higher, the currency liquidity is stronger. Secondly, following Huang et al. [70], this paper mainly selects the 7-day interbank lending rate to reflect the strength of banking system liquidity. Thirdly, we draw on the study of Amihud [71] and further adjusts it by the following Equation (13), where, R_t is the absolute return of the Shanghai Composite Index, and TC_t is the turnover rate of stocks. When the index is higher, it means that the price fluctuation caused by the unit turnover rate is greater. That is, the market liquidity is worse, and on the contrary, the market liquidity is better.

$$LM_t = \frac{|R_t|}{TC_t}. \tag{13}$$

Monetary policy. In this paper, the year-on-year growth rate of broad money supply and the Shanghai interbank offered rate (7 days) are selected as the monetary policy indicators to reflect the quantity (M2) and price-based (R) monetary policy regulation [72, 73].

Macroeconomy. The year-on-year growth rate of GDP and the year-on-year growth rate of consumer price index are selected as macroeconomic indicators to reflect the output level (GDP) and the price level (CPI) [72–74].

The data was on monthly frequency, covering from January 2007 to December 2020, and the original data in this study mainly come from Wind Information Finance Terminal (WIND), and China Stock Market and Accounting Research Database (CSMAR). The descriptive statistics of the main variables are depicted in Table 1.

4.2. Unit Root Test. Table 2 shows the unit root ADF test results. At the significance level of 1%, all other variables except SP and HP fail to pass the unit root test. However, the first-order differences of M2, R, LC, LB, LM, GDP and CPI all pass the unit root test and belong to stable variables. Therefore, stable variables will be used for the model construction in the following research.

4.3. Identification of the High and Low Volatility State of Asset Prices

4.3.1. Parameter Estimation. According to the partial autocorrelation coefficients of SP and HP, the optimal lag is 2 and the MS-AR (2) model can be established. The parameter estimation results of the model are shown in Table 3. Most of these estimated parameters are all significant at the significance level of 5% or 1% except for a few parameters. The continuity probabilities of SP in the low volatility state (State 1) and high volatility state (State 2) are 0.6334 and 0.9651, respectively, indicating that China's stock market is in the high volatility state for a long time. According to equation $1/(1 - p_{ii})$, the average duration of low and high volatility in China's stock market can be calculated to be 2.7280 and 28.6918 months, respectively (For details, see Table 3). The duration of high volatility state is 10.51 times that of the low volatility state, which shows that the China's stock market fluctuates more intensely. However, the average duration of low and high volatility in China's real estate market is 26.4593 and 16.8826 months, respectively. The continuity probabilities of HP in the low volatility state and high volatility state are 0.9622 and 0.9408, respectively, indicating that the high and low volatility state of China's real estate market have higher continuity, and it is not easy to shift between the high and low volatility state.

Table 2: Unit root ADF test.

Variables	(C, T, P)	ADF	Critical value [1%]	P value	Testing results
M2	(C, 0, 3)	−1.9251	−4.0966	$p > 0.0100$	Unstable
R	(0, 0, 0)	−0.7972	−2.5791	$p > 0.0100$	Unstable
LC	(C, 0, 0)	−1.6695	−3.4697	$p > 0.0100$	Unstable
LB	(0, 0, 0)	−0.7278	−2.5791	$p > 0.0100$	Unstable
LM	(C, 0, 0)	−3.2719	−3.4697	$p > 0.0100$	Unstable
GDP	(C, 0, 0)	−2.0849	−3.4697	$p > 0.0100$	Unstable
CPI	(C, 0, 2)	−2.7578	−3.4702	$p > 0.0100$	Unstable
SP	(C, 0, 5)	−5.0759	−3.4709	$p < 0.0100$	Stable
HP	(C, 0, 7)	−3.5427	−3.4715	$p < 0.0100$	Stable
DM2	(C, 0, 2)	−4.9591	−3.4704	$p < 0.0100$	Stable
DR	(0, 0, 0)	−10.9863	−2.5791	$p < 0.0100$	Stable
DLC	(C, 0, 0)	−13.8789	−3.4699	$p < 0.0100$	Stable
DLB	(0, 0, 0)	−10.6607	−2.5791	$p < 0.0100$	Stable
DLM	(C, 0, 0)	−11.6370	−3.4699	$p < 0.0100$	Stable
DGDP	(C, 0, 0)	−12.8441	−3.4699	$p < 0.0100$	Stable
DCPI	(C, 0, 2)	−5.1034	−3.4704	$p < 0.0100$	Stable

Note. DM2, DR, DLC, DLB, DLM, DGDP and DCPI represent the first-order differences of M2, R, LC, LB, LM, GDP and CPI, respectively; C, T and P in the test form (C, T, P) represent the constant term, the trend and the optimal lag order, respectively.

Table 3: Parameter estimation of the MS-AR (2) model.

Variables	SP		HP	
	Parameter estimation	P value	Parameter estimation	P value
μ_{s_1}	-17.0983^{**}	$p < 0.0500$	3.1835^{**}	$p < 0.0500$
μ_{s_2}	9.3499	$p > 0.0500$	14.1057^{***}	$p < 0.0001$
ρ_1	1.5935^{***}	$p < 0.0001$	1.1972^{***}	$p < 0.0001$
ρ_2	-0.6458^{***}	$p < 0.0001$	-0.3078^{***}	$p < 0.0001$
p_{11}	0.6334		0.9622	
p_{22}	0.9651		0.9408	
$\ln L$	−635.5482		−352.3782	
lags	2		2	
Model	MS (2)-AR (2)		MS (2)-AR (2)	
State	State 1	State 2	State 1	State 2
Duration	2.7280	28.6918	26.4593	16.8826

Note: ∗∗ and ∗∗∗ represent significance level at 5% and 1%, respectively.

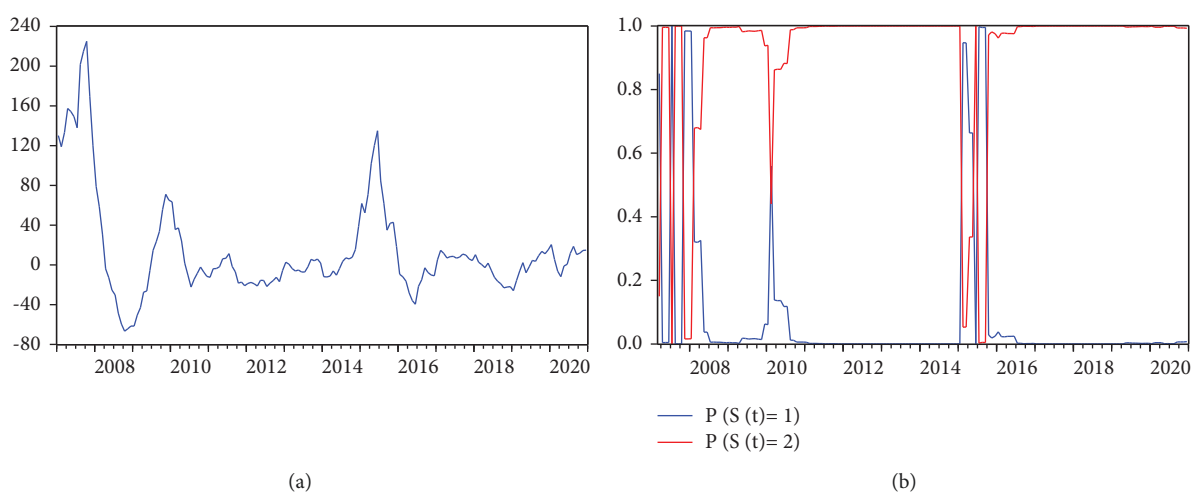

Figure 1: The volatility trend of China's stock market (a) and the smoothing probability of its volatility state (b).

4.3.2. State Transition Characteristics of Asset Price Volatility. The smoothing probability ($S(t) = 1$ and $S(t) = 2$ represent low volatility state and high volatility state, respectively; $P(S(t) = 1)$ and $P(S(t) = 2)$ are the smoothing probabilities of asset price in a low and high volatility state, respectively) can more accurately describe the process of asset price conversion

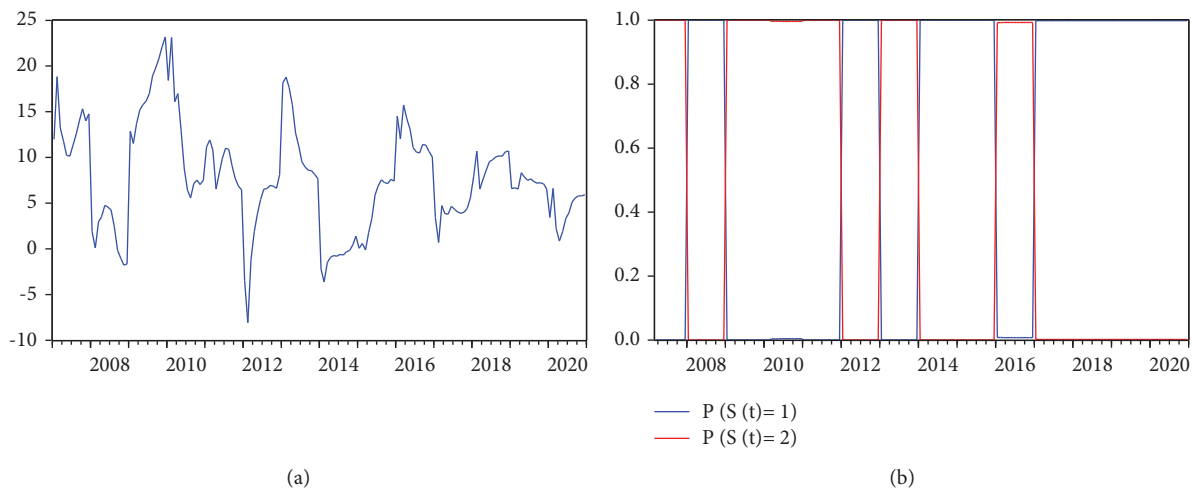

Figure 2: The volatility trend of China's real estate market (a) and the smoothing probability of its volatility state (b).

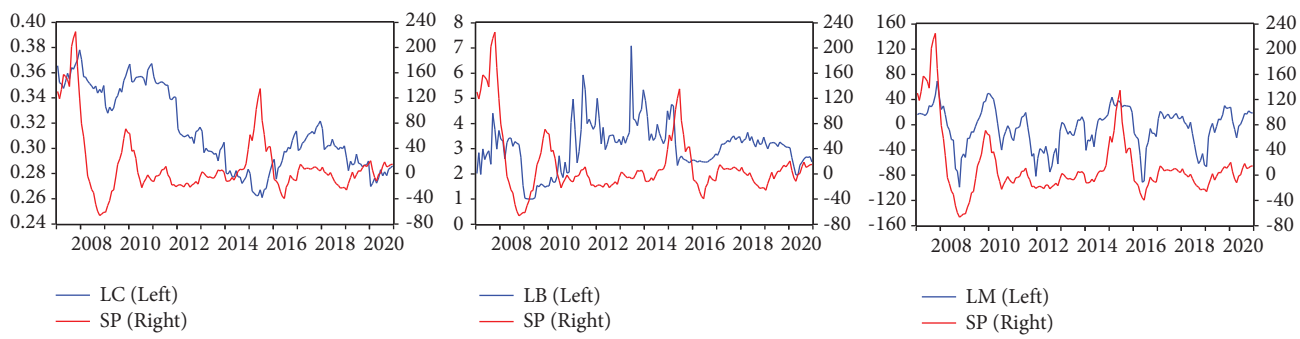

Figure 3: Liquidity characteristics of China's stock market in the high and low volatility states.

between "low volatility state" and "high volatility state", to determine the potential states of asset price volatility at each moment. Figure 1 shows the smoothing probability and the volatility trend of China's stock market. It reveals that the low and high volatility state of the stock market can be clearly divided, and they have a good match and consistency with the volatility trend of the stock market. The stock market has a large amplitude, and it hit two peaks around 2008 and 2015, but after experiencing the high point, it dropped rapidly and entered the low volatility state. Specifically, both before the global financial crisis in 2008 and from 2014 to 2015, the volatility of the stock market showed the characteristics of alternating high volatility and low volatility, but after the global financial crisis in 2008 to 2010, China's stock market is in a high volatility state, especially the state also reflects the phenomenon that the stock market was greatly impacted on June 15, 2015, and the characteristics of high volatility in the stock market are more obvious.

Moreover, the smoothing probability and volatility trend of China's real estate market can be shown in Figure 2. It clearly demonstrates that the characteristics of the real estate market volatility transition are more obvious, and it is more consistent with the volatility trend of China's real estate market during some periods. The real estate market was in a low volatility state before 2008, but it was volatile due to the global financial crisis in 2008. Subsequently, the Chinese government took measures in response to the financial crisis and China's housing price reached its peak in 2009. In addition, China faced a severe domestic and foreign environment after 2013, the Chinese government continued to move forward with supply-side structural reform of the real estate market in 2015, which led to the continuous rise of housing prices in most cities in China. It is similar to the previous studies [9, 10]. Since 2018, the time for the decline in housing price growth has been significantly prolonged, indicating that it is in a low volatility state. It is more consistent with the smoothing probability of its volatility state.

4.3.3. Liquidity Characteristics of Asset Price Volatility. We examine the liquidity characteristics of China's stock market (SP) and real estate market (HP) in the high and low volatility state. Figure 3 and Figure 4 further show the liquidity characteristics of China's asset price volatility from January 2007 to December 2020. It can be seen that there is a close relationship between the liquidity of different dimensions. Monetary liquidity is the basis of overall liquidity and can provide the total amount of liquidity for the whole financial system. Banking system liquidity and market liquidity are the reflection of the characteristics of liquidity that can be obtained through lending and trading. On the one hand, the rapid expansion of M2 can promote the

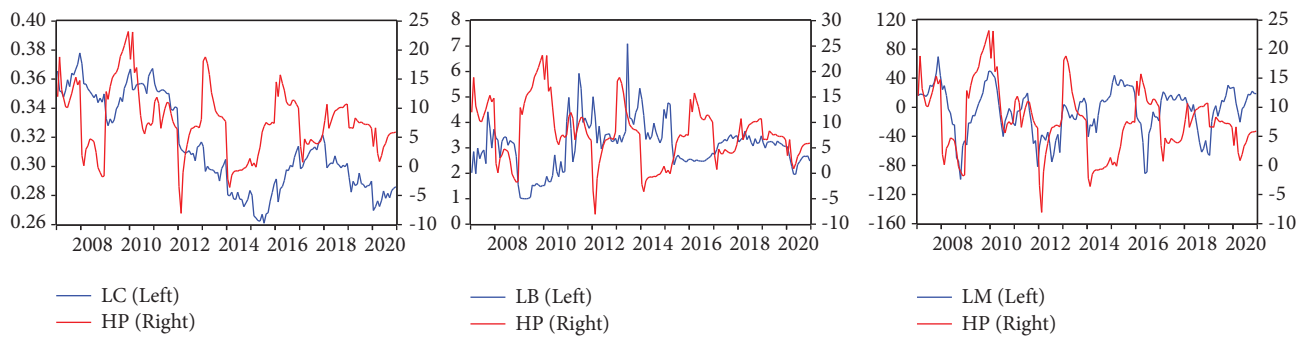

Figure 4: Liquidity characteristics of China's real estate market in the high and low volatility states.

Table 4: Estimation parameters of the TVP-SV-VAR model.

Parameter	Mean	St.dev.	95% interval	CD statistics	Inefficiency
sb1	0.0226	0.0026	[0.0181, 0.0285]	0.202	8.48
sb2	0.0227	0.0025	[0.0183, 0.0283]	0.902	7.06
sa1	0.0596	0.0282	[0.0338, 0.1334]	0.838	32.85
sa2	0.0631	0.0165	[0.0381, 0.1015]	0.657	30.45
sh1	0.2776	0.0847	[0.1471, 0.4743]	0.029	52.62
sh2	0.7918	0.1823	[0.4833, 1.1864]	0.794	78.04

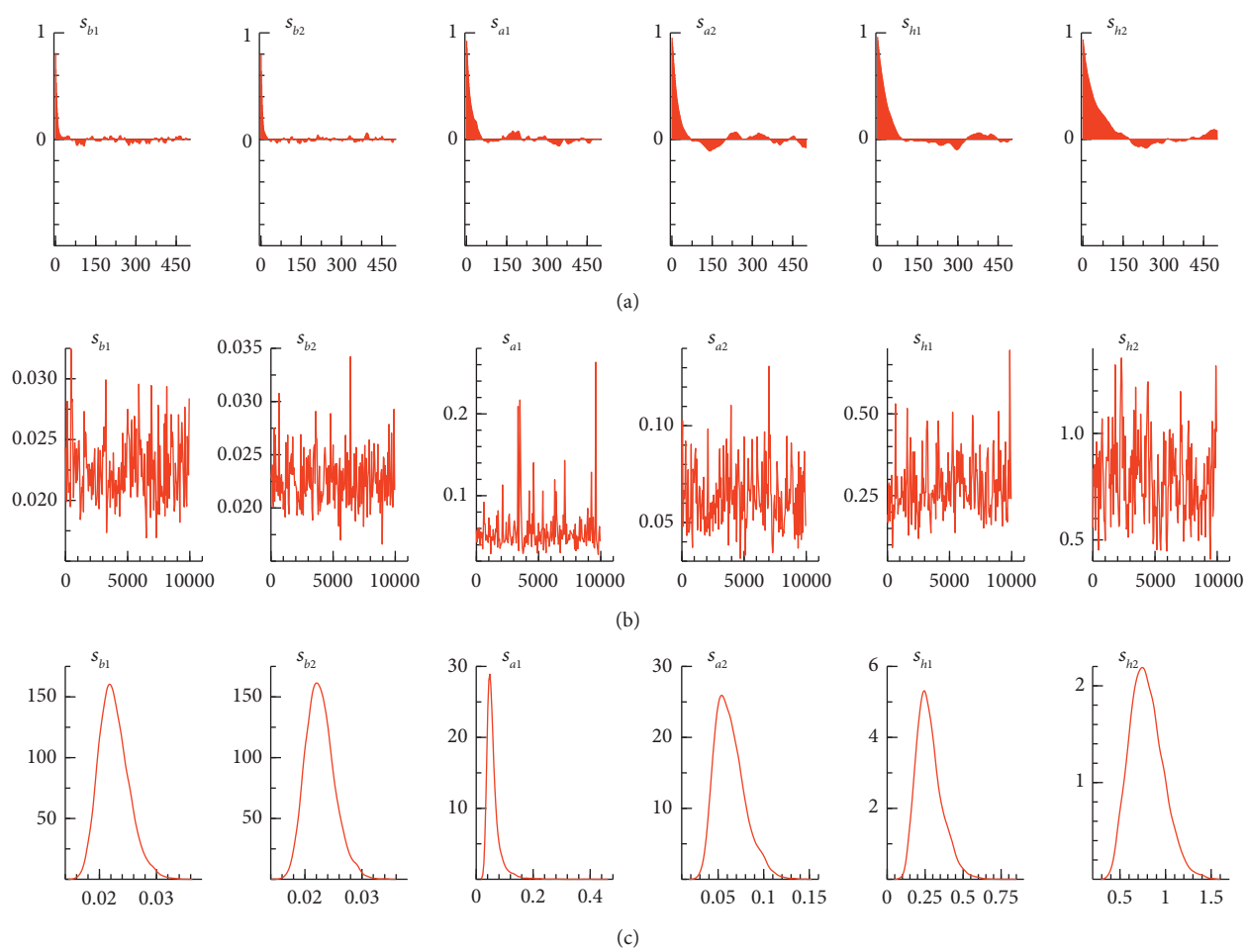

Figure 5: Estimation results of parameters in the TVP-SV-VAR Model. Sample autocorrelations (a), sample paths (b), and posterior densities (c).

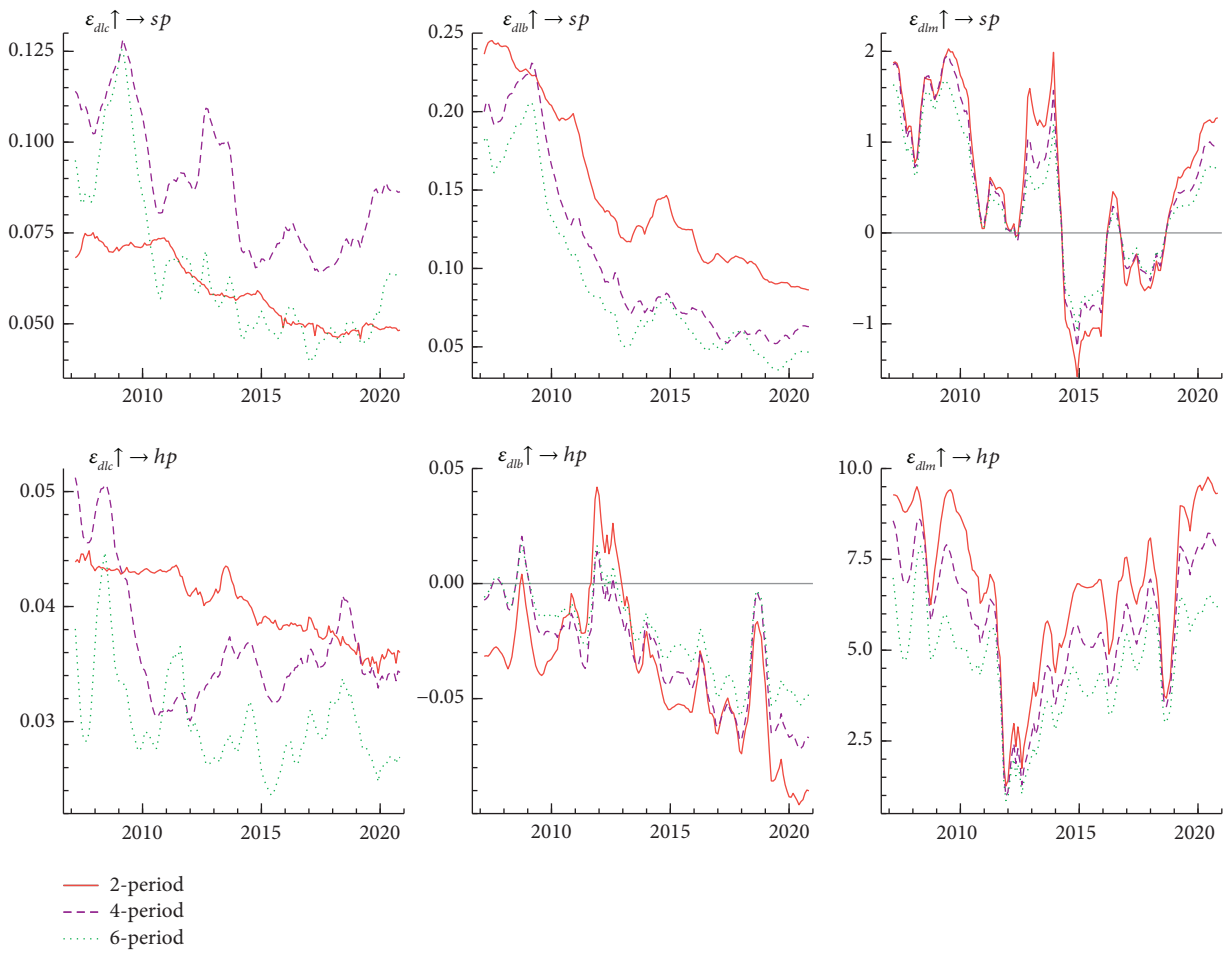

Figure 6: The impulse responses of liquidity to asset price volatility with an equal interval.

expansion of bank credit, thus driving the monetary expansion, leading to changes in the structure of monetary liquidity, and affecting the banking system liquidity and market liquidity. On the other hand, the banking system liquidity and market liquidity can affect the macroeconomy through interest rates, thus indirectly affecting asset prices. Hence, it shows that liquidity in different dimensions can better explain the information of financial market reflection and macroeconomic policy expectations [1, 2], and can improve the ability to monitor abnormal asset price volatility.

Specifically, there are obvious differences in the changing trends of liquidity in different dimensions. Firstly, China's currency liquidity has generally shown a downward trend. The downward trend has been more pronounced since 2010. It did not rebound until it reached a trough in 2015, but it has begun to show a downward trend since 2017. The domestic people's transactional demands for currency have gradually weakened, which lead to an increasing proportion of deposits and quasi-currencies. The decline in the proportion of liquid currency may reduce the accuracy of monetary policy regulation. In general, China's currency liquidity level has begun to change from a surplus situation ten years ago to a tight feature under the current situation. Secondly, banking system liquidity began to decline gradually after reaching its peak in 2013, and reached the bottom in 2015. Although it has started to increase in recent years, it still shows a tight trend. This is mainly because China's currency liquidity continues to tighten, which has aggravated the tightening of the banking system liquidity. Thirdly, China's market liquidity showed strong cyclical fluctuations, especially when it reached a low value in 2008, indicating that the market turnover rate has begun to rise sharply, and the liquidity is at a high level. Although market liquidity reached a new peak in May 2015, the financial market investment sentiment has been poor since 2018, which has made market liquidity at a relatively low level.

In addition, the different dimensions of liquidity are not completely consistent with the state of asset price volatility in China. Firstly, currency liquidity has a strong correlation with stock market and real estate market volatility, but it shows some hysteresis effects. The sharp rise or rapid decline of the stock market is not synchronized with the expansion or contraction of currency liquidity. However, the cyclical characteristics of the real estate market are highly correlated with the trends of currency liquidity. Secondly, stock market and real estate market volatility are related to the trend of the banking system liquidity, with strong explanatory power and obvious market lag. Thirdly,

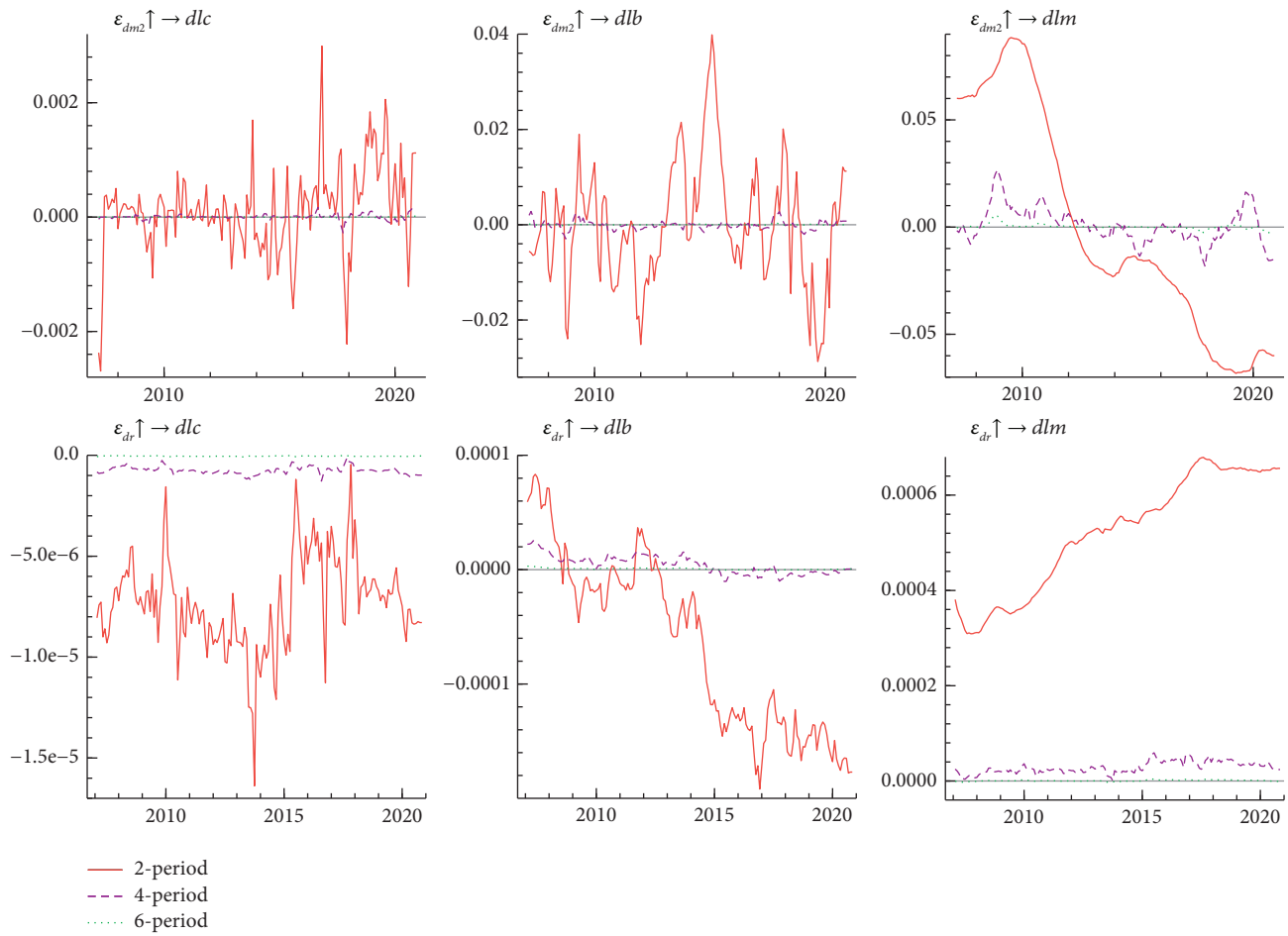

Figure 7: The impulse responses of monetary policy to liquidity with an equal interval.

the stock market volatility is highly consistent with market liquidity, but shows a typical negative correlation in certain intervals.

Combing these results with the state transition characteristics of asset price volatility, we can further know that different dimensions of liquidity have different explanatory for the high and low volatility state of China's asset prices, and summarize the effective information in the following three aspects: firstly, currency liquidity, banking system liquidity and market liquidity have a strong ability to explain the high volatility and low volatility state of China's asset prices. However, the explanatory effect of market liquidity on the fluctuation of the real estate market showed a divergence characteristic during some periods. Secondly, the high volatility and low volatility of China's asset prices are not completely consistent with the rapid expansion and rapid contraction of currency liquidity, but show a certain degree of lag. Lastly, market liquidity has a stronger explanatory power for the volatility of China's stock market, which can be an indicator of regulating the stock market volatility. Therefore, the different dimensions of liquidity can provide useful early warning information for the central bank to pay attention to asset price bubbles and potential financial risks [15, 16].

4.4. Analysis of the Regulatory Effects of Monetary Policy on Asset Price Volatility

4.4.1. Parameter Estimation. As is discussed above, we know that liquidity has a strong explanatory for China's asset price volatility, and there are linkage effects between asset price volatility and liquidity of different dimensions. Most literature shows that monetary policy plays an important role in regulating liquidity and asset price volatility [40, 41]. Therefore, we adopt the TVP-SV-VAR model to study the regulatory effects of monetary policy on liquidity, asset price volatility and macroeconomy. Based on the AIC and SC criteria, the optimal lag of the TVP-SV-VAR model is 2. To calculate the posterior estimation of the parameters, the sample of the MCMC algorithm is set to 10000, and the initial 1000 samples are discarded.

Table 4 reports the estimated results of the model parameters, including the mean of the posterior distribution, standard deviations, the 95% confidence intervals, the CD statistics of Geweke [75], and inefficiency factors. At the 5% significance level, the maximum of the CD statistics is 0.902, which is significantly less than 1.96, indicating the Markov chain fitting effect is effective. All inefficiency factors are less than 100, showing that the MCMC algorithm can effectively sample the posterior distribution of the parameters.

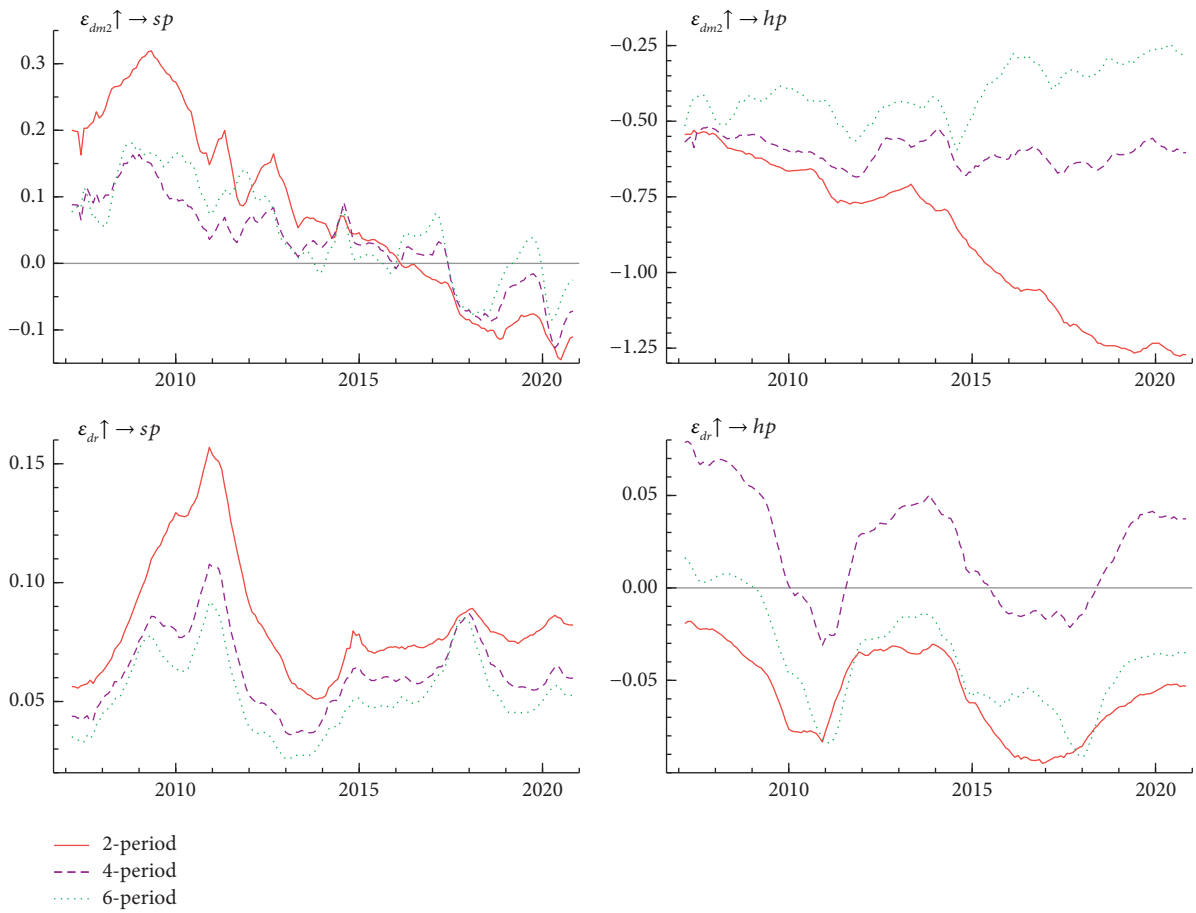

Figure 8: The impulse responses of monetary policy to asset price volatility with an equal interval.

Furthermore, to study the effectiveness of the TVP-SV-VAR model, this paper presents the sample autocorrelation function, the sample paths, and the posterior distribution diagram of the sample parameters. Figure 5 shows that the autocorrelation coefficients of the sample are in a tailing state and eventually converge to zero as the sample simulation progresses, indicating that the correlation between the samples is gradually decreasing. The sample paths fluctuate around the mean, and there are fewer extreme outliers, which means that the sampling method is effective [75].

4.4.2. Time-Varying Impulse Responses with Equal Interval. The TVP-SV-VAR model can use variable parameters to calculate the impulse response results of each variable in different lag periods at all time points, which is different from the impulse response of the VAR model [62, 76]. This paper studies the impulse responses of monetary policy on liquidity, asset prices and macroeconomy. Moreover, we also study the impulse responses of liquidity to asset prices, and compare the regulating effects of different monetary policy choices. Figure 6, Figure 7, Figure 8, and Figure 9 clearly depict the results of impulse responses with equal interval between different variables. The solid line, the long-dashed line, and the short-dashed line represent 2 months, 4 months, and 6 months ahead, corresponding to short-term, medium-term, and long-term impulse response curves with equal interval, respectively.

Moreover, Figure 6 reports the impulse responses of liquidity to asset price volatility with equal interval, showing that iquidity can become an important factor driving asset price volatility [1, 8, 17].The impulse response trends of liquidity shocks with different ahead times to asset price volatility are relatively consistent, but different in intensity. First, currency liquidity has a greater impact on China's asset price volatility, and the short-term effect of currency liquidity on the stock market is better than the medium-term and long-term effect, while the effect on the real estate market is just the opposite. Second, the banking system liquidity has a greater impact on the stock market, while the impact on the real estate market is lower. However, the banking system liquidity has played a role in regulating both the stock market and the real estate market in the mid-term and long-term. Third, the short-term influence of market liquidity on the stock market and the real estate market tends to converge, while the influence is weak in the mid-term and long-term [25]. However, there was a divergence in 2015, which showed the impact of market liquidity on the stock market reached a low point, while the impact on the real estate market was at a high point. Hence, the results can

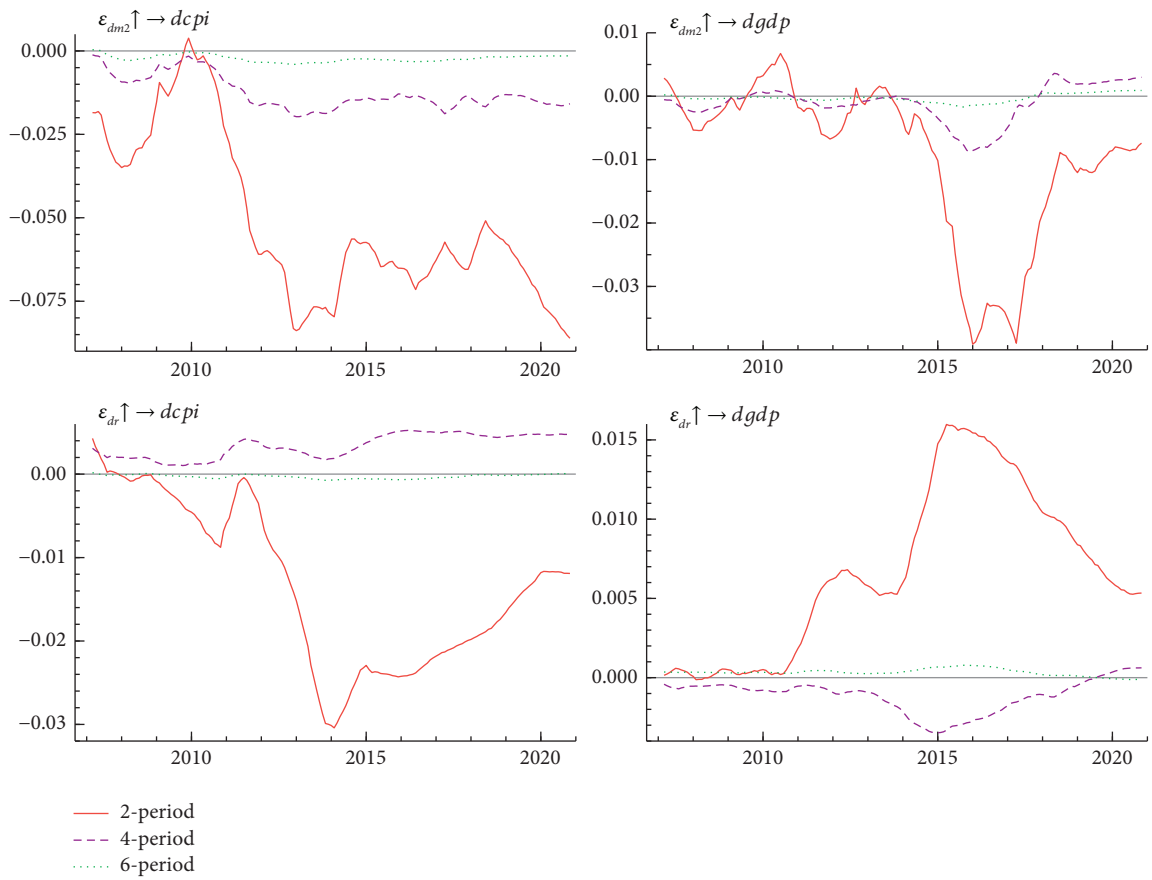

Figure 9: The impulse responses of monetary policy to macroeconomy with an equal interval.

support the first key hypothesis, that is, liquidity of different dimensions can affect asset price volatility through different channels, and has obvious time-varying characteristics.

The impulse responses of monetary policy to liquidity with equal interval are shown in Figure 7. In the short-term (2 months ahead), the influence of money supply (M2) and interest rate (R) on currency liquidity tend to be relatively consistent, but the former fluctuates alternately in positive and negative directions, while the latter only has a negative feedback effect. The response to market liquidity under the M2 shocks has declined significantly since 2009, but the banking system liquidity shows volatility. In addition, the shocks of interest rate on the banking system liquidity reveal a negative feedback after 2013, while the response of market liquidity has increased significantly since 2008, and has shown a low and positive effect. In the medium-term (4 months ahead) and long-term (6 months ahead), the impulse responses of monetary policy to liquidity tend to be more stable. We can conclude that the short-term regulatory effect of monetary policy on liquidity is more obvious, and the price-based monetary policy based on interest rate has a better regulatory effect on the banking system liquidity and market liquidity. It further verifies the conclusions of existing studies [18], and the effectiveness of monetary policy is worth further discussion especially for China and other emerging economies.

In addition, the impulse responses of monetary policy to asset price volatility with equal interval are depicted in Figure 8. First, the money supply had a positive effect on the stock market before 2015. However, China's stock market experienced severe volatility after 2015, and the stock price showed a continuous negative effect and a weak response in the mid-term and long-term, which is relatively consistent with the results of Galí and Gambetti [43]. Second, the regulatory effects of interest rates in the short-term on the stock market are better than that in the mid-term and long-term, but still showed some hysteresis effects. The impact had continued to decline after 2011, and reached a trough in 2014, then rose slightly and remained stable. Third, the short-term effects of the decline in housing prices were more obvious under the shocks of the money supply, but it had boosted high housing prices in the mid-term and long-term with the continuous increase in the money supply from 2014 to 2017. In addition, the shock responses of the real estate market roughly show the characteristics of "W-shaped" under the shocks of interest rates, and the impact of interest rates on housing prices has time-varying features in the mid-term and long-term [44]. Consequently, the second key hypothesis can be supported, that is, monetary policy plays a key role in coping with asset price volatility and maintaining fiancial stability.

It is worth noting that the impulse responses of monetary policy to macroeconomy with equal intervals are clearly demonstrated in Figure 9. First, the short-term effects of macroeconomy are significant under the impact of money supply, but just remain stable in the medium and long term,

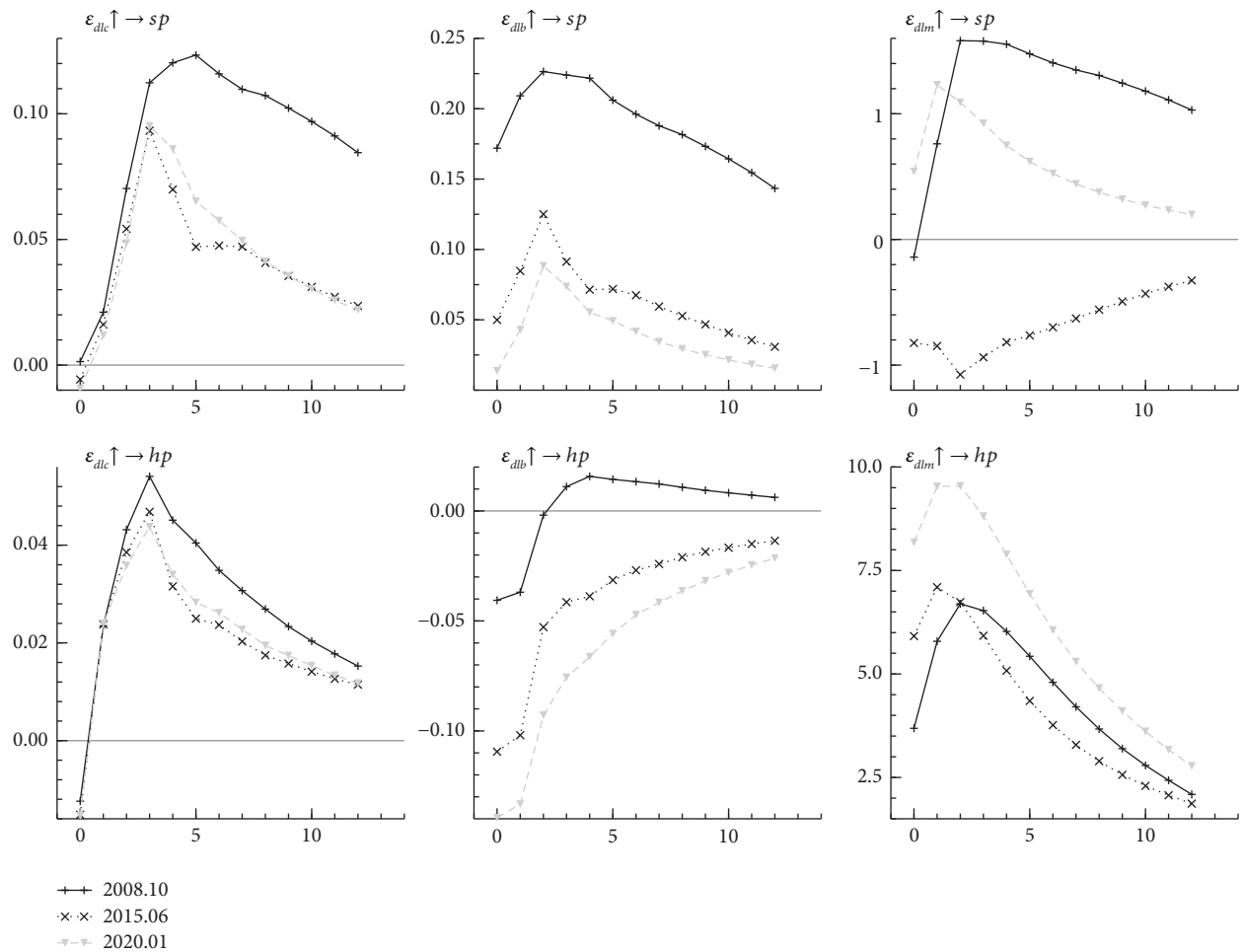

Figure 10: Impulse responses of liquidity to asset price volatility at different time points.

which shows that the effect of quantitative monetary policy will decline in the mid-term and long-term. It is similar to the studies of Ayodeji and Oluwole [77]. Second, the impulse response of the output level and the price level has opposite directions in the short and medium term under the interest rate shocks, but the direction is the same in the long-term. However, the former showed a positive feedback effect, while the latter showed a negative feedback effect since 2011. More recently, Zheng and Zhu [78] also find interest rate has negative effects on output growth, and the impacts in different terms are not similar. It is illustrated that raising interest rates can increase the output level and curb inflation in the short term [79], but it may cause macroeconomic deflation in the mid-term and long-term,which is consistent with the existing research results [14].

4.4.3. Time-Varying Impulse Responses of Internal Shocks at Different Time Points. We further adopt impulse response functions at different time points to dynamically compare the regulatory effects of monetary policy choices at different time points. Based on the previous analysis of the state transition characteristics of China's asset price volatility, we select October 2008, June 2015, and January 2020 as some typical time points, corresponding to the global financial crisis, China's stock market crash, and COVID-19, respectively.

Furthermore, in Figure 10, the impulse responses of liquidity to asset price volatility at different time points significantly vary over time. First, under the impact of currency liquidity and banking system liquidity, the stock market exhibited a positive feedback effect, especially in October 2008, which showed that currency liquidity and banking system liquidity had a significant impact on asset prices due to the global financial crisis [5]. Second, under the impact of market liquidity, the stock market and real estate market at all other times showed a strong feature of "inverted V" shape except in June 2015. In addition, the real estate market has a typical negative effect in June 2015 and January 2020 under the shocks of market liquidity, which shows that China's stock market crash and COVID-19 pandemic have affected the liquidity, which indicates some differences in the transmission effects of asset prices.

It can be seen from Figure 11 that the impulse responses of monetary policy to liquidity at different time points. Specifically, when the positive information impact of one unit of money supply was given, both currency liquidity and banking system liquidity in October 2008 showed a negative

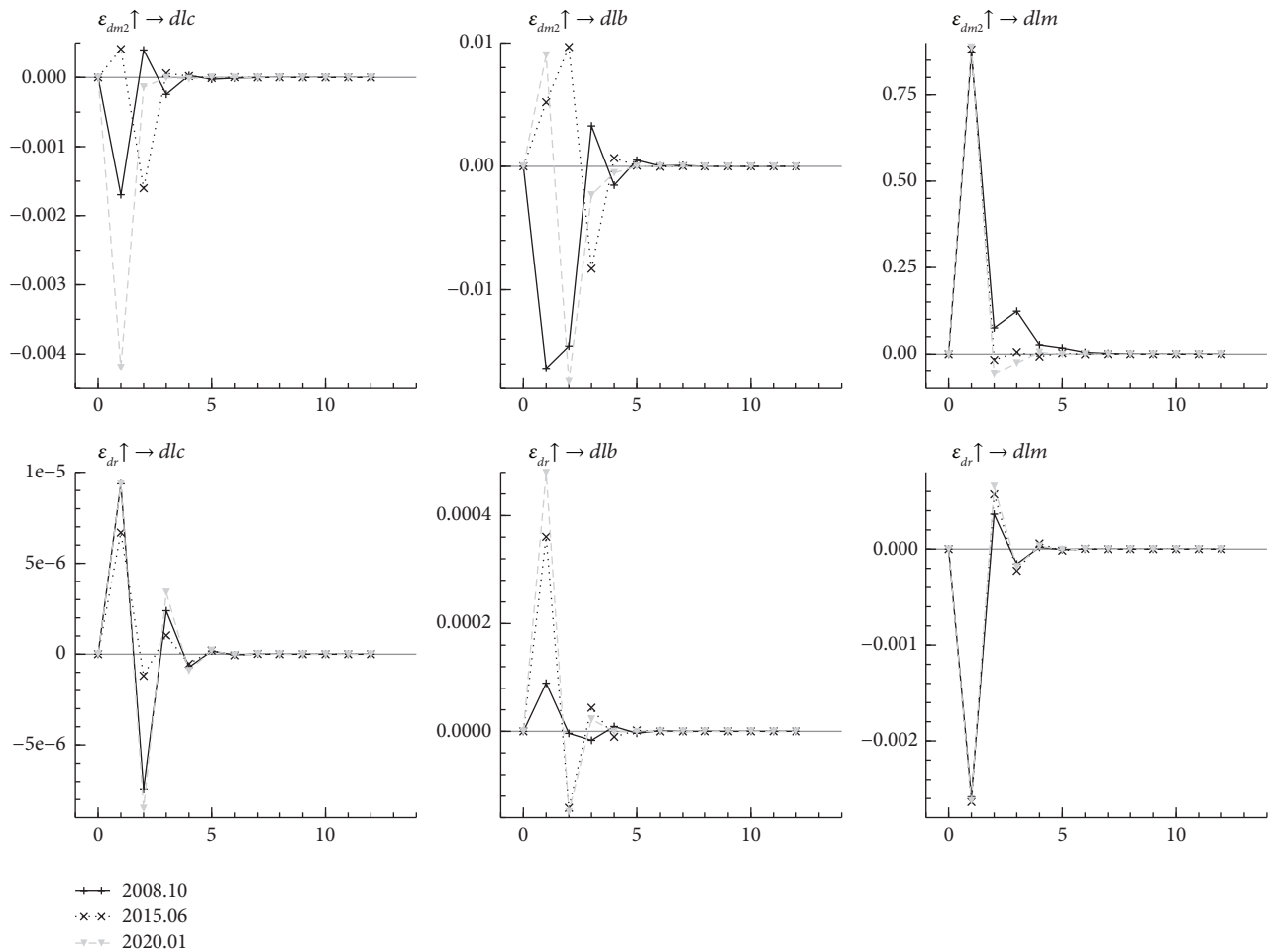

Figure 11: Impulse responses of monetary policy to liquidity at different time points.

effect and reached a low value in the first phase, and then turned to a positive effect in the second and third phases, respectively, and began to decline and remain stable. However, thecurrency liquidity and banking system liquidity in June 2015 turned negative in the second and third phases, respectively, and reached the bottom. Under the impact of the money supply, the currency liquidity, banking system liquidity and market liquidity at the three time points in January 2020 basically showed a positive feedback effect. When the interest rate is impacted by one unit of positive information, the impulse response function of currency liquidity and banking system liquidity at three different time points has a similar trend. Both of them reach the peak and show a positive response at the first stage, and then turn negative and gradually remain stable, presenting a typical oblique "Z" curve. However, after the impact of interest rate, market liquidity showed negative in the first period, and then improved and stabilized, with an obvious "V-shaped" trend. In general, at three different time points, the regulating effect of money supply on liquidity of different dimensions is greater than that of interest rate on liquidity of different dimensions, but the quantitative and price regulation strategy of monetary policy has a greater impact on market liquidity and better effect. This shows that market liquidity is more sensitive to the reaction of monetary policy when subjected to extreme events, which is relatively consistent with the results of these studies [3, 4].

The impulse responses of monetary policy to asset price volatility at different time points in Figure 12 show that: on the one hand, the impulse response trend of the money supply on the stock market showed positive and negative effects in October 2008 and January 2020, respectively. Moreover, the impulse response on the real estate market showed the three time points all reached the maximum in the first period, then began to show the negative effect, indicating the money supply has an obvious positive response to the real estate market in the short term, but still has a negative effect in the long term. Assenmcher-Wesche and Gerlach [80] reveal that the impact of monetary policy on stock prices and housing prices is quite different, and it is also reflected in our findings. On the other hand, the impacts of the stock market on interest rates showed a positive effect at all three points in time and a downward trend, which revealed that interest rates have a better regulatory effect on stock price volatility [16], especially in 2015. In addition, after the real estate market was hit by interest rates, the impulse response trend at the three time points was consistent. Therefore, it further indicates that there is an

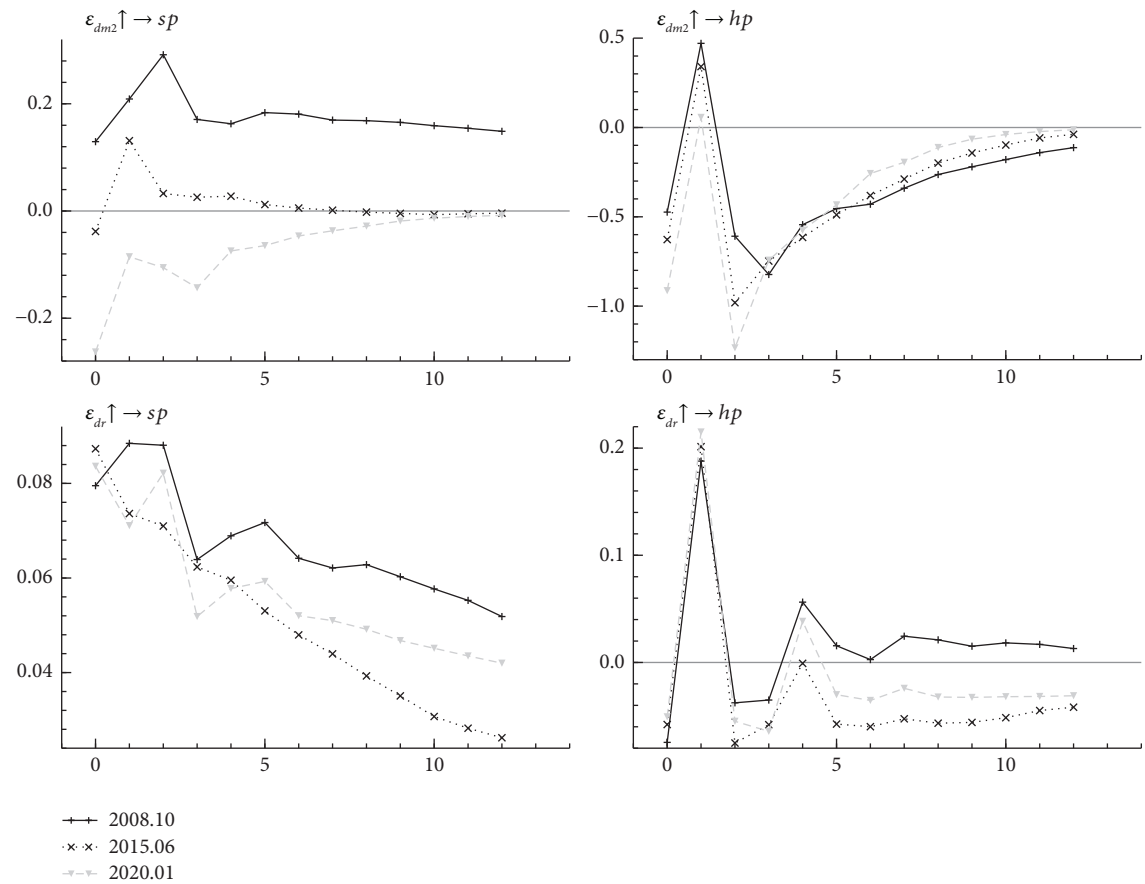

Figure 12: Impulse responses of monetary policy to asset price volatility at different time points.

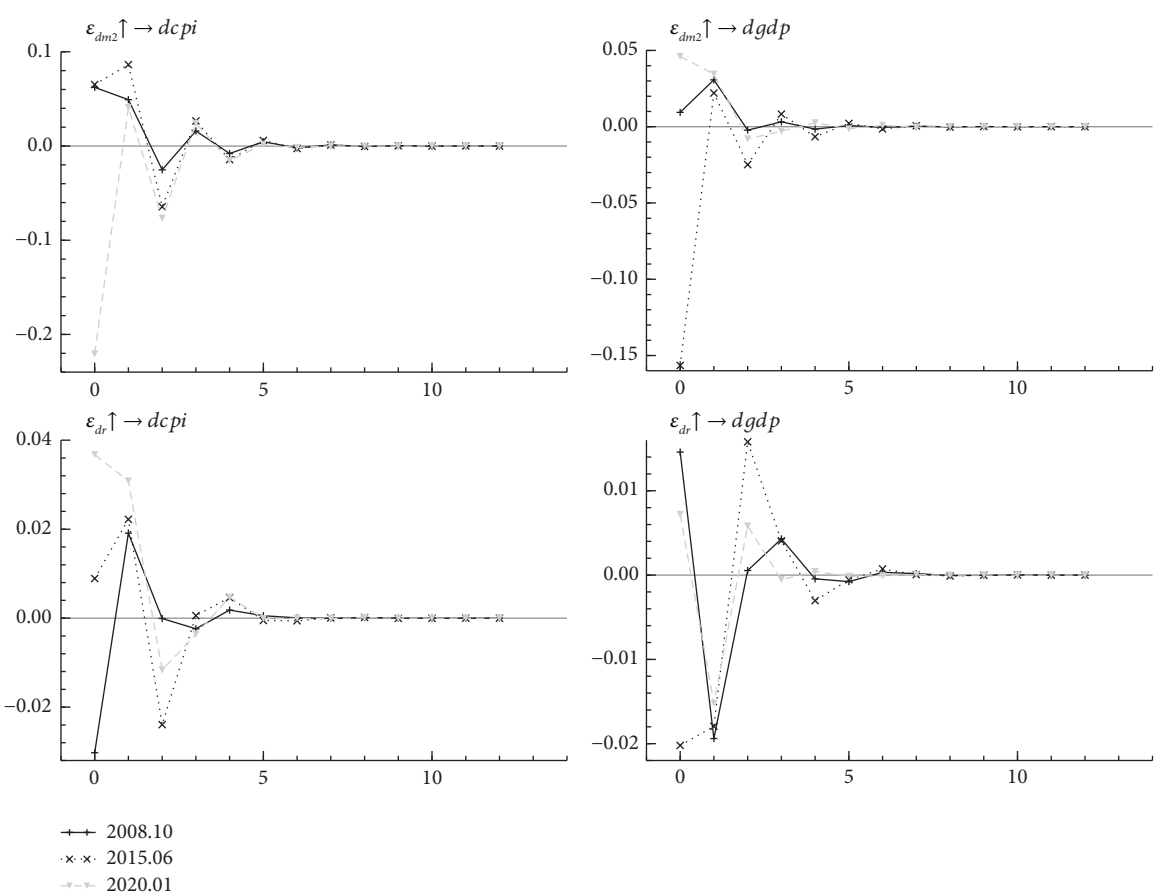

Figure 13: Impulse responses of monetary policy to macroeconomics at different time points.

important connection between monetary policy signals and financial market transaction behavior, which has important policy implications.

Moreover, Figure 13 can depict the impulse responses of monetary policy to macroeconomy, including the output and price level. First, under the shocks of the money supply, the output level at the three time points all reached their maximum in the first period, and showed a significant positive expansion trend, indicating that the shocks of loose money supply can be conducive to stimulating economic growth in the short term, especially under the global financial crisis in 2008. Second, the price level at the three time points reached the maximum in the first period, and then remained stable under the shocks of the money supply. This shows that quantitative monetary policy can effectively curb inflation in the long-term, which is similar to the research findings of Liu et al. [79]. Moreover, under the shocks of interest rate, the impulse response results of the output level and the price level are complementary in the short-term and consistent in the long-term [19], which further show that the differentiated monetary policy should be implemented for the reason that the single monetary policy cannot simultaneously guarantee higher economic growth and lower inflation in different periods [13]. Hence, a reasonable combination of quantitative and price monetary policies can be needed to seek optimal regulatory effects.

5. Conclusions and Discussions

This paper adopts the MS-AR model to effectively identify the high and low volatility state of the stock market and real estate market in China, and further combs the characteristics between different dimensions of liquidity and asset price volatility. Then we use the TVP-SV-VAR model to empirically analyse and compare the time-varying characteristics and regulatory effects of the quantitative and price-based monetary policy. We draw the following conclusions: firstly, the high and low volatility state of China's stock market and real estate market can be clearly divided, and it shows good matching and consistency with the trend of asset prices. Secondly, different dimensions of liquidity have a strong ability to explain the high and low volatility state of China's asset prices. However, the high and low volatility state of asset prices are not completely consistent with the rapid expansion and contraction of currency liquidity, but the explanatory effect of market liquidity on the real estate market clearly shows a divergence characteristic during some periods. Moreover, market liquidity can provide an explanation for the volatility of the stock market, which plays a guiding role in regulating the stock market. Lastly, the effects of monetary policy regulation is clearly time-varying, and the response cycle of quantitative monetary policy regulation based on money supply is relatively short, and it reflects the effect of macroeconomic operations more accurately. However, the response cycle of price-based monetary policy regulation based on interest rates is longer, which mainly reflects the anticipatory and fine-tuning effects of liquidity, macroeconomy and asset price volatility. In addition, the regulation of price-based monetary policy choices has relatively excellent effects on asset price volatility, but the quantitative monetary policy can have great impacts on the the macroeconomy, which further shows that China needs to adopt both the quantitative and price-based monetary policy choices.

These findings of the study can provide early warning information for paying attention to asset price bubbles and potential financial risks, and serve as indicators for the central bank to maintain reasonable liquidity and regulate asset price volatility more reasonably. It also provides reference basis for subsequent policy formulation and implementation when the monetary policy regulating effect changes. Moreover, some implications should be obtained from the study. On the one hand, according to the state transition characteristics of asset price volatility, we should pay attention to the duration of high and low volatility state. In addition, the characteristics of liquidity in different dimensions should be considered to predict the transition period and the possible fluctuations in asset prices, providing a reference for investors to adjust their investment behaviour. On the other hand, monetary policy should fully focus on the time-varying policy chain effects on the capital market when intervening in asset prices and macroeconomy. On the basis of considering the structural changes of liquidity in different dimensions brought about by asset price volatility and the resulting impacts on the asset price spiral, the intervention intensity and timing are accurately grasped. Lastly, the transmission mechanisms of monetary policy should be enhanced, and we can further leverage the synergistic effects of quantitative and price-based monetary policy, which form a virtuous circle of interlinked expected results and policy guidance. However, the causes of asset price volatility are complex and diverse. In order to effectively regulate asset prices in the new situation, the optimal combination of monetary policies and macro-prudential policies should be explored in the future study.

Data Availability

All the original data in this study were mainly taken from Wind Information Finance Terminal (WIND) and China Stock Market and Accounting Research Database (CSMAR). The data in relation to the findings of this study are available from the corresponding author upon reasonable request.

Conflicts of Interest

The authors declare that there are no conflicts of interest regarding the publication of this article.

Acknowledgments

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