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Taylor Rule or McCallum Rule for China's Monetary Policy*

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1 Introduction

With China's rapid economic development, China's monetary policy is attracting the attention of researchers and investors all over the world. However, compared with developed countries, China's monetary policy has many distinct features. One of the most important features is that the intermediate target of monetary policy in China is not interest rates but money supply, which indicates that rather than the Taylor rule, the McCallum rule must be the more active policy rule in China. In this paper, both the traditional Taylor rule and basic McCallum rule are modified by adding the nominal exchange rate to check their applicability in China.

The central bank of China is the People's Bank of China (PBC). Having assumed the role of central bank in 1984, it is still young compared with other major central banks across the world. According to the *Law of the People's Bank of China*, the monetary policy of the PBC has two targets: maintaining the stability of the currency and promoting economic growth. Maintaining the stability of the currency is achieved by simultaneously controlling inflation and stabilizing the exchange rate. Therefore, the PBC has three de facto targets: rapid economic growth, low inflation, and a stable nominal exchange rate. Each of these three variables will be included in the empirical analysis.

There are empirical analyses on the monetary policy rules of China, but since most of the Chinese macro data are only available from the early 1990s, the sample size is still quite small, even if quarterly data is used. To solve this problem, in this paper monthly data is used. In order to measure monthly economic growth, three output measurements are used. These are generated electricity, fixed asset investment and industrial added value growth rate. In prior research, the real effective exchange rate (REER) and real exchange rate were used as targets of the Taylor rule and the McCallum rule models, but there have not been any robust results thus far.[1] Considering

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1) Refer to Fan, Yu and Zhang (2011), Burdekin and Siklos (2008).

the de facto dollar-peg exchange rate regime in China, instead of REER and real exchange rate, empirical analysis with the nominal exchange rate against the United States Dollar (USD) is likely to be significant. This idea will be explored in the third and fourth parts of this paper.

Both GMM (Generalized Method of Moments) and SVAR (Structural Vector Autoregression) are used for estimation, and both indicate that the McCallum rule is an active policy rule and the Taylor rule is not, and that the McCallum rule can trace actual m2 effectively.

The GMM estimation suggests that the requirements for an active Taylor rule cannot be satisfied, because for a unit change in inflation and output gap, the change in interest rate is not significant enough compared with the U.S; moreover, the nominal exchange rate is statistically insignificant in most cases. In contrast, the McCallum rule suggests that policy to affect the money supply in China not only focuses on inflation and economic growth, but also targets the nominal exchange rate. Such an active monetary policy is consistent with the actual situation in China.

The empirical results of structural VAR are almost consistent with the GMM estimations for both the Taylor rule and McCallum rule. The results suggest that the interest rate responds actively to Consumer Price Index (CPI) but passively to output gap and exchange rate, while money supply responds actively to both CPI and output.

From 1996 to 2012, China's monetary policy experienced various challenges: inflation (in the early 1990s, 2007-2008, and 2010-2011), deflation in the early 2000s and economic recession following the Asian Financial Crisis of 1998 and the Subprime Crisis of 2008, all of which can be seen in Figure 3.1.

2 Literature Review

The literature on basic policy rules and empirical analysis of policy rules in China is summarized in this part. Particular emphasis is given to the literature on empirical analysis of policy rule in China, most of which is written in Chinese and has not been reviewed in English so far.

2.1 Theoretical aspects of the Taylor rule and the McCallum rule

Taylor (1993a) originally presented what would become known as the Taylor rule at the November 1992 Carnegie Rochester Conference on Public Policy, when he suggested that "good policy rules call for changes in the federal funds rate in response to change in the price level and changes in real income".

$$r = p + 0.5y + 0.5(p-2) + 2 \tag{2.1}$$

Where y = percent deviation of real GDP from the trend, p = rate of inflation over the previous four quarters.

Within a few months of the publication of this conference volume, the Federal Open Market Committee (FOMC) decided to adopt the formula to inform their monetary policy deliberations. Consequently, this allowed Taylor-type rules to serve as the standard by which monetary policy is introduced in macroeconomic models. Taylor-type rules helped policymakers to gain the insight of how policy has been set in the past and how policy should be set in the future, which gradually turned into benchmarks to evaluate the current situation on monetary policy and determine a future policy path.

The McCallum rule proposed by McCallum (1987, 1988, 1993), can be expressed as follows

$$\Delta b_t = \Delta x^* - \Delta v_t^a + 0.5(\Delta x^* - \Delta x_{t-1}) \tag{2.2}$$

Δb_t is the change in the log of the adjusted monetary base, (i.e., the growth rate of the base between periods $t-1$ and t).

Δx^* is a target growth rate for nominal GDP (Δx^* is specified as $\pi^*+\Delta y^*$, where Δy^* is the long-run average rate of growth of real GDP).

Δx_t is the change in the log of nominal GDP.

Δv_t^a is the average growth of base velocity over the previous 16 quarters, $v_t=x_t-b_t$ being the log of base velocity.

2.2 The empirical analysis of the Taylor rule and McCallum rule in China

Up until August 2012, there had been 235 papers related to the Taylor Rule published in China, including master's and Ph.D. dissertations, but only 15 papers related to the McCallum rule. There have been approximately five papers about the Taylor rule published in *Economic Research Journal*, a leading Chinese economics journal. However, there are no papers concerning the McCallum Rule. This reflects the much greater popularity of the Taylor rule in the economic community, especially in developed countries. It also shows that Chinese economists have paid a lot more attention to the Taylor rule than to the McCallum rule, even though there are some problems concerning the application of the Taylor rule to China's monetary policy.[2)]

Empirical analysis of Taylor rule in the case of China:

There are many papers containing empirical analysis of China's monetary policy via the Taylor rule. The methods and empirical results of these studies are generally similar. Three of them will be reviewed presently, as these three are particularly important and influential.

Xie and Luo (2002) use historical analysis[3)] and reaction function.[4)] They suggest that the parameter of inflation in the Taylor rule is 0.81, smaller than 1. That is to say, the monetary policy of China is an unstable system, which may be the main reason for the high inflation in the 1990s and deflation in the early 2000s. Their paper is the first to analyze the Taylor rule based on Chinese economic data, but their estimation method is outdated.

Lu and Zhong (2003), the first to do cointegration analysis on the Taylor rule, suggest that the coefficient of the GDP gap is 0.497, which is very close to the result obtained in Taylor (1993a). But the coefficient of the inflation gap is estimated at only 0.089, which is very small. This result indicates that the PBC put more emphasis on GDP than inflation. In addition, the paper introduces a forward-looking Taylor rule for the cointegration analysis, and finds the coefficient of the GDP gap to be 0.509, while that of CPI expectation is just 0.131. They are close to their traditional Taylor rule estimation. What is worth mentioning is that since the data span from 1992 to 2001, which includes the hyperinflation period of 1993 to 1994, there may be some bias in the estimation.

Fan, Yu and Zhang (2011) use a Vector Error Correction Model (VECM) to analyze the responsiveness and activeness of Chinese monetary policy of 1992–2009 by estimating Taylor rule. The results show that the official interest rate responds passively to inflation and does not respond to real output. By using a smoothed Taylor rule, they draw three conclusions. First, the coefficient

2) For instance, problems arising from the manipulation of the interest rate by the PBC.
3) Taylor (1993a, 1999).
4) Clarida, Gali and Gertler (1998, 2000).

of inflation is positive but less than 1. Second, the official interest rate exhibits a statistically significant response to output gap. Third, the coefficient of the real effective exchange rate is negative and not statistically significant. With a VAR model, impulse response and variance decomposition analysis are conducted in two orders $x_t=(\pi_t, y_t, e_t, r_t, m_t)$ and $x_t=(\pi_t, y_t, e_t, m_t, r_t)$. The results show that the responses of the inflation rate, output gap and real effective exchange rate to the official interest rate are near zero for all the horizons.

Empirical analysis of McCallum rule in the case of China:

Song and Li (2007) employ cointegration analysis, impulse response and variance decomposition to check the relationship between money supply and fluctuations in the economy. The distinctive feature of this paper is that money supply is reclassified as in the following equations: MM2＝M2－M1, MM1＝M1－M0. Further, RM0, RMM1, RMM2 and RINDU are defined as the growth rate of M0, MM1, MM2 and industrial added value, respectively. Using the Granger test, they suggest that the PBC closely controlled the money supply, because RM0 Granger causes RMM1 and RMM2, and that RMM1 Granger causes RMM2. Accordingly, they reach the conclusion that as long as PBC controls M0, it can also keep M1 and M2 under control. Furthermore, since both RMM0 and RMM1 are Granger caused by RINDU, PBC could comply with the McCallum rule to affect economic growth through money supply management. That is to say, they indicate that changes to the money supply could affect economic growth. However, there are several deficiencies in this paper. For instance, some problems arise because their reclassification scheme of the money supply is not commonly used.

Burdekin and Siklos (2008) have modeled post-1990 Chinese monetary policy with an augmented McCallum-type rule using both monetary base and m2. They employ three different models in their research, which are presented as follows. First, by estimating a basic McCallum rule,[5] the coefficients of the GDP gap[6] are -0.42 for m2 and -0.008 for the monetary base. Second, after adding a deflation dummy variable which is set equal to one from 1997 on, the estimated coefficient of the GDP gap remains negative but is statistically insignificant when monetary base is the dependent variable; however, the deflation dummy variable is highly significant and negative. Third, when real exchange rate and foreign exchange reserves are added to the model, the coefficients continue to be negative and are statistically significant for both monetary measures. The coefficient on the real exchange rate is negative and statistically significant for m2, indicating that real exchange rate depreciation leads to a negative monetary policy response. The weaker link between foreign exchange reserves and monetary growth may be indicative of PBC success at sterilizing inflows of foreign exchange. Two techniques are adopted. First, GMM is used to avoid the shortcomings of OLS. Second, for the constant deflation dummy, two lags of each of the variables in the equation, and two lags in export growth were used as instruments with nearly identical results.

Fan, Yu and Zhang (2011) use a VECM model to analyze the responsiveness and activeness of China's monetary policy in 1992-2009 by estimating a McCallum rule. The results show that money

5) The basic McCallum rule is shown in equation (2.2).
6) GDP gap is the gap between target and actual nominal GDP growth.

supply[7] not only responds actively to both inflation rate and real output, but also has certain effects on future inflation and real output. In the whole sample, the growth rate of money supply is negatively and significantly related to the output gap and inflation rate, but its response to the real effective exchange rate is insignificant. With a dummy variable in the year 2000, what is interesting is that the real money supply in the second subperiod is more responsive to inflation but insensitive to the output gap. The VAR model shows that the responses of the inflation rate and output gap to the money supply are significant, but are insignificant with respect to the real effective exchange rate. Instead of the real effective exchange rate, real exchange rate should be used, because the PBC does not watch the real effective exchange rate, but instead watches the nominal exchange rate against the USD.

The problems of previous papers and the contribution of this paper:

Previous research on this subject is plagued with various problems, such as outdated estimation methods, insufficient sample sizes and inappropriate data measurements. In addition, instead of REER and real exchange rate, nominal exchange rate should be used in the model as the target of PBC.

These problems will be addressed in this paper. Both GMM and structural VAR will be used for estimation, and monthly data will be selected to ensure adequate sample size. Along with CPI and output gap, the nominal exchange rate will be included in monetary policy rule estimations.

3 The empirical analysis of Taylor rule and McCallum rule in China

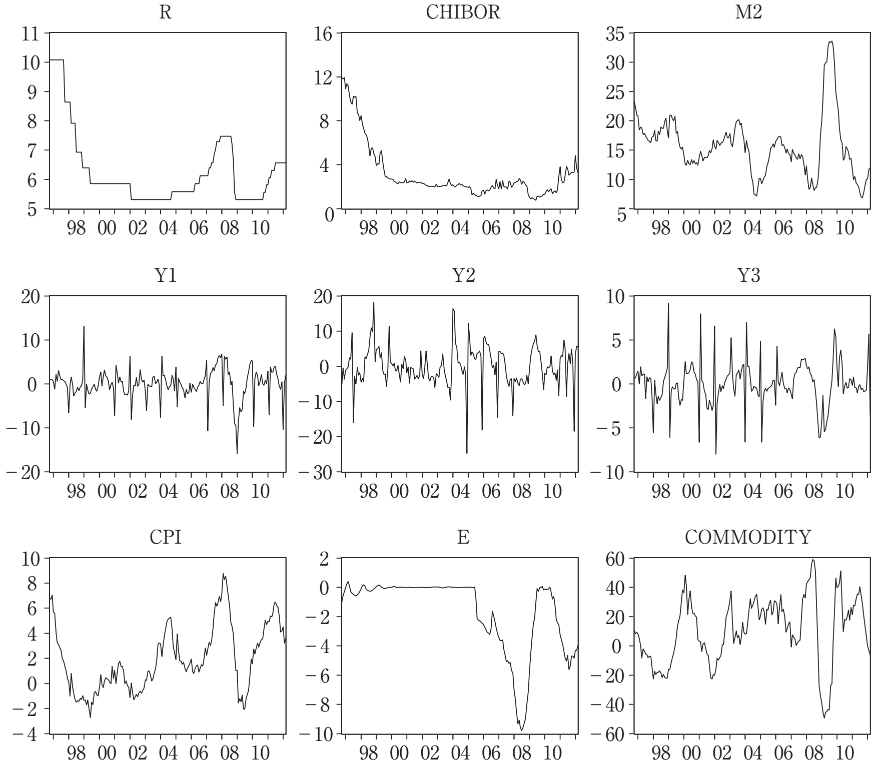
3.1 Data

The People's Bank of China (PBC) has a very short history, as it assumed the role of central bank in 1984. Because most available data begins from the year 1996, the sample in this paper is from 1996M10 to 2012M3, yielding 186 observations.

For Taylor rule and McCallum rule, monetary policy analysis, both interest rate and money supply, will be taken into consideration. China Interbank Offered Rate (Chibor) is used as the market interest rate (source: Wind[8]). r refers to the official one-year lending rate (source: PBC), and m2 is the annual growth rate of the money supply m2 (source: PBC) minus the annual inflation rate.[9] The reason m2 is used to measure money supply is not only that the growth rate of m2 is one of the most important targets of both PBC and the government, but also because the results of the estimations of m2 are more robust than those from using m1 or m0.[10] As to output gap, since monthly GDP data are not available, three measurements are used for the estimation. The output gaps are estimated by generated electricity[11] and real fixed asset investment[12] (source: National

7) Money supply here refers to quarterly observation of the annual growth rate of M1, minus the annual inflation rate.
8) Wind is a leading database in China.
9) Real money supply, rather than the nominal one, better reflects the true economic situation, unmasked by inflation. McCallum (2000), Esanov *et al.* (2005) both use similar measures of real money supply in their analyses.
10) The results will not be shown in this paper. If you have an interest in them, please email the author directly.
11) In fact, instead of generated electricity, electricity consumption should be used to simulate GDP gap. However, collection of monthly electricity consumption data began from the year 2006, and the two data types are quite close to each other, so generated electricity is used instead.

Figure 3.1 Time series of macroeconomic variables in China (1996M10-2012M3)



Note: Census X-11 (Historical) is used for seasonal adjustment.

Bureau of Statistics of China (NBS)). These are named y1 and y2, respectively. y3 refers to the output gap estimated by the industrial added value (source: NBS). The output gap data are calculated by using Hodrick-Prescott filter. CPI is the monthly observation of the annual Consumer Price Index (Source: NBS), and e is the rate of change of the nominal exchange rate of CNY (Chinese Yuan) against USD (source: IFS). Commodity is the commodity price index series from IMF.

Figure 3.1 shows the monthly time-series plots of the macroeconomic variables in percentages. Many economic features are apparent in this figure. First, both Chibor and policy interest rates lack much volatility, and the growth rate of m2 is quite high, the average of which is about 17%. Second, due to a monthly sampling rate, the output data are quite volatile. There are differences between y1 and y2: y1 is less volatile from 1996 to 2008, but y2 is less volatile from 1998 to 2004. Third, regarding inflation, the most notable features are the deflation during 1998–2000 and the high inflation of 1996, 2008 and 2010. The nominal exchange rate also lacks fluctuation despite appreciation in two periods, July 2005 to July 2008 and May 2010 to March 2012.

12) The fixed asset investment is adjusted to real value based on the inflation measurement CPI.

3.2 GMM analysis of Taylor rule

In line with Clarida, Gali and Gertler (1998), we assume that within each operating period the PBC has a target for the nominal short term interest rate r_t^*, that is based on the state of the economy. In the baseline case, we assume that the target depends on both expected inflation and output. Specifically,

$$r_t^* = \bar{r} + a_{cpi}[E(cpi_t|\Omega_t) - cpi^*] + a_y(E[y_t|\Omega_t] - y_t^*) \tag{3.1}$$

where $\bar{r}$ is the long-run equilibrium nominal rate, cpi_t is the realized annual inflation rate at t, y, is real output, and cpi^* and y_t^* are respective bliss points for inflation and output. We assume that y_t^* is given by potential output, defined as the level that would arise if wages and prices were perfectly flexible. In addition, E is the expectation operator and Ω_t is the information available to the central bank at the time it sets interest rates.

It is instructive to consider the implied target for the ex-ante real interest rate, $rr_t \equiv r_t - E(cpi_t|\Omega_t)$. Rearranging Eq. (3.1) yields

$$rr_t^* = \overline{rr} + (a_{cpi} - 1)(E[cpi_t|\Omega_t] - \pi^*) + a_y(E[y_t|\Omega_t] - y_t^*) \tag{3.2}$$

where $\overline{rr}$ is the long-run equilibrium real rate of interest. Given the economic environment, we are presuming that purely real factors determine $\overline{rr}$. According to Eq. (3.2), the target real rate adjusts relative to its natural rate in response to departures of either expected inflation or output from their respective targets. The magnitude of the parameter a_{cpi} is the key to determining whether the policy rule is active or not. If $a_{cpi} > 1$, the target real rate adjusts to stabilize inflation. With $a_{cpi} < 1$, it instead moves to accommodate changes in inflation, meaning that though the central bank raises the nominal rate in response to an expected rise in inflation, it is not sufficient to keep the real rate from declining.

In practice, central banks tend to maintain smoothness in the actual interest rate. Alternatively, central banks may sometimes compromise the market forces reflected in the existing interest rate. In the literature, it is commonly assumed that the actual interest rate r_t is a weighted average of the target rate r_t^* and the existing interest rate r_{t-1}, plus a noise term ε_t, due to other random factors at the same time. This smoothing behavior is represented by Eq. (3.3).

$$r_t = (1-\rho) r_t^* + \rho r_{t-1} + \varepsilon_t \tag{3.3}$$

where $0 \leq \rho < 1$. The case of $\rho = 0$ corresponds to the original Taylor rule without smoothing.

To obtain an estimable equation, we define $a_c \equiv \bar{r} - a_{cpi} cpi^*$ and $x_t \equiv y_t - y_t^*$. We then rewrite Eq. (3.1) as

$$r_t^* = a_c + a_{cpi}[E(cpi_t|\Omega_t)] + a_y(E[x_t|\Omega_t]) \tag{3.4}$$

Combining the target model (3.4) with the partial adjustment mechanism (3.3) yields

$$r_t = (1-\rho) a_c + (1-\rho) a_{cpi}[E(cpi_t|\Omega_t)] + (1-\rho) a_y(E[x_t|\Omega_t]) + \rho r_{t-1} + \varepsilon_t \tag{3.5}$$

Finally, we eliminate the unobserved forecast variables from the expression by rewriting the policy rule in terms of realized variables as follows:

$$r_t = (1-\rho) a_c + (1-\rho) a_{cpi} cpi_t + (1-\rho) a_y x_t + \rho r_{t-1} + v_t \tag{3.6}$$

where the error term $v_t \equiv -(1-\rho)\{a_{cpi}(cpi_t - E[cpi_t|\Omega_t]) + a_y(x_t - E[x_t|\Omega_t])\} + \varepsilon_t$ is a linear combination of the forecast errors of inflation, output and the exogenous disturbance ε_t.

It is quite possible that there may be other important factors that influence rate setting besides those captured in the baseline model in Eq. (3.6). For example, some central banks may pursue monetary policies to maintain exchange rates within reasonable bounds. According to Clarida, Gali and Gertler (1998), this scenario was pertinent to some European countries' central banks prior to the collapse of the ERM in 1992. Having mentioned in Section 1 that the exchange rate is one of the targets of PBC, the relation for the target Eq. (3.6) could be replaced with the following equation, where e_t is the nominal exchange rate of CNY against USD at t:

$$r_t=(1-\rho)(a_c+a_{cpi}cpi_t+a_y x_t+a_e e_t)+\rho r_{t-1}+v_t \tag{3.7}$$

where the error term $v_t\equiv-(1-\rho)\{a_{cpi}(cpi_t-E[cpi_t|\Omega_t])+a_y(x_t-E[x_t|\Omega_t])+a_e(e_t-E[e_t|\Omega_t])\}+\varepsilon_t$ is a linear combination of the forecast errors of inflation, output, exchange rate and the exogenous disturbance ε_t. Let u_t be a vector of variables within the central bank's information set at the time it chooses the interest rate ($u_t\in\Omega_t$), that are orthogonal to v_t. Possible elements of u_t include any lagged variables that help forecast inflation, output, exchange rate and any contemporaneous variables that are uncorrelated with the current interest rate shock ε_t. Then, since $E[v_t|u_t]=0$, Eq. (3.7) implies the following set of orthogonality conditions that we exploit for estimation:

$$E[r_t-(1-\rho)a_c-(1-\rho)a_{cpi}cpi_t-(1-\rho)a_y x_t-(1-\rho)a_e e_t-\rho r_{t-1}|u_t]=0 \tag{3.8}$$

To estimate the parameter vector $[a_c, a_{cpi}, a_y, a_e, \rho]$ we use GMM.[13] The instrument set u_t includes lagged values of output, inflation and interest rates. Each of these variables are potentially useful for forecasting inflation, output and exchange rate, and are exogenous with respect to the interest rate, given our identifying assumptions.[14]

In Eq. (3.2) $a_{cpi}>1$ is the key to determining whether the policy rule is active or not. But here in Eq. (3.7), besides $a_{cpi}>1$, $a_y>0$ and $a_e>0$ are also keys to determining the activeness of policy rule. The reason is that when the economy gets overheated or the CNY depreciates, which means x_t or e_t is increasing, the interest rate must be raised to cool the economy or to induce investors to buy more CNY. As a result, both of the macro variables will return to their equilibrium level.

$$a_{cpi}>1,\ a_y>0 \text{ and } a_e>0 \tag{3.9}$$

Two estimations of the Taylor rule are shown in Table 3.1 and 3.2, given by Eq. (3.7). The traditional Taylor rule insists that the market interest rule should be used to estimate the Taylor rule. But in China, instead of the market, the PBC determines the interest rate. For clarity, both the policy interest rate (one-year lending rate) (Table 3.1) and market interest rate (Chibor) (Table 3.2) are used for estimation.

In table.3.1, the results of three regressions are given for y1, y2 and y3, respectively. Let's check the sign of the parameters and then evaluate the activeness of the Taylor rule for China's monetary policy. According to the Taylor rule, $a_{cpi}>0$ and $a_y>0$ must be met. During the entire sample period, the regressions show that official interest rate responds positively and significantly to both CPI and output gap in Regression (1.1) and Regression (1.3). For Regression (1.2), official interest rate responds significantly to inflation rate alone.

$a_{cpi}>1$ represents an active interest rate policy. Official interest rate responds significantly to

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13) The composite disturbance term for our model has an MA (n-1) representations. In this case, the GMM estimator of the parameter vector is a two-step nonlinear two-stage least squares estimator when the model is overidentified (Clarida *et al.* (1998)).

14) Our econometric approach relies on the assumption that, within our short samples, short-term interest rate and inflation rate are $I(0)$. Please refer to Table 4.1.

Table 3.1 The estimation of Taylor rule with policy interest rate r on sample (1996M10-2012M3)

Taylor Rule	a_c	a_{cpi}	a_{y1}	a_{y2}	a_{y3}	a_e	ρ	R^2
Regression (1.1)	5.49^{***} (0.3301)	0.3469^{*} (0.1798)	0.2145^{*} (0.1152)			0.1584 (0.1518)	0.9426^{***} (0.0126)	0.9732
Regression (1.2)	5.20^{***} (0.4144)	0.6027^{***} (0.2151)		0.0652 (0.1280)		0.2930^{*} (0.1691)	0.9483^{***} (0.0126)	0.9728
Regression (1.3)	5.36^{***} (0.3560)	0.3989^{**} (0.1839)			0.3731^{*} (0.2205)	0.1561 (0.1630)	0.9472^{***} (0.0124)	0.9731

Note: The instruments are y_{t-1}, y_{t-2}, y_{t-3}, y_{t-4}, y_{t-5}, y_{t-6}, cpi_{t-1}, cpi_{t-2}, cpi_{t-3}, cpi_{t-4}, cpi_{t-5}, cpi_{t-6},, r_{t-1}, r_{t-2}, r_{t-3}, r_{t-4}, r_{t-5}, r_{t-6}, e_{t-1}, e_{t-2}, e_{t-3}, e_{t-4}, e_{t-5}, e_{t-6}, $Commodity_{t-1}$, $Commodity_{t-2}$, $Commodity_{t-3}$, $Commodity_{t-4}$, $Commodity_{t-5}$, $Commodity_{t-6}$.

*** indicates that the coefficient is statistically significant at 1% level, ** at the 5% level and * at the 10% level.

Table 3.2 The estimation of Taylor rule with market interest rate Chibor on sample (1996M10-2012M3)

Taylor Rule	a_c	a_{cpi}	a_{y1}	a_{y2}	a_{y3}	a_e	ρ	R^2
Regression (2.1)	1.59^{**} (0.7094)	0.6573^{*} (0.3650)	−0.2799 (0.2687)			0.3851 (0.2869)	0.9406^{***} (0.0134)	0.9667
Regression (2.2)	1.96^{***} (0.6621)	0.3380 (0.2762)		−0.1004 (0.2130)		0.2292 (0.2443)	0.9387^{***} (0.0133)	0.9669
Regression (2.3)	1.70^{***} (0.6528)	0.6978^{**} (0.3195)			-0.7167^{*} (0.3721)	0.4800^{*} (0.2780)	0.9378^{***} (0.0137)	0.9652

Note: The instruments are y_{t-1}, y_{t-2}, y_{t-3}, y_{t-4}, y_{t-5}, y_{t-6}, cpi_{t-1}, cpi_{t-2}, cpi_{t-3}, cpi_{t-4}, cpi_{t-5}, cpi_{t-6}, $Chibor_{t-1}$, $Chibor_{t-2}$, $Chibor_{t-3}$, $Chibor_{t-4}$, $Chibor_{t-5}$, $Chibor_{t-6}$, e_{t-1}, e_{t-2}, e_{t-3}, e_{t-4}, e_{t-5}, e_{t-6}, $Commodity_{t-1}$, $Commodity_{t-2}$, $Commodity_{t-3}$, $Commodity_{t-4}$, $Commodity_{t-5}$, $Commodity_{t-6}$.

*** indicates that the coefficient is statistically significant at 1% level, ** at the 5% level and * at the 10% level.

inflation rate in Regression (1.1), (1.2) and (1.3), however, $a_{cpi}=1$ could be rejected with 10% Wald Test.

For $a_e>0$, a_e turns out to be significantly positive in Regression (1.2) and insignificant in Regression (1.1) and (1.3).

It is worth mentioning that a_c is higher than that of the U.S. (which is 2%), which indicates that the long-term equilibrium nominal interest rate is higher than that of the U.S. Considering the high inflation rate in China, the long-term equilibrium nominal rate is at about 5%, which indicates Regression (1.1), (1.2) and (1.3) are reliable.

In table 3.2, the market interest rate, Chibor, is used instead. Among these three regression results in Table 3.2, Regression (2.3) is the most robust. In Regression (2.3), a_{cpi}, a_y and a_e are all statistically significant. However, a_y is negative, and $a_{cpi}=1$ could be rejected with 10% Wald Test.

From these three outcomes, we conclude that among all of the regressions in Table 3.1 and Table 3.2, none can meet the active requirements of the Taylor rule. That is to say that the estimation of Taylor rule suggests that the interest rate policy of China is not an active one, so we cannot trace China's interest rate policy by using Taylor rule.

3.3 GMM analysis of McCallum rule

Much like the Taylor rule, the specialized McCallum rule for the targeted growth rate of the real money supply is a function of inflation, output gap, and nominal exchange rate. That is,

$$m_t^* = \overline{m} + b_{cpi}[E(cpi_t|\Omega_t) - cpi^*] + b_y(E(y_t|\Omega_t) - y_t^*) + b_e(E(exchange_t|\Omega_t) - exchange_t^*) \tag{3.10}$$

whereis $\overline{m}$ the long-run equilibrium nominal rate, cpi_t is the realized annual inflation rate at t y_t, is real output, and cpi^* and y_t^* are respective bliss points for inflation and output. We assume that y_t^* is given by potential output, defined as the level that would arise if wages and prices were perfectly flexible. In addition, E is the expectation operator and Ω_t is the information available to the central bank at the time it sets interest rates.

In practice, central banks tend to maintain smoothness in money supply. In the literature, it is commonly assumed that the actual interest rate m_t is a weighted average of the target rate m_t^* and the existing interest rate m_{t-1}, plus a noise term ε_t, due to other random factors at the same time. This smoothing behavior is represented by Eq. (3.11).

$$m_t = (1-\phi)m_t^* + \phi m_{t-1} + \varepsilon_t \tag{3.11}$$

where $0 \leq \phi < 1$. The case of $\phi = 0$ corresponds to the original Taylor rule without smoothing.

To obtain an estimable equation, we define $b_c \equiv \overline{m} - b_{cpi}cpi^*$, $x_t \equiv y_t - y_t^*$ and $e_t \equiv exchange_t - exchange_t^*$. We then rewrite Eq. (3.10) as

$$m_t^* = b_c + b_{cpi}[E(cpi_t|\Omega_t)] + b_y(E[x_t|\Omega_t]) + b_e(E(e_t|\Omega_t]) \tag{3.12}$$

Combining the target model (3.12) with the adjustment mechanism (3.11) yields

$$m_t = (1-\phi)[b_c + b_{cpi}[E(cpi_t|\Omega_t)] + b_y(E[x_t|\Omega_t]) + b_e(E[e_t|\Omega_t])] + \phi m_{t-1} + \varepsilon_t \tag{3.13}$$

Finally, we eliminate the unobserved forecast variables from the expression by rewriting the policy rule in terms of realized variables as follows:

$$m_t = (1-\phi)[b_c + b_{cpi}cpi_t + b_y x_t + b_e e_t] + \phi m_{t-1} + v_t \tag{3.14}$$

where the error term $v_t \equiv -(1-\phi)\{b_{cpi}(cpi_t - E[cpi_t|\Omega_t]) + b_y(x_t - E[x_t|\Omega_t]) + b_e(e_t - E[e_t|\Omega_t])\} + \varepsilon_t$ is a linear combination of the forecast errors of inflation, output, exchange rate and the exogenous disturbance ε_t. Let u_t be a vector of variables within the central bank's information set at the time it chooses the interest rate ($u_t \in \Omega_t$) that is orthogonal to v_t. Possible elements of u_t include any lagged variables that help forecast inflation, output, exchange rate and any contemporaneous variables that are uncorrelated with the current interest rate shock ε_t. Then, since $E[v_t|u_t] = 0$, Eq. (3.14) implies the following set of orthogonality conditions that we exploit for estimation:

$$E[m_t - (1-\phi)(b_c + b_{cpi}cpi_t + b_y x_t + b_e e_t) - \phi m_{t-1}|u_t] = 0 \tag{3.15}$$

To estimate the parameter vector $[b_c, b_{cpi}, b_y, b_e, \phi]$ we use GMM.[15] The instrument set u_t includes lagged values of output, inflation, exchange rate and money growth. Each of these variables are potentially useful for forecasting inflation, output and exchange rate, and are exogenous with respect to the interest rate, given our identifying assumptions.[16]

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15) The composite disturbance term for our model has an MA (n-1) representations. In this case, the GMM estimator of the parameter vector is a two-step nonlinear two-stage least squares estimator when the model is overidentified (Clarida *et al.* (1998)).

16) Our econometric approach relies on the assumption that, within our short samples, money growth rate and inflation rate are $I(0)$. Please refer to Table 4.1.

Table 3.3 The estimation of McCallum rule with sample (1996M10-2012M3)

McCallum Rule	b_c	b_{cpi}	b_{y1}	b_{y2}	b_{y3}	b_e	ϕ	R^2
Regression (3.1)	16.54*** (1.5997)	−2.9814*** (0.9060)	−2.3653** (1.0630)			−2.2473** (0.9044)	0.9226 (0.0221)	0.9480
Regression (3.2)	16.78*** (1.2888)	−3.3093*** (0.7572)		1.2688** (0.5109)		−2.5586*** (0.7773)	0.8937*** (0.0245)	0.9348
Regression (3.3)	16.85*** (2.4761)	−3.8952** (1.5950)			−7.1859 (4.5095)	−2.8392* (1.6435)	0.9492*** (0.0253)	0.9407

Note: The instruments are y_{t-1}, y_{t-2}, y_{t-3}, y_{t-4}, y_{t-5}, y_{t-6}, cpi_{t-1}, cpi_{t-2}, cpi_{t-3}, cpi_{t-4}, cpi_{t-5}, cpi_{t-6}, m_{t-1}, m_{t-2}, m_{t-3}, m_{t-4}, m_{t-5}, m_{t-6}, e_{t-1},e_{t-2}, e_{t-3}, e_{t-4}, e_{t-5}, e_{t-6}, $Commodity_{t-1}$, $Commodity_{t-2}$, $Commodity_{t-3}$, $Commodity_{t-4}$, $Commodity_{t-5}$, $Commodity_{t-6}$.
*** indicates that the coefficient is statistically significant at 1% level, ** at the 5% level and * at the 10% level.

Again following the Taylor rule, a stabilized rule for money supply is supposed to be counter-cyclical. Therefore, the active McCallum rule hypothesis is

$$b_{cpi}<0,\ b_y<0 \text{ and } b_e<0 \tag{3.16}$$

This is because when the inflation rate increases, output increases and the CNY depreciates. In this instance, the money supply should be reduced to control inflation, to prevent an overheated economy or to stabilize the nominal exchange rate.

The estimation of the McCallum rule is shown in Table 3.3. In Table 3.3, equation (3.11) is used for estimation and the sample period is from 1996M10 to 2012M3.

The hypothesis $b_{cpi}<0$ is statistically significant for all the regressions in Table 3.3, which indicates that the money supply rule does focus on the inflation target. b_{cpi} is −2.98 in Regression (3.1), which means that with a 1% increase in inflation, the real money supply growth rate would be reduced by 2.98%.

Afterwards in Regression (3.1), hypothesis $b_y<0$ is significantly met, while in Regression (3.2) b_y is significantly positive. In Regression (3.3), b_y is statistically insignificant.

The hypothesis $b_e<0$ is met for all the regressions in Table 3.3. As the absolute values of parameters b_e all exceed 2, the money supply would fall by about 2% if the nominal exchange rate were to increase by 1%. b_c is notably high, indicating that the long-term money supply growth rate is about 17%, consistent with the PBC's annual m2 target.

Among the three regressions in Table 3.3, Regression (3.1) is the most robust, and can satisfy the entire active money supply policy hypothesis. In China, money supply management can not only prevent inflation and stabilize economic growth, but respond to nominal exchange rate changes as well. Compared with interest rate policy, money supply policy is much more active.

To measure how well our model can explain the behavior of PBC, we plot the implied target policy interest rate versus the actual interest rate and target m2 versus the actual m2 in Figure 3.2 and 3.3. As Regression (1.1) and (3.1) are the most robust results for Taylor rule and McCallum rule respectively, we employ them for the comparison. Both the target interest rate implied by Regression (1.1) and the target m2 implied by Regression (3.1) nicely tracked the behavior of actual interest rate and actual m2 from 1996 to 2012. If we know the targets of CPI, output gap and nominal exchange rate for PBC, we can use Regression (1.1) and (3.1) to predict policy interest

Figure 3.2　Target r and Actual r

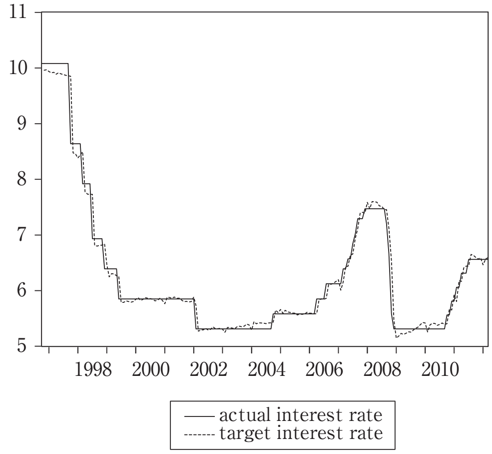
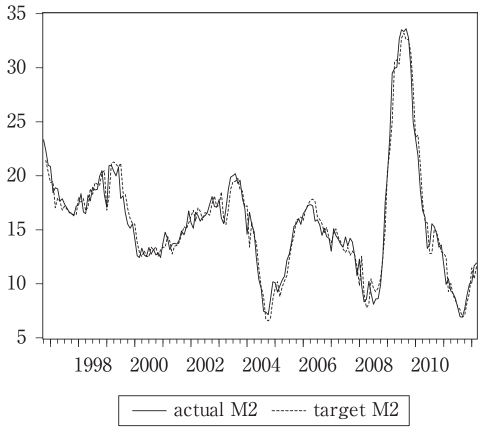


Figure 3.3　Target m2 and Actual m2



rate and m2.

Our conclusion is that money supply management in China not only focuses on inflation and economic growth, but also takes the nominal exchange rate into account. China's money supply policy is an active policy rule. In order to respond to the appreciation of the CNY, the growth rate of money supply remains high, which leads to excess liquidity during 2007-2008. Again, the McCallum rule better explains China's monetary policy than the Taylor rule.

4　The simulation of Taylor rule and McCallum rule with VAR model

Having analyzed GMM estimation of both Taylor and McCallum rules in the third part of this paper, the same rules will now be estimated with a Structural VAR (SVAR) model. The SVAR model can be used to trace the dynamic effects of shocks of monetary policy on inflation, output and exchange rate. Because VAR models involve current and lagged values of multiple time series, they capture comovements that cannot be detected in univariate or bivariate models.

4.1 Variables included in the SVAR

We will use a simple SVAR model to analyze the relationship among interest rates, money supply, inflation, output gap and nominal exchange rate. The interest rate and money supply are policy instruments. Let $z_t=\{cpi_t, y_t, e_t, r_t, m_t\}$ be 5-element vectors of endogenous variables. According to the results of Taylor and McCallum rules in GMM models, the estimations with output gap estimated by electricity $y1$ are the most robust, so $y1$ will be used in the VAR models. The lag order is 6 months, since in monetary policy analysis 6 month lag is commonly used.

4.2 Identification

According to Amisano and Giannini (1997), the SVAR model equation takes the form shown in equation (4.1):

$$Az_t=A_1^*z_{t-1}+A_2^*z_{t-2}+\cdots+A_p^*z_{t-6}+B\varepsilon_t=\sum_{i=1}^{6}A_i^*z_{t-i}+B\varepsilon_t \tag{4.1}$$

For simplicity, constant terms, deterministic terms, and exogenous variables are ignored. Matrix A (5*5) is invertible, and summarize the contemporaneous (instantaneous) relationship among the variables. Thes A_i^* are (5*5) coefficient matrices. Structural shocks are properly identified from the error terms of the estimated reduced form with the appropriate identifying restrictions. Zone-zero off-diagonal elements of matrix B (5*5) allow some shocks to affect more than one endogenous variable in the system directly. ε_t is a vector of structural disturbance postulated to follow a white-noise process. Their linear combinations are assumed to be white-noise processes with zero means and constant variances, and are serially uncorrelated individually. The variance-covariance matrix of ε_t is usually restricted to be diagonal.

The reduced form is obtained by premultiplying with A^{-1}, provided that A is non-singular:

$$z_t=A_1z_{t-1}+A_2z_{t-2}+\cdots A_6z_{t-6}+u_t \tag{4.2}$$

where $A_j=A^{-1}A_j^*$ $(j=1,\dots6)$, $u_t=A^{-1}B\varepsilon_t$, describes the relation between the reduced form disturbances (u_t) and underlying structure shocks (ε_t). Thus, we obtain

$$E(u_tu_t')=A^{-1}BE(\varepsilon_t\varepsilon_t')B'A^{-1} \tag{4.3}$$

Moreover, assuming that the variance of each disturbance is standardized, and substituting population moments with the sample moments, we have

$$\sum u=A^{-1}BB'A^{-1}$$

$\sum u$ contains $k^*(k+1)/2$ different elements, so $k^*(k+1)/2$ is the maximum number of identifiable parameters in matrices A and B. Therefore, a necessary condition for identification is that the maximum number of parameters of A and B should equal the number of unknowns in equation (4.3). Here, the total number of elements of the structural form matrices A and B is $2k^2$. Thus,

$$2k^2-k^*(k+1)/2=k^2+k^*(k-1)/2 \tag{4.4}$$

restrictions should be imposed for identification. If one of the matrices A or B is an identity matrix, then $k^*(k-1)/2$ restrictions are left to be imposed. Hence, identification necessitates the imposition of some identifying restrictions on the parameters of A and B. In practice, the four most common patterns for identifying restrictions are A model ($B=I_k$), B model ($A=I_k$), AB model ($Au_t=B\varepsilon_t$), and the long run restrictions, such as Blanchard and Quah (1989).

We have the basic structural VAR (SVAR) specification based on an A model ($B=I_k$), and the system of equations can be written in the following matrix form:

$$\begin{pmatrix} 1 & 0 & 0 & 0 & 0 \\ a_{ycpi} & 1 & 0 & 0 & 0 \\ a_{ecpi} & a_{ey} & 1 & 0 & 0 \\ a_{rcpi} & a_{ry} & a_{re} & 1 & 0 \\ a_{mcpi} & a_{my} & a_{me} & a_{mr} & 1 \end{pmatrix} \begin{pmatrix} cpi_t \\ y_t \\ e_t \\ r_t \\ m_t \end{pmatrix} = c + A(L) \begin{pmatrix} cpi_t \\ y_t \\ e_t \\ r_t \\ m_t \end{pmatrix} + \begin{pmatrix} \varepsilon_{cpi} \\ \varepsilon_y \\ \varepsilon_e \\ \varepsilon_r \\ \varepsilon_m \end{pmatrix} \tag{4.5}$$

This is the case of just-identification restriction. In this model, the structural shocks to money supply $m2$ are assumed to be related to the reduced form innovations in inflation and output gap according to the McCallum rule. The five-variable VAR is ordered as: inflation rate cpi, GDP gap y, nominal exchange rate e, policy interest rate r and money supply $m2$. Various orderings have been tried, and the results turn out to be the same.

In the case of interest a_{rcpi} is −0.0086, a_{ry} is −0.0060, a_{re} is 0.0534. All of them are much smaller than the corresponding parameters estimated by GMM model, which are listed in Table 3.1. This is because the 4th equation in Eq. (4.5) indicates that r is not only affected by current realizations of macroeconomic variables such as CPI, output gap and exchange rate, but is also affected by their past six months realizations.

Since a_{rcpi}, a_{ry}, a_{re} are on the left side of Eq. (4.5), the signs should be opposite to GMM model. The sign of a_{rcpi}, a_{ry} are negative, consistent with GMM model. As to a_{re}, the sign is positive, inconsistent with GMM model. However, considering that a_{re} is statistically insignificant in both GMM (displayed in Regression 1.1 in Table 3.1) and SAVR (displayed in the first row third column in Figure 4.1), when discussing the response of interest rate to nominal exchange rate, there is no need to take the sign of a_{re} into consideration.

Similarly, in the case of money supply, a_{mcpi} is 0.5446, a_{my} is 0.0441, and a_{me} is 0.1992. All of them are smaller than the corresponding parameters estimated by GMM model, listed in Regression 3.1 in Table 3.3. The reason is the same as the case of interest rate above. Furthermore, a_{mcpi}, a_{my}, a_{me} are on the left side of Eq. (4.5), so the signs (negative) are consistent with GMM, illustrating that McCallum rule is an active policy rule.

4.3 Impulse responses

Impulse responses trace out the response of current and future values of each of the variables to a one-unit increase in the current value of one of the VAR errors, assuming that this error returns to zero in subsequent periods and that all other errors are equal to zero.

The impulse responses for the SVAR, ordered cpi, y, e, r, and m2 are plotted in Figure 4.1. In SVAR model, the criterion to measure whether the impulse response is statistically significant or not is the position of both ±2 standard-error bands. The impulse response function is statistically significant as long as both standard-error bands are above or below zero on the y-axis. The following analysis is carried out based on this criterion.

In the case of Taylor rule, three figures in the first row show the responses of interest rate r to an unexpected one percentage point increase of three macroeconomic variables. The first figure suggests that when inflation rate increases, interest rate r will move upwards. On this point, it is consistent with the result of GMM model in Regression 1.1 in Table 3.1. The third figure illustrates that the response of interest rate to nominal exchange rate is statistically insignificant, which is also consistent with the result of GMM model. It is necessary to point out that, the second

Figure 4.1 Impulse responses in the five-variable SVAR

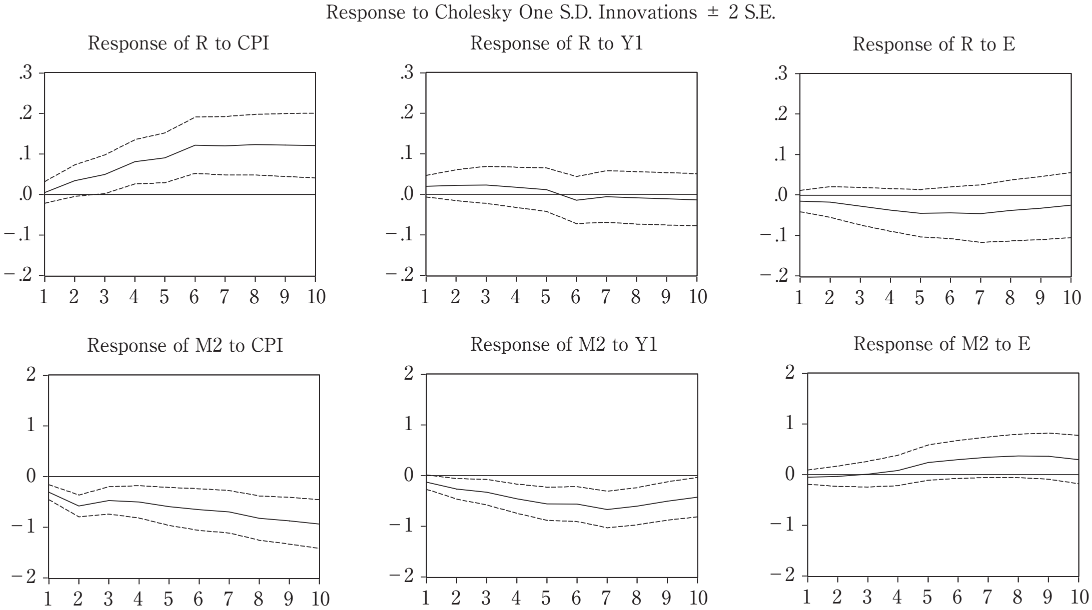


figure indicates that the response of interest rate to output gap is insignificant, while it is significant in the GMM model.

In the case of McCallum rule, three figures in the second row show the responses of money supply m2 to an unexpected one percentage point increase of three macroeconomic variables. The first two figures suggest that when inflation rate increases or the GDP output gap rises, money supply m2 will move downwards, which is consistent with the result of GMM model. However, the third figure shows that the response of m2 to nominal exchange rate is positive, which is opposite to GMM results in Regression 3.1 in Table 3.3.

There is also an inconsistency between the results of the GMM and SVAR models, as seen in the top-middle and bottom-right plots of Figure 4.1. In both cases, the GMM results are significant while the SVAR results are not. Since the SVAR model has many more parameters than the GMM, each parameter in SVAR is less likely to achieve statistical significance.

In conclusion, the results of GMM are statistically convincing, compared with SVAR model. Besides, money supply m2 is more active and responds better to CPI and output gap than interest rate in both GMM model and SVAR model.

5 Concluding remarks

The GMM estimation suggests that the requirements for an active Taylor rule are not satisfied for several reasons. First, for a unit change of inflation rate and output gap, the response of the interest rate is not large enough. Second, in many cases of the Regressions, both the inflation and the output gap are not statistically significant. In addition, as explanatory variables in the Taylor rule, nominal exchange rate is statistically insignificant in most cases.

Compared with the Taylor rule, the McCallum rule is more active and can be more effectively used to trace China's monetary policy. It is because all of the active requirements are met, such that money supply m2 responds significantly and negatively to CPI, output gap and nominal exchange rate.

The results of SVAR are consistent with the GMM estimations of the Taylor rule and McCallum rule. Money supply responds to CPI and economic growth significantly negatively, so targeting the money supply is a better device to trace China's monetary policy.

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《SUMMARY》

TAYLOR RULE OR MCCALLUM RULE FOR CHINA'S MONETARY POLICY

By CICELY LIU

Using both GMM (Generalized Method of Moments) and SVAR (Structural Vector Autoregression), this paper aims to tackle an important problem in China's recent monetary policy: whether the policy is better captured by the Taylor rule or the McCallum rule. The estimations suggest that the McCallum rule is more active than the Taylor rule in China. Furthermore, GMM model gives the formula to predict money supply m2 by giving inflation, output, and nominal exchange rate targets, which can nicely track the behavior of actual m2. In order to get more accurate results and to grasp the nuances of the economic variables, monthly data are used. The paper also includes a comprehensive literature review on China's monetary policy rule.

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