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Does China's monetary policy framework incorporate financial stability?

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ABSTRACT

This article investigates the response of monetary policy to financial instability in China. We estimate a forward-looking Taylor rule model with a constructed comprehensive financial stress index using the time-varying coefficient method. Empirical results suggest that financial stability has always been a main concern for China's monetary authorities even in periods with low financial pressure. Moreover, China's central bank tends to lower the policy interest rate in response to financial instability, but the size of policy responses varies substantially over time. Although the proportion of policy interest rate change due to financial stability concern is less relative to developed countries, financial stability is increasing in importance for monetary policymaking in China. We also find that banking stress and stock-market stress are two main concerns for China's central bank, while little evidence supports that exchange-market stress can drive the reaction of China's central bank.

KEYWORDS

Forward-looking Taylor rule; financial stability; monetary policy; time-varying coefficient model

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1. Introduction

Central banks intrinsically play an important role in stabilizing the financial system (Minsky and Kaufman 2008). Yet, this role has not been emphasized by policymakers (De Gregorio 2010) until the outbreak of the global financial crisis in 2008 (Agénor and Pereira da Silva 2012). Since then, although central banks have no clearly articulated financial-stability objective, it has become a vital part of monetary policymaking in many developed countries (Oosterloo, de Haan, and Jong-A-Pin 2007; Albulescu 2013).

In this article, we want to determine whether financial stress also matters for the monetary policy in developing countries, like China. The answer from theoretical studies is not unanimous. For example, Bernanke and Gertler (2001) suggest that there are few gains to respond to asset prices since the stabilization of inflation and output can contribute to financial stability substantially. Faia and Monacelli (2007)

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also confirm that strict inflation stabilization gives the optimal result by a welfare analysis. However, some researchers argue that monetary-policy rule should include some measures of financial instability (Cecchetti and Li 2008; Brousseau and Detken 2001; Akram, Bårdsen, and Lindquist 2007). Further, whether monetary policy should respond to financial instability depends on the financial structure (Teranishi 2012), the characters of shock (Akram, Bårdsen, and Lindquist 2007) and the time horizon of monetary-policy objectives (Bauducco, Cihák, and Bulíř 2008).

From the perspective of empirical research, very little work has been done to study the response of monetary policy to financial instability, partially due to the difficulty in constructing a comprehensive indicator of overall financial instability. Instead, most studies evaluate the reaction of monetary policy using a broader measure of financial stress, like asset prices (Rigobon and Sack 2003; Fuhrer and Tootell 2008), the volatility of asset prices (Borio and Lowe 2004), the stress in the banking system (Cecchetti and Li 2008) and the probability of a crisis (Bulíř and Čihák 2008). Besides, these studies mainly employ data from developed and highly industrialized countries (Borio and Lowe 2004; Cecchetti and Li 2008) or a panel of developing countries (Bulíř and Čihák 2008; Floro and Van Roye 2017), but none of them focus on a single developing country. The results of the literature, in general, suggest that developed countries often adopt a loose monetary policy in response to financial distress, but this conclusion does not apply to countries with an emerging market (Bulíř and Čihák 2008; Floro and Van Roye 2017; Baxa, Horváth, and Vašíček 2013; Cesa-Bianchi and Rebucci 2017; Kashyap and Siegert 2020). Even for the developed countries, some of them do not make a quick response to financial imbalance, for example, Germany, Australia, Japan and Finland (Borio and Lowe 2004; Cecchetti and Li 2008; Verona, Martins, and Drumond 2017) and some only react to financial stress during the period of high volatility in the financial market (Baxa, Horváth, and Vašíček 2013; Floro and Van Roye 2017).

The subtle disparity in these studies that use a selection of different countries, implies responses of monetary policy to financial instability may differ significantly across countries. On top of that, monetary policy rules or reaction functions are estimated with time-invariant parameters in these studies, which is inconsistent with the evolvement of monetary policy setting and exogenous shocks outside the economic system. Therefore, empirical studies about monetary policy should apply to the unstable and changing structure of estimated coefficients of monetary policy rules in the long run (Baxa, Horváth, and Vašíček 2013) and be conducted with time-varying coefficient structure (Trecroci and Vassalli 2010).

This article adopts the method of 'time-varying coefficients' (TVC)[1] to estimate a forward-looking Taylor rule model in China. To reflect all potential financial risks in China, we construct a comprehensive index for financial stability, covering the foreign exchange market, the banking system, the stock market and the global financial market. Some studies have been done to estimate monetary policy rules with the TVC method (Liu and Zhang 2012; Baxa, Horváth, and Vašíček 2013; Aragón and de Medeiros 2015; Liu and Bi 2019). Yet, very few study the relationship between monetary policy and financial stability. To fill this gap, using the TVC approach, this article researches the evolving relationship between monetary policy and financial stability.

As we mentioned, many previous studies about the response of monetary policy to financial stability primarily focus on developed and industrialized countries (Borio and Lowe 2004; Cecchetti and Li 2008; Baxa, Horváth, and Vašíček 2013). And empirical results concerning a single developing country are still lacking. As one of the largest developing countries in the world, the findings in China's financial system can be representative and applicable to other emerging markets. Moreover, financial stability has been a premise of China's current monetary policy.[2] For example, China's central bank mentioned stabilization of the financial system by implementing a comprehensive plan several times since 2012.[3] Furthermore, a new financial agency, Bureau of Financial Stability, is established to routinely post the reports on China's financial stability (Zhang and Sun 2006). Our work can be considered as an illustrative study that analyzes the time-varying reaction of monetary policy to financial instability in developing countries like China. These features of this article constitute a potentially important contribution to the literature.

Despite the ongoing controversy about the role of financial instability in central banks' policymaking, our results show that financial instability is always a concern for China's central bank, and, in response to financial instability, policymakers tend to loosen monetary policy and lower the interest rate target. We also find that the size of responses of policy interest rate varies over time and there is a growing trend of the proportion of change in interest rate depending on the degree of concern for financial stress. Further, China's central bank was concerned more about banking stress in the 1997 Asian financial crisis, stock market stress during the global financial crisis in 2008 and the stock market boom and bust cycle in 2015. Foreign exchange market stress, however, has little effect on monetary policymaking over the last two decades.

The remainder of this article is organized as follows. Theoretical framework and empirical model, including the time-varying coefficient model and identification strategy, are provided in Section 2. Section 3 presents data and measurement. Section 4 reports the empirical results and interpretations. The last section discusses some policy implications and provides concluding remarks.

2. The empirical model

2.1. Baseline model

As a central bank's policy reaction function, the forward-looking monetary policy rule assumes that the central bank's interest rate policy is designed in a forward-looking manner (Clarida, Galı, and Gertler 1998, 2000):

$$r_t^* = r^* + \beta(E\{\pi_{t+k}|\Omega_t\} - \pi^*) + \gamma E[y_{t+q}|\Omega_t] \tag{1}$$

where r_t^* denotes the target interest rate in period t. π_{t+k} indicates the percentage change of the price level from period t to $t+k$ and π^* is referred to as the target inflation rate. y_{t+q} measures the average output gap from period t to $\mathrm{t+q}$. E is the expectation operator and Ω_t represents the information set as the interest rate is determined. r^* denotes the expected interest rate when inflation and output are both at target levels.

To further adjust the interest rate for the target set by central banks, local adjustments are included in Equation (1) in many empirical studies as follows (Baxa, Horváth, and Vašíček 2013):

$$r_t = \rho(L)r^*_{t-1} + (1 - \rho(L))r^*_t + e_t \quad (2)$$

where e_t indicates exogenous shocks to the target interest rate. $\rho \in [0, 1]$ is the smoothing parameter.

Combining Equation (1) with Equation (2), we obtain the forward-looking monetary policy rule under the interest rate smoothing condition:

$$r_t = (1 - \rho)\left[\alpha + \beta\left(E\{\pi_{t+k}|\Omega_t\} - \pi^*\right) + \gamma E\left(y_{t+q}|\Omega_t\right)\right] + \rho r_{t-1} + e_t \quad (3)$$

We can derive the optimal policy rule using the linear monetary policy rule in Equation (3) under the framework of the central bank's loss function. However, in this framework, the central bank only aims to achieve price stability and maintain sustainable economic growth (Baxa, Horváth, and Vašíček 2013). On the contrary, Bauducco, Cihák, and Bulíř (2008) insist that central banks have access to privileged information of credit risk, and thus the traditional monetary policy rules should be extended by adding proxy variables for financial sectors. Therefore, we adopt a forward-looking monetary policy rule that includes an index for financial instability, which indicates that the central bank reacts to financial stress when setting the target interest rate. After eliminating the unobservable predictive variables and including an index of financial stability, the forward-looking monetary policy rule is represented as:

$$r_t = (1 - \rho)\left[\alpha + \beta(\pi_{t+k} - \pi^*) + \gamma y_{t+q}\right] + \rho r_{t-1} + \Phi f_{t+p} + \varepsilon_t \quad (4)$$

where α coincides with the policy-neutral rate r^*. The stochastic error term ε_t is the combination of forecast errors and the exogenous disturbance e_t. The indicator of financial instability, f_{t+p}, does no influence the policy interest rate r^*_t, but it might affect the lagged interest rate. This explains why the actual interest rate deviates from the target one (Baxa, Horváth, and Vašíček 2013). In addition, the coefficient Φ tends to be larger when the financial system is unstable, showing that central banks respond to financial instability, but these responses are always delayed (Mishkin 2009). Coefficients ρ and Φ are usually negatively related since central banks can stabilize the financial system by smoothing or adjusting the interest rates (Baxa, Horváth, and Vašíček 2013). Lastly, as with the setting in other articles (e.g., Baxa, Horváth, and Vašíček 2013), k is set equal to 6,[4] q equals to 0 and p equals to –1.

2.2. Time-varying coefficient model with Taylor rules

Since a few years ago, some more complicated methods, like the time-varying coefficient model, have been given more attention in the empirical studies. Compared to traditional time-invariant estimation, time-varying coefficient estimation can improve the model by fully considering a central bank's preference over interest rate adjustment aimed at inflation gap, output gap and financial instability (Cooper and Priestley 2009). To overcome inherent limitations in traditional time-invariant coefficient and state-space models,[5] this article employs the time-varying coefficient model proposed by Schlicht and Ludsteck (2006) to estimate the forward-looking Taylor rules model that includes an index for financial instability.

The reverse causality between financial instability and policy interest rate can make estimates inconsistent (Kim 2006). To deal with the potential endogeneity, we rewrite the Equation (4) as the following structural form based upon the two-stage method (Kim and Nelson 2006):

$$r_t = (1-\rho_t)(\alpha_t + \beta_t\pi_{t+k} + \gamma_t y_{t+q}) + \rho_t r_{t-1} + \Phi_t f_{t+p} + \varepsilon_t \tag{5}$$

$$\rho_t = 1/\left(1 + \exp(-\theta_t)\right) \tag{6}$$

$$\alpha_t = \alpha_{t-1} + v_{1,t},\ \ v_{1,t} \sim i.i.d.\ N(0, \sigma^2_{v_1}) \tag{7}$$

$$\beta_t = \beta_{t-1} + v_{2,t},\ \ v_{2,t} \sim i.i.d.\ N(0, \sigma^2_{v_2}) \tag{8}$$

$$\gamma_t = \gamma_{t-1} + v_{3,t},\ \ v_{3,t} \sim i.i.d.\ N(0, \sigma^2_{v_3}) \tag{9}$$

$$\Phi_t = \Phi_{t-1} + v_{4,t},\ \ v_{4,t} \sim i.i.d.\ N(0, \sigma^2_{v_4}) \tag{10}$$

$$\theta_t = \theta_{t-1} + v_{5,t},\ \ v_{5,t} \sim i.i.d.\ N(0, \sigma^2_{v_5}) \tag{11}$$

Equation (5) represents the state-space measurement form of the forward-looking monetary policy rule. Equations (6) to (11) characterize the time-varying coefficients in a random walk process without a drift. Instrumental variables are adopted to estimate the parameters in Equation (5). The structural equation system of the endogenous variables π_{t+k}, y_{t+q}, f_{t+p} and the vector of instrumental variables z_t is:

$$\pi_{t+k} = z_t'\delta_{1t} + \upsilon_{1t},\ \ \upsilon_{1t} \sim N(0, \sigma^2_{\upsilon_{1t}}) \tag{12}$$

$$y_{t+k} = z_t'\delta_{2t} + \upsilon_{2t},\ \ \upsilon_{2t} \sim N(0, \sigma^2_{\upsilon_{2t}}) \tag{13}$$

$$f_{t+k} = z_t'\delta_{3t} + \upsilon_{3t},\ \ \upsilon_{3t} \sim N(0, \sigma^2_{\upsilon_{3t}}) \tag{14}$$

$$\delta_{it} = \delta_{i,t-1} + u_{i,t},\ \ u_{i,t} \sim i.i.d.\ N(0, \textstyle\sum_{u,i}),\ \ i = 1,2,3 \tag{15}$$

$$\sigma^2_{\upsilon j,t} = a_{0j} + a_{1j}\upsilon^2_{j,t-1} + a_{2j}\sigma^2_{\upsilon j,t-1},\ j = 1,2,3 \tag{16}$$

The equation system shows that the correlation of explanatory variables and instrumental variables is time-varying and there may be heteroskedasticity in the error terms in Equations (12) to (14). In addition, Equations (12) to (14) indicate the uncertainty of future inflation, output and financial stability can change over time. Endogenous variables π_t, y_t and f_t can be divided into two parts, the predicted value and prediction error:

$$\begin{bmatrix} \pi_t \\ y_t \\ f_t \end{bmatrix} = E\begin{bmatrix} \pi_t & \\ y_t & |\xi_{t-1} \\ f_t & \end{bmatrix} + \begin{bmatrix} \upsilon_{1,t|t-1} \\ \upsilon_{2,t|t-1} \\ \upsilon_{3,t|t-1} \end{bmatrix} \tag{17}$$

$$\begin{bmatrix} \upsilon_{1,t|t-1} \\ \upsilon_{2,t|t-1} \\ \upsilon_{3,t|t-1} \end{bmatrix} = \Lambda^{1/2}_{t|t-1}\begin{bmatrix} \upsilon^*_{1,t} \\ \upsilon^*_{2,t} \\ \upsilon^*_{3,t} \end{bmatrix},\ \begin{bmatrix} \upsilon^*_{1,t} \\ \upsilon^*_{2,t} \\ \upsilon^*_{3,t} \end{bmatrix} \sim i.i.d.\ N\left(\begin{bmatrix} 0 \\ 0 \\ 0 \end{bmatrix}, \begin{bmatrix} 1 & 0 & 0 \\ 0 & 1 & 0 \\ 0 & 0 & 1 \end{bmatrix}\right) \tag{18}$$

where ξ_{t-1} denotes the information set in period $t-1$ and $\Lambda_{t|t-1}$ indicates a time-varying variance-covariance matrix of the prediction error vector, $\upsilon_{t|t-1} = [\upsilon_{1,t|t-1}, \upsilon_{2,t|t-1}, \upsilon_{3,t|t-1}]'$. Furthermore, $\Lambda_{t|t-1}$ and $\upsilon_{t|t-1}$ can be estimated by Kalman filtering given the equations from (12) to (16).

We set up one 3×1 standardized prediction error vector, $\upsilon^*_t = [\upsilon^*_{1,t}, \upsilon^*_{2,t}, \upsilon^*_{3,t}]'$ and, without loss of generality, assume that υ^*_t and ε_t have the covariance structure below:

$$\begin{bmatrix} \upsilon^*_t \\ \varepsilon_t \end{bmatrix} \sim N\left(\begin{bmatrix} 0 \\ 0 \end{bmatrix}, \begin{bmatrix} I_3 & \tau\sigma_{\varepsilon,t} \\ \tau'\sigma_{\varepsilon,t} & \sigma^2_{\varepsilon,t} \end{bmatrix}\right) \tag{19}$$

where $\tau = [\tau_1, \tau_2, \tau_3]'$ denotes a constant 3×1 vector. Based on (19), we could rewrite ε_t as:

$$\varepsilon_t = \tau_1\sigma_{\varepsilon,t}\upsilon^*_{1,t} + \tau_2\sigma_{\varepsilon,t}\upsilon^*_{2,t} + \tau_3\sigma_{\varepsilon,t}\upsilon^*_{3,t} + \Psi^*_t,\ \ \Psi^*_t \sim N(0, (1-\tau_1^2-\tau_2^2-\tau_3^2)\sigma^2_{\varepsilon,t}) \tag{20}$$

where Ψ^*_t is unrelated to $\upsilon^*_{1,t}$, $\upsilon^*_{2,t}$ and $\upsilon^*_{3,t}$. Substituting Equation (20) into (5), we get:

$$r_t = (1-\rho_t)[\alpha_t + \beta_t\pi_{t+k} + \gamma_t y_{t+q}] + \rho_t r_{t-1} + \Phi_t f_{t+p} + \tau_1\sigma_{\varepsilon,t}\nu^*_{1t} + \tau_2\sigma_{\varepsilon,t}\nu^*_{2t} + \tau_3\sigma_{\varepsilon,t}\nu^*_{3t} + \Psi^*_t \tag{21}$$

The consistent estimator in Equation (5) could be obtained by two-stage MLE. At the first stage, we adopt the maximum likelihood to estimate Equations (12) to (14) and attain the standardized prediction errors $\hat{\upsilon}^*_{1,t|t-1}$, $\hat{\upsilon}^*_{2,t|t-1}$ and $\hat{\upsilon}^*_{3,t|t-1}$. At the second stage, we estimate Equation (21) by MLE after Kalman filtering.

3. Data and measurement

3.1. Data source

Our data come from International Financial Statistics (IFS) database provided by the International Monetary Fund and China's Wind database. We adopt the sample data from January 1996 to December 2019 on a monthly basis because compared to quarterly or yearly data, monthly data can capture the short-run adjustment in the monetary policy changing with the simultaneous economic situation.

3.2. Policy interest rate

The interbank lending market and bond repo market in China have the highest degree of marketization and the corresponding market-based interest rate can rapidly adjust to the change of price level and output gap (Christensen, Lopez, and Rudebusch 2014). We choose 7-day inter-bank offered rates as the proxy for the policy interest rate. The monthly data from January 1996 to December 2019 are from the website of the People's Bank of China[6] and Shanghai Financing Center (see Figure 1).

3.3. Inflation target and inflation rate

China's overall inflation is measured by the monthly year-on-year growth rate of the Consumer Price Index (CPI). Specifically, CPI inflation (%) = (current price level- base price level)/base price level × 100, where monthly CPI data is from the National Bureau of Statistics of China, with base the same period previous year = 100. The system aiming at an inflation target has not been put into effect in China, thus the inflation target is not made public officially. Nonetheless, National Development and Reform Commission reports to National People's Congress of the People's Republic of China every year, based on the reports, we set the target inflation rate at 4% to obtain the inflation gap accordingly, which is also consistent with Xie and Luo (2002) as well as Liu and Zhang (2012). Figure 2 shows the inflation gap from January 1996 to December 2019.

3.4. Output gap

Existing statistical data include only cumulative nominal seasonal GDP and the nominal seasonal GDP can be calculated by subtracting cumulative values in the previous season from the current season in the same year. Quarterly nominal GDP is then transformed into monthly nominal GDP.[7] After seasonal adjustment, we convert nominal monthly GDP into real monthly GDP.[8] Output Gap (%) is measured as (real GDP-potential GDP)/potential GDP × 100.[9] Figure 3 plots the time series of the real output gap from January 1996 to December 2019.

3.5. Financial instability

Many studies adopt Financial Stress Index (FSI) as the proxy variable for financial instability (Cardarelli, Elekdag, and Lall 2009; Baxa, Horváth, and Vašíček 2013). FSI is a comprehensive financial index composed of the banking system, the foreign

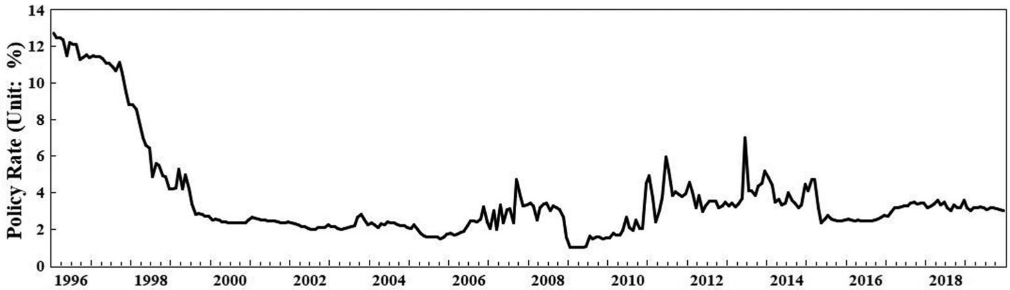

Figure 1. 7-day inter-bank offered rates. Source: Website of the People's Bank of China and Shanghai Financing Center.

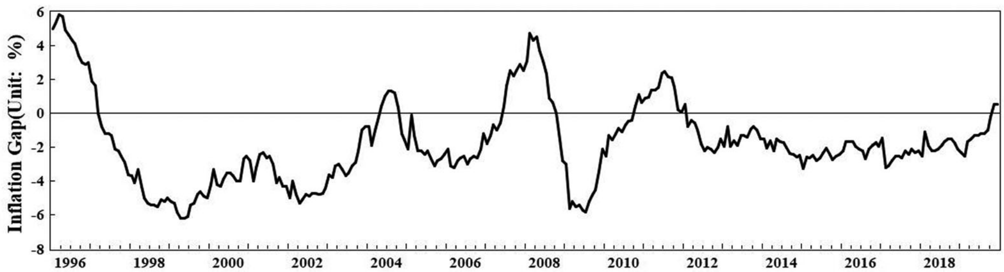

Figure 2. Inflation gap. Source: The National Bureau of Statistics of China and authors' calculations

exchange and stock markets. It reflects real-time financial stress in a country and assesses the potential risk of the entire financial market (Oet, Dooley, and Ong 2015). To measure financial risks of developing countries, Balakrishnan et al. (2011) put forward a way to construct an index named Emerging Market Financial Stress Index (EM-FSI) that involves Exchange Market Pressure Index (EMPI), Sovereign Risk Index, Banking Risk Index, rate of return in the stock market and volatility in stock price. This article adopts EM-FSI but excludes the Sovereign Risk.[10] Instead, we incorporate the TED-Spread that indicates liquidity risk in the banking system. TED-Spread is the difference between the three-month interbank lending rate and yield to maturity of the three-month treasury bond.[11] When TED-Spread rises, the liquidity in the banking system declines and the corresponding risk goes up.

As financial reform goes further, China's market is closer to the international market and becomes more relevant to the global economy. Accordingly, EM-FSI in this article also includes an indicator that measures the volatility of the international financial market, CBOE (Chicago Board Options Exchange) Volatility Index (VIX). Similar to Balakrishnan et al. (2011), the financial stress index is constructed according to the following formula:

$$\mathrm{FSI} = w_{em}\mathrm{EMPI} + w_{\beta}\beta + w_{ted}\mathrm{TED} + w_{sr}\mathrm{SR} + w_{sv}\mathrm{SV} + w_{vix}\mathrm{VIX} \tag{22}$$

where EMPI denotes the Exchange Market Pressure Index. β is the beta coefficient of the banking system estimating the risk in the banking sector. TED-Spread reflects the liquidity of banks. Stock Market Return (SR) and Stock Market Volatility (SV) are

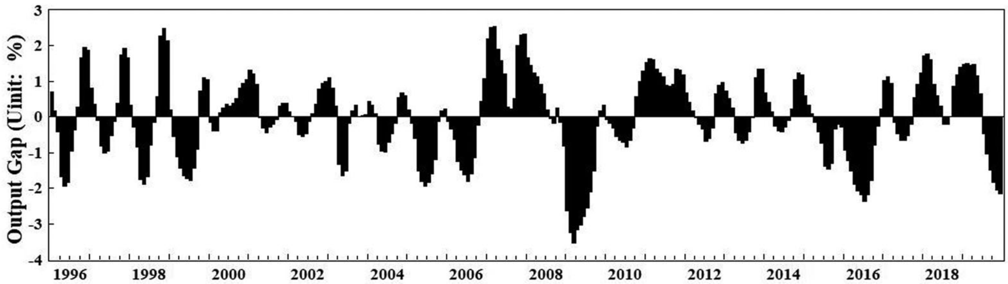

Figure 3. Output gap. Source: China's Wind database and authors' calculations.

the rate of return and volatility in the stock market, respectively. VIX is the CBOE Volatility Index. FSI is a linear combination of all variables with corresponding weights.

The Exchange Market Pressure Index (EMPI) is measured as follows:

$$\mathrm{EMPI}_t = \frac{(\Delta er_t - \mu_{\Delta e})}{\sigma_{\Delta e}} - \frac{(\Delta \mathrm{FER}_t - \mu_{\Delta \mathrm{FER}})}{\sigma_{\Delta \mathrm{FER}}} \tag{23}$$

where Δer_t And $\Delta \mathrm{FER}_t$ denote the change of monthly nominal exchange rate and monthly foreign reserve; μ and σ represent mean values and standard deviations of each variable.

We calculate the weights of the components by the CRITIC (criteria importance through inter-criteria correlation) objective weighting method[12] using the formula: $W_j = C_j / \sum_{j=1}^{n} C_j$, where $C_j = \sigma_j \sum_{i=1}^{n} (1 - r_{ij})$. σ_j denotes the standard deviation of indicators j and r_{ij} is the correlation coefficient between indicators i and j for $j = 1, 2, \ldots, n$. n is set to be 6 in this article.

Figure 4 shows the financial stress index of China from January 1996 to December 2019. A higher FSI indicates a higher risk one country takes in the financial system. Most of the time, financial risk in China is small, while it becomes larger due to the Asian financial crisis in 1997, the subprime mortgage crisis in 2008, the stock market boom and bust cycle and the huge devaluation of the RMB in 2015.

3.6. Descriptive statistics

Detailed definitions for all the variables used in the article are provided in Table 1. Table 2 shows the summary statistics of the sample data. The policy interest rate and the inflation gap are more volatile than the output gap and FSI. The mean values of the output gap and FSI are both close to zero. The final series mange to pass several conventional unit root tests at the 5% level of significance,[13] indicating that they are all stationary.

4. Empirical results

In this section, we first estimate a time-invariant monetary policy rule, including the traditional and the forward-looking Taylor rule models. The results are then

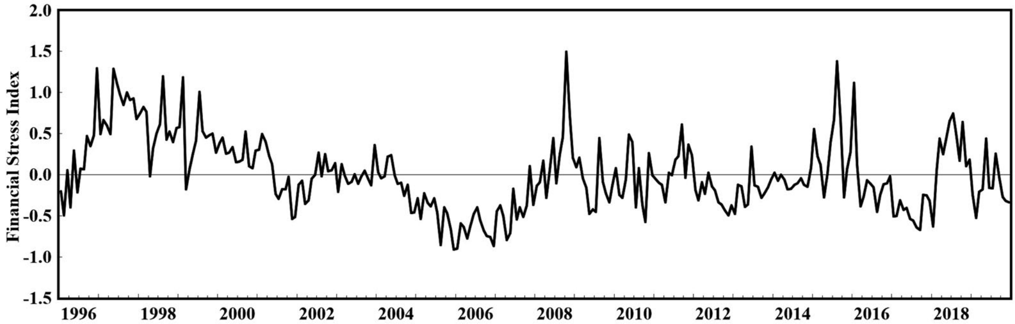

Figure 4. China's FSI from January 1996 to December 2019. Source: Authors' calculations.

Table 1. Variable definitions.

Variable	Definitions
Policy Interest Rate	7-day inter-bank offered rates as the proxy for the policy interest rate
Inflation Gap	Inflation Gap = (inflation rate – inflation target). CPI inflation rate (%) = (current price level – base price level)/base price level × 100, where monthly CPI is from the National Bureau of Statistics of China, with base the same month previous year = 100. The target inflation rate is 4%.
Output Gap	Output Gap (%) = (real GDP-potential GDP)/potential GDP × 100. Real GDP = (Nominal Monthly GDP/CPI in the current month) × 100, where CPI is with the year 2000 as the base year. Quarterly GDP is converted to monthly GDP after seasonal adjustment and frequency transformation.
FSI	FSI = w_{em}EMPI + $w_\beta\beta$ + w_{ted}TED + w_{sr}SR + w_{sv}SV + w_{vix}VIX. EMPI is the Exchange Market Pressure Index. β is the beta coefficient of the banking sector. TED-Spread reflects the liquidity of banks. SR and SV are the rate of return and volatility in the stock market. VIX is the CBOE Volatility Index. FSI is a linear combination of all variables with corresponding weights, calculated by the CRITIC objective weighting method.

Table 2. Descriptive statistics of variables.

Variables	Mean	Maximum	Minimum	Std. deviation	ADF test	Observations
Policy interest rate r_t(%)	3.690	12.720	0.990	2.599	–3.573***	288
Inflation gap $\pi_t - \pi^*$(%)	–1.765	5.800	–6.200	2.445	–3.337**	288
Output gap y_t (%)	–0.023	2.525	–3.533	1.158	–5.745***	288
FSI	0.037	1.294	–0.911	0.436	–3.487***	288

For the ADF test, ***, ** and * indicate significance at the 1%, 5% and 10% significance levels, respectively and the optimal lag length is determined based on Schwarz Info Criterion with a maximum lag of 15 periods.

compared with those from the forward-looking time-varying Taylor rule model. We also analyze the effect of financial instability on the policy interest rate, as well as the impact of the sub-components of financial instability in detail.

4.1. Traditional and forward-looking Taylor rule models

Table 3 shows the estimation results for the traditional and forward-looking Taylor rule models. Given the estimates in models I and II, we find that the response of the policy interest rate to the inflation gap is significantly positive, while the response to the output gap is also positive but not significant. Both responses are inadequate. For example, coefficients of the inflation gap are both smaller than 1 (0.4506 and 0.5120), implying the discordance with the Taylor principle. Furthermore, the policy interest rate responds positively to financial instability in model II.

Table 3. Estimation results for traditional and forward-looking Taylor rule models.

Type of monetary policy	Traditional Taylor rule		Forward-looking Taylor rule	
Coefficients	I	II	III	IV
α	4.4854*** (0.6300)	4.4835*** (0.6463)	4.4540*** (0.6619)	4.1742*** (0.7231)
β	0.4506*** (0.1393)	0.5120*** (0.1455)	0.7829** (0.3394)	0.6545* (0.3638)
γ	0.0134 (0.1424)	0.0527 (0.1135)	0.0941 (0.3289)	0.0762 (0.3902)
ρ			0.9556*** (0.0182)	0.9635*** (0.0183)
Φ		2.4015** (0.9927)		−0.126** (0.0541)
R^2	0.1810	0.3259	0.9583	0.9587
Adjusted R^2	0.1753	0.3187	0.9579	0.9581
Obs.	288	288	281	288

Model I represents the traditional Taylor rule without FSI, $r_t = \alpha + \beta(\pi_t - \pi^*) + \gamma y_t + \varepsilon_t$; Model II represents the traditional Taylor rule with FSI, $r_t = \alpha + \beta(\pi_t - \pi^*) + \gamma y_t + \Phi f_{t-1} + \varepsilon_t$; Model III is the forward-looking Taylor rule model without FSI, $r_t = (1-\rho)[\alpha + \beta(\pi_{t+6} - \pi^*) + \gamma y_t] + \rho r_{t-1} + \varepsilon_t$; Model IV is the forward-looking Taylor rule model including FSI, $r_t = (1-\rho)[\alpha + \beta(\pi_{t+6} - \pi^*) + \gamma y_t] + \rho r_{t-1} + \Phi f_{t-1} + \varepsilon_t$.

***, ** and * indicate the significance at 1, 5 and 10% levels, and values in parentheses are HAC (Newey-West) standard errors, pre-whitening with the optimal lag determined based on Akaike Info Criterion with a maximum lag of 12 periods.

The estimates in the forward-looking Taylor rule models III and IV are close to those in models I and II, except for the estimated coefficient of Φ in model IV. Specifically, the smoothness coefficients ρ of the interest rate are 0.9556 and 0.9635, respectively, which indicates the adjustment of interest rate is at a slow pace and heavily depends on the lags of interest rates. China's central bank tends to smooth interest rates when designing the policy interest rate. The implementation of monetary policy with such a large ρ might not have an obvious economic effect but can avoid the negative influence on the economy due to dramatic changes in the interest rate (Clarida, Galı, and Gertler1998). The significantly negative value of FSI in model IV proves that China's central bank responds to financial instability when setting the monetary policy in a forward-looking way.

Further, the higher goodness of fit (adjusted R^2) suggests that forward-looking Taylor rule models better explain the dynamic change of policy interest rate in the short run, compared to traditional Taylor rule models. Some other researches also provide similar results to findings about China's monetary policy in this article (Wang 2006; Lu and Zhong 2003; Liu and Zhang 2012).

However, note that the coefficients are restricted to be time-invariant for both traditional and forward-looking Taylor rule models in Table 3. This disagrees with the fact that the policy interest rate usually swiftly adjusts for the real-time economic situation. Thus, to make the model better fit the interest rate adjustment in response to inflation gap, output gap and financial stress, we relax the restriction on coefficients in model IV and allow them to be time-varying in the following estimations.

4.2. Time-varying forward-looking Taylor rule model

The evolution of time-varying estimates of the forward-looking Taylor Rule model with financial instability index is illustrated in Figure 5 with 95% confidence bands.

The curve of the policy-neutral rate (α) shows a significant time-varying trend. Since 1997, China's policy-neutral rate has been declining due to the increasing capital-labor ratio. A higher capital-labor ratio causes lower marginal benefit of capital

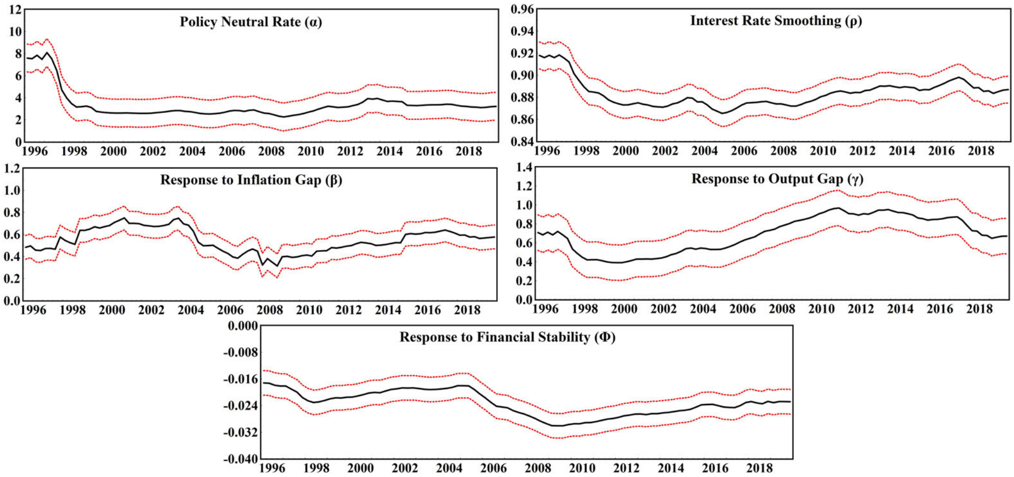

Figure 5. Time-varying estimates of forward-looking Taylor Rule model and 95% confidence bands. Source: Authors' calculations.

and equilibrium real interest rate. The TVC monetary policy model fits the descending trend of the policy-neutral rate well.

Secondly, the estimated time-varying coefficients of the policy rate to inflation gap (β) are always less than 1, indicating that the response of policy interest rate to inflation is insensitive. This finding is similar to that of Hofmann and Bogdanova (2012) who argue that the average adjustment coefficients of the inflation gap in emerging markets economies are significantly less than 1. The inadequate response of the policy interest rate to inflation gap helps explain the long-lasting deflation from late 1997 to 2000 in China (Kanbur and Zhang 2005) and the high inflation during the third quarter of 2010 and early 2015.[14] Moreover, the declining β from 2004 to 2008 suggests an increasing pressure of high inflation facing China's central bank at that time.

Third, the point estimates of the response of policy rate to output gap (γ) stay significantly positive over the whole sample period, showing that monetary policy is stable.[15] If $\gamma > 0$ and the actual GDP is below the potential GDP, the decrease in the target interest rate can ease the real interest rate and increase the aggregate demand, holding the inflation rate constant. This can reduce the output gap and raise aggregate output. A monetary policy rule with positive γ can help prevent an economy from overheating. Moreover, the point estimates of the response are increasing from 2000 to 2010. Combing this result with the response to inflation gap, we could conclude that China's central bank starts to pay closer attention to real economic growth than price stability after 2000. On the contrary, the declining coefficients of γ since 2011 suggest a weakening ability of policy rate to adjust to output, which could be a reasonable explanation for the economy stepping into a 'new normal' phase.

Compared to the traditional Taylor rule model in Table 3, the interest rate smoothing parameter (ρ) estimated by the time-varying forward-looking Taylor Rule model is smaller on average. At a 95% confidence level, the estimated smoothing parameter is within the interval (0.85–0.93) (see Figure 5). In particular, the smooth parameter has been decreasing year by year since 1997, which indicates that the interest

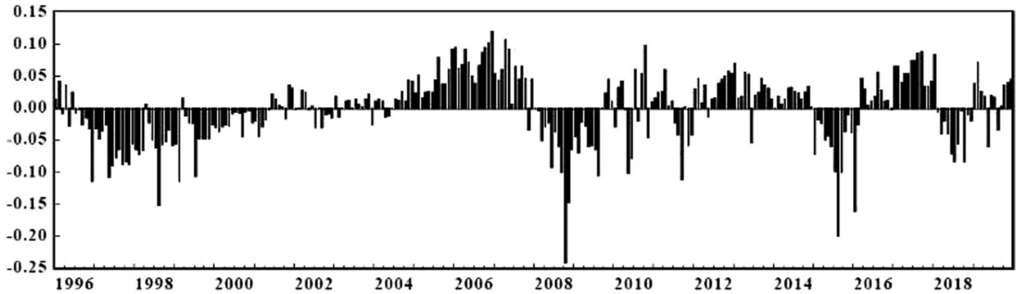

Figure 6. Effect of financial instability. Source: Authors' calculations.

rate policy of monetary authority is gradually changing from 'discretionary' to 'regular' interest rate regulation policy (Liu and Zhang 2012).

Φ represents the response of the policy interest rate to financial instability. Given the 95% confidence interval, this coefficient is significantly less than 0 during the entire sample period. This finding is opposite to other existing research arguing that the response of interest rate to financial instability is insignificant in developing countries and significant only when the financial market is highly volatile, such as during the global financial crisis (Floro and Van Roye 2017; Baxa, Horváth, and Vašíček 2013). Our empirical results show that financial stability has always been a main concern for China's monetary authorities even in periods without much financial stress. And China's central bank tends to lower the policy interest rate in response to financial instability.

4.3. Effect of financial instability

The bottom panel in Figure 5 shows that some negative responses to financial pressure could result from an increase in the interest rate and a decline in financial instability. For example, the benchmark 1-year saving rate increases by 1.62% from August 2006 to December 2007 when FSI drops to the historic low. To better study the effect of FSI on China's policy interest rate, we compute the effect of financial instability as the product of the estimated coefficient of FSI in the forward-looking monetary policy rule and the index of financial instability. This effect can measure the extent to which the policy interest rate responds to financial stress (Baxa, Horváth, and Vašíček 2013). We then analyze the time trend of the magnitude of the responses and compare the results with those in developed countries.

Figure 6 shows the effect of FSI. The response reaches a very low level[16] during the 1997 Asian financial crisis, the global financial crisis in 2008 and China's stock market boom and bust in 2015.

Facing the Asian financial crisis and serious deflation in the domestic economy in 1997, China's central bank chose to decrease the policy interest rate (i.e., 1-year benchmark lending rate) by 225 basis points from October 1997 to December 1998, to counteract the long-lasting deflation. Figure 6 also illustrates that, during the same period, the policy interest rate is set about 15 basis points lower than the counterfactual policy interest rate without a response to financial instability. This finding shows

Table 4. The rate of decrease in policy interest rate due to concerns over financial-stability.

Time for 3 lows of FSI effects	1997 Asian financial crisis	2008–2009 Global financial crisis	2015 Stock market boom and bust and sharp devaluation of RMB
Period for policy rate changes	1997.10 – 1998.12	2007.12 – 2008.12	2015.3 – 2015.10
Effect of financial instability	↓ 15 basis points	↓ 25 basis points	↓ 20 basis points
(A) Benchmark lending rate	↓ 2.25%	↓ 2.16%	↓ 1%
(B) Benchmark saving rate	↓ 1.89%	↓ 1.89%	↓ 1%
(C) 7-Day interbank lending rate	↓ 6.27%	↓ 1.75%	↓ 2%
Ratio of FSI effect to (A)	6.67%	11.57%	20.00%
Ratio of FSI effect to (B)	7.94%	13.24%	20.00%
Ratio of FSI effect to (C)	2.39%	14.28%	10.00%

A, B and C refer to the benchmark lending rate (1-year), saving rate (1-year) and 7-day interbank lending rate respectively. And the huge change of 7-day interbank lending rate during March 2015 to October 2015 is mainly caused by a shortage of money.

that around 6.67% of the decline in the policy interest rate can be explained by the response to financial instability.

To counteract the deflation and maintain economic growth from late 2007 to 2009, China's central bank also decreased the 1-year benchmark lending rate seven times by 216 basis points during the 2008 global financial crisis. This implies approximately 11.57% of the decrease in the policy interest rate was motivated by financial stability factors in China during the financial crisis in 2008. Moreover, China's stock market boom and bust in 2015 come along with a devaluation of RMB and the proportion of the decrease in policy interest rate related to financial stability increased to 20%.

Table 4 summarizes the main findings regarding the effects of FSI. We consider 3 types of policy interest rates: benchmark lending rate, saving rate and 7-day interbank lending rate. Several interesting findings merit discussion. First, the last three rows of Table 4 show that the ratios of FSI effect to changes in policy interest rates are all below 20%, and more than half of them are even below 15%. According to Baxa, Horváth, and Vašíček (2013), in the 2008 global financial crisis, US, Sweden, Canada and Australia decreased policy interest rate by approximately 10–30% (50–100 basis points) out of the concern over financial instability. And the size of this impact for the UK is up to 50% (250 basis points). Our results show that although financial-stability is a main concern for the People's Bank of China, the proportion of change in the policy interest rate due to this concern is still lower relative to developed countries.

Second, the ratio of FSI effect to policy interest rate keeps increasing over time, suggesting that the People's Bank of China makes a larger response to financial instability facing higher financial stress. Moreover, China takes the stabilization of the financial system more seriously and becomes more responsible for financial-stability in its monetary decision making.

We think China's central bank has been paying more attention to financial stability for some reason. First, a central bank responding to financial instability based on a forward-looking Taylor rule instead of traditional Taylor rules can achieve different

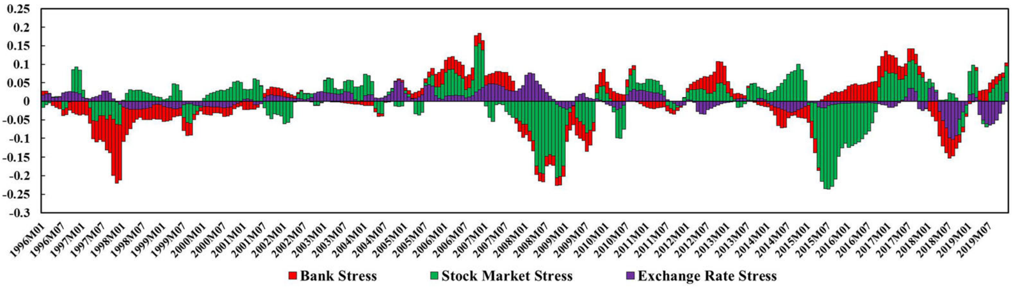

Figure 7. The evolution of the components of the financial-stress effect. Source: Authors' calculations.

goals for output and inflation in the short run. As long as the shock from financial instability is transitory, central banks having a forward-looking Taylor rule can support the banking system via monetary ease and avoid a short-run decrease in output and consumption. Based on the forward-looking Taylor rule, central banks sacrifice current stability in output and inflation rate in exchange for a faster return to the trend later (Bauducco, Cihák, and Bulíř 2008). In addition, Dupor and Conley (2004) find that the Federal Reserve responds to stock-market activity and raises the target interest rate to prevent the stock price from increasing due to perceived non-fundamental factors, especially when Fed's low and stable inflation target is achieved. Indeed. China's stock market boom and bust in 2015 are likely due to some non-fundamental elements and China's central bank reacts to financial instability by adjusting the interest rate to deal with the perceived non-fundamental change of stock price.

4.4. Decomposition of the FSI effect

To further test which components of financial instability affect policy interest rate setting, we compute the financial stress effect for each component, including stock market stress effect, bank stress effect and exchange rate stress effect. Specifically, we use the returns of the stock market and stock-return volatility to construct a stock market stress index and use the bank beta coefficient, TED spread to build a banking system stress index. EMPI is used to represent financial stress in the exchange market. The evolution of the components of the financial instability effect is computed in a similar way to measuring the overall FSI effect.

Figure 7 shows that the main concern of China's central bank was banking stress due to the huge ratio of non-performing loans (NPLs) in the banking system during the Asian financial crisis in 1997. In fact, this crisis had a moderate effect on China's stock market and foreign exchange market, but many state-owned commercial banks were on the verge of bankruptcy technically due to the high NPLs ratio (Shi 2004). Another concern was about the stock market stress, especially during the global financial crisis in 2008 and the stock market boom and bust cycle in 2015. At that time, the SSE Composite Index fell by around 72% from October 2007 to October 2008, which was the biggest drop in global stock markets. Moreover, this index increased from 3075 to 5166 and then decreased to 3038 sharply afterward within 7 months (from March 2015 to October 2015).

Surprisingly, there exists little response to stress in the foreign exchange market until 2016.[17] This implies China's central bank paid little attention to exchange-rate stress for interest-rate consideration due to the low degree of financial openness, restricted capital account and a floating band of the RMB exchange rate in China. This finding is consistent with Baxa, Horváth, and Vašíček (2013) arguing that exchange-rate stress only drives the reaction of central banks in more open countries like Canada and Sweden.

5. Conclusion

The global financial crisis in 2008 necessitates the study of the relationship between monetary policy and financial instability. This article aims to examine whether and to what extent China's central bank responds to financial stress over the last two decades. We construct a comprehensive financial stress index to estimate the time-varying responses of monetary policy to financial instability with TVC methods in the context of China's financial market.

Empirical results show that financial stability has always been a main concern for China's monetary policymakers and China's central bank tends to lower the policy interest rate to counteract the financial instability. Although the proportion of a decrease in the policy interest rate due to the concern over financial stability in China is still lower relative to developed countries, proportion keeps rising over time, implying that China's central bank is taking more responsibility for financial-stability in its monetary decision making when faced with high financial pressure. In addition, we find that the main concerns for China's central bank are financial stress in the banking system and the stock market. In contrast, the exchange rate did not drive the reaction of China's central bank. The evidence shows that financial stability is incorporated into the monetary policy framework in China.

The empirical results in this article provide some policy insights for developing countries like China, especially in the monetary decision-making process. First and foremost, the policy authorities should pay more attention to financial stability when formulating and implementing monetary policies, safeguard the bottom line of no systemic financial risks, and incorporate financial stability as one of the regulatory goals of monetary policy. In this sense, our empirical results could be used as a reference point to adjust monetary policy-making according to the time-varying economic condition.

Second, the authorities could consider constructing a regional financial stability index. Not only will doing so helps to monitor and identify systemic risks of the financial system in real-time, but it also facilitates monetary authorities to take necessary measures promptly.

Third, the Chinese government should continue to promote the process of interest rate liberalization, improve the transmission mechanism of monetary policy, and create a more favorable policy environment for a rule-based policy framework. The change in the interest rate affects the real economy through the Taylor rule by adjusting the expectations of economic agents. An effective monetary policy transmission relies crucially on a perfect interest rate formation mechanism, a high degree of interest rate marketization and a sensitive market response. Therefore, a final achievement of the goal of interest rate liberalization in China still requires substantial additional efforts.

Notes

1. Time-varying coefficient (TVC) model is first proposed by Schlicht and Ludsteck (2006).
2. In October 2012, Xiaochuan Zhou, the president of China's central bank, gave a talk in the Lecture hosted by 2012 annual Per Jacobson foundation during the conference of International Monetary Fund and World Bank in Japan, and set forth that Chinese government always takes the financial stability seriously and views it as the premise of stable price.
3. Source: China's Monetary Policy Execution Report from the last quarters of years 2012 and 2013.
4. To compare with the literatures, we also do the estimations for $k = 1$ and 3, and the results are quite similar.
5. State-space models have some limitations for the empirical work. For example, it is hard to attain accurate estimated parameters since the results are sensitive to their initial values. Moreover, the log likelihood function is highly non-linear, leading to failure in optimization of the log likelihood (Baxa et al., 2013).
6. See http://www.pbc.gov.cn.
7. We use the package for data frequency transformation in EVIEWS to do the frequency transformation and also exclude the seasonal factor in GDP by X-12 seasonal adjustment.
8. Real GDP = (nominal monthly GDP/CPI in the current month) × 100, where monthly CPI is with year 2000 as the base year.
9. We adopt Hodrick–Prescott filter to estimate the potential GDP and the output gap.
10. We exclude sovereign risk since China holds the largest amount of foreign reserve in the world, its composition of foreign debts is reasonable and it maintains a low level of sovereign risk during the sample periods.
11. Treasury bond market in China is relatively small and there is no three-month bond traded. Besides, the issue of Treasury bond is not regular. Hence, we employ the three-month time deposit rates as the proxy for yield to maturity of three-month Treasury bond.
12. Subjective weighting method heavily relies on experts' experience. Instead objective weighting method is widely recognized by academia. For the detailed description about CRITIC method, readers can refer to Diakoulaki et al. (1995). We also take the variance-equal weighting approach to construct FSI index and the resulting key estimations remain unchanged.
13. Several classic unit root tests include ADF test, Phillips-Perron test and KPSS test. The results are similar, except that the null for the KPSS test is rejected at the 5% significance level for the policy interest rate. This is due to a break point in the policy rate series in Oct. 1997. We employ a breakpoint DF unit root test to take account of the break and the result show that the unit root in the policy rate can be rejected at the 1% significance level.
14. The high inflation during this period is largely caused by China's 4 trillion RMB Stimulus Plan to counteract the negative effect of global financial crisis.
15. Here, a monetary policy rule is stable because it could maintain the actual GDP around the potential GDP.
16. As argued in Baxa et al. (2013), the positive effect of financial instability on the policy interest rate might result from scaling the financial instability index. Thus, we do not care about the positive impact of FSI unless it is caused by the positive and significant regression coefficient of FSI, which is not the case based on Figure 6.

17. The RMB exchange rate regime switched to a managed float with reference to a basket of currencies on July. 2015.

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