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"Monetary Policy Rule for China: 1994-2006"

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ABSTRACT

With the development of market-oriented economic reforms, Chinese monetary policy plays an important role in the world. The objective of this paper is to review the recent conduct of Chinese monetary policy and the central bank's rule-based behavior in period 1994-2006 by estimating the monetary policy rules (monetary policy reaction function). It compares four kinds of monetary policy rules -Taylor rule, McCallum rule, Modified Taylor rule and Modified McCallum rule and conducts the empirical study of these four rules with Chinese data. The findings are that these four estimated rules can describe Chinese monetary policy stance in some degree and Taylor rules are better than McCallum rules in evaluating Chinese monetary policy performance. This study includes five sections. Section 1 is the introduction. Section 2 is the brief literature review. Section 3 indicates four model specifications of monetary policy rule. Section 4 evaluates Chinese monetary policy performance utilizing models mentioned in Section 3. Section 5 provides concluding remarks.

Monetary Policy Rule for China: 1994-2006

Danfeng KONG

1. Introduction

In recent years, the technical study regarding monetary policy attracts more and more attention in both academic and policy-making circles. This study includes two research directions. One is to study the effects of exogenous monetary policy shocks on real economy. The other is to investigate monetary policy rule, which mainly describes how a central bank sets the nominal interest rate or base money growth in response to macroeconomic variables (the inflation rate , output gap, nominal GDP growth rate deviation, etc.) endogenously. Regarding monetary policy rules, there exist two kinds of methodology. One is theoretical derivation of the optimal monetary policy rule. The optimal monetary policy rule can be obtained by analyzing the optimal behavior of central bank in context of loss function and macroeconomic structure restraint. The other is to set the monetary policy rule exogenously, that is, let instruments variables respond to inflation, output gap, etc.. This kind of monetary policy rule includes Taylor rule and McCallum rule（Taylor，1993,1999；McCallum，1988,1999）. Since the exogenously set monetary policy rule has close relationships with the actual monetary policy decision and operation, it attracts greater interests of policy makers and scholars than theoretically derived monetary policy rule. In large degree, the estimated Taylor rule and McCallum rule can be considered as a guideline/benchmark-or explicit formula-for the central bank to follow when making monetary policy decisions.

Based on the previous literature, this paper purposes to estimate the monetary policy rule (Taylor rule, Modified Taylor rule, McCallum rule and Modified McCallum rule) for China during the period 1994:1-2006:4. It attempts to find how Chinese monetary policy responds to inflation, output gap or nominal GDP growth deviation and which types of Taylor rule and McCallum rule can better describe Chinese monetary policy stance. Compared with the related previous literatures, the originality of this paper is the systematically comparative analysis of Taylor rule, Modified Taylor rule, McCallum rule and Modified McCallum rule in context of China. Most of the previous literature regarding Chinese monetary policy rule just focus Taylor rule and McCallum rule respectively, not combine them together. Yang (2002) is the only Chinese paper conducting the comparative analysis. In this paper, he just analyzes original Taylor rule and the original McCallum rule. Another novelty of this paper is the systematic analysis of the fundamental contents of monetary policy rule. In this paper, the research dynamics, nature, theoretical origin of monetary policy rule and the relationship between the policy rule and inflation targeting framework, etc. are well discussed.

The remaining includes four sections. Section 2 is the brief literature review. Section 3 indicates four model specifications of monetary policy rule. Section 4 evaluates Chinese monetary policy performance utilizing models mentioned in Section 4. Section 5 provides concluding remarks.

2. Brief Literature Review

There is a long history to research monetary policy rule in macroeconomics and monetary economics (McCallum, 1997). If we goes back to the origin of related literature, the early studies include Thornton(1802), Bagehot(1873), Wicksell(1907), Fisher(1920,1926), Simon(1935), etc.. The modern researches on monetary policy rule start from Friedman(1948,1960). Friedman & Schwartzs（1968）indicate that central bank should supply money at 3-4% growth rate provided that money demand is stable. With the development of theories of rational expectation（Lucas，1972）and time inconsistency (Kydland & Prescott,1977；Barro & Gordon,1983), the study of monetary policy rule comes into a new era. The traditional convention is that discretion with the period-by-period-reoptimization is better than rule-based policy. The occurrence of theories of rational expectation and time inconsistency makes ones recognize that the rule commitment can realize time consistency and prevent inflation bias, although the monetary policy rule can only be treated as guidelines in the actual conduct of monetary policy.

Since 1990, with the development of industrial and emerging countries' monetary policy practice, the literatures in monetary policy rules increase quickly. Most of these theoretical and empirical literatures are centered by Taylor rule and McCallum rule. Taylor rule mainly describes how central bank maintains low and stable inflation and avoids large fluctuations of output and employment by utilizing the instrument of interest rate. In this rule, nominal interest rate responds to the inflation deviation and output gap. Here, interest rate is the instrument, price stabilization and economic growth are the main targets. The seminal Taylor rule （Taylor, 1993, 1999）is backward-looking. Rudebusch and Svensson (1999), Clarida, Gali and Gertler(2000), Orphanides (2001) develop it into forward-looking type. Some economists（Rotemberg and Woodford,1999; Batini and Haldane,1999; Levin, Wieland,and Williams,1999）focus on the robustness of Taylor rule in different macroeconomic structure models. Different from Taylor rule, McCallum rule (1988，1993，1997，1999，2003）describes how central bank avoids big fluctuation of output deviation by utilizing the means of base money. The McCallum rule is the rule that base money reacts to the nominal growth rate deviation. In this rule, base money is the instrument and economic growth is the main target. In a sense, the McCallum rule is developed from Friedman's fixed growth rate rule. McCallum and other researchers （Judd and Motley, 1991; Dueker and Fisher, 1998）modify the original rule in different ways.

In terms of Chinese monetary policy rule, till now, there is no English literature on the application of Taylor rule to China. There is only one English discussion paper (Burdekin and Siklos, 2005) examining the McCallum rule with Chinese data. On the other hand, the Chinese literature on studying monetary policy effectiveness and monetary policy rule is increasing after 2000. Xie & Luo (2002) is the first Chinese paper to conduct the empirical study of Taylor rule with Chinese data and their viewpoint is that Taylor rule can well measure Chinese monetary policy. Lu & Zhong (2003), Fan (2004), Liu (2004), Bian (2006) , Zhang & Zhang（2007）further study the application of backward-looking and looking-forward Taylor rule to China. Different

papers have different empirical results due to the selection of data period and indicators. Regarding McCallum rule, Yin et al. (2001) is the first paper to analyze the application of McCallum rule to China. They use simple calibration method to compute the McCallum rule. Yang (2002) estimates McCallum rule, but he did not conduct the unit root and cointegration test. Xiang (2004) proposed the McCallum rule in context of open economy and examined its application to China. Yuan (2006) indicates the application of Open Economy McCallum rule to China. Song et al. (2007) examines the effectiveness of McCallum rule.

3. Model Specifications of Monetary Policy Rule

Next I specify four monetary policy models, that is, Taylor rule, Modified Taylor rule, McCallum rule and Modified McCallum rule. To conserve the space, I do not analyze the open-economy monetary policy rule and robustness of policy rule. The original Taylor rule and McCallum rule can be derived form the traditional equation of quantity of money（Taylor，1999）.

3.1 Taylor Rule

Taylor rule mainly describes how central bank maintains low and stable inflation and avoids large fluctuation of output and employment by utilizing the means of interest rate. It is a rule that nominal interest rate reacts to the inflation deviation and output gap. The seminal backward-looking Taylor rule is as follows.

$$r = r^* + \pi + 0.5(\pi - \pi^*) + 0.5(y) \tag{1}$$

where r is the federal fund rate, r^* is the equilibrium real rate, π is the average of current and the previous three period, π^* is the inflation target, y is the output gap.

The forward-looking Taylor rule describes how central bank responds to expected inflation deviation and expected output gap. Among forward-looking rules, the most famous is eq. (2) proposed by Clarida et al.(2000). For eq. (2), if the expected output gap can be treated as the pressure on the future inflation, this rule can be regarded as inflation targeting framework. Given the expected output gap, when expected inflation rate is higher than inflation target, the nominal rate will increase and this will reduce investment and consumption expenditures of firms and individuals. The aggregate demand will reduce correspondingly. This will lead to the decrease of inflation. Therefore, in some degree, Taylor rule can provide a nominal anchor for central bank to react to the various shocks. It can also provide an automatic stabilizer for macroeconomy. In this sense, eq.(2) can be regarded as a kind of inflation targeting framework.

$$i^*_t = i^* + \beta(E(\pi_{t+n}) - \pi^*) + \gamma(E(y_{t+q})) \tag{2}$$

Considering the behavior of interest rate smoothing or policy inertia (eq.（3）), substitution of eq. (2) into eq. (3) yields a forward-looking interest rate rule with interest rate smoothing (eq.(4)).

$$i_t = \rho i_{t-1} + (1 - \rho)i^*_t \tag{3}$$

3

$$i_t = (1-\rho)\alpha + (1-\rho)\beta\pi_{t+n} + (1-\rho)\gamma y_{t+q} + \rho i_{t-1} + \varepsilon_t \qquad (4)$$

where i_t^*, i^*, i denotes the nominal rate target, long-run equilibrium nominal rate and nominal rate, π_{t+n} is the inflation rate between t period and $t+n$ period, $E(\pi_{t+n})$ is the expected inflation rate between t period and $t+n$ period, π^* is inflation target, $E(y_{t+q})$ is the average expected output gap, $\beta > 0$, $\gamma > 0$, $\alpha = i^* - \beta\pi^*$, Ω_t is the information set of setting the interest rate, $\varepsilon_t \equiv -(1-\rho)\{\beta(\pi_{t+n} - E[\pi_{t+n} \mid \Omega_t]) + \gamma(y_{t+q} - E[y_{t+q} \mid \Omega_t])\}$. According to eq.(4), the interest rate of current period should respond to the lagged one-period interest rate, n-period-ahead inflation and q-period-ahead output gap.

For convenience, I set $n = 1$, $q = 1$, eq. (4) can be changed into eq. (5),

$$i_t = (1-\rho)\alpha + (1-\rho)\beta\pi_{t+1} + (1-\rho)\gamma y_{t+1} + \rho i_{t-1} + \varepsilon_t \qquad (5)$$

3.2 McCallum Rule

Different from Taylor rule, McCallum rule (1987, 1988, 1993, 2000) describes how a central bank avoids the big fluctuations of output by utilizing the instrument of base money. The seminal McCallum rule is as follows.

$$\Delta b_t = \Delta x^* - \Delta V_t^a + \lambda(\Delta x^* - \Delta x_{t-1}) \qquad (6)$$

where Δb_t is growth rate of base money, $\Delta b_t = \ln b_t - \ln b_{t-1}$, Δx^* is the target of nominal GDP growth rate. Δx^* is a constant and equals to the sum of inflation rate target and long-run average real GDP growth rate. ΔV_t^a is the average base money velocity (McCallum used the average of lagged sixteen quarter) and it is calculated by dividing base money variable into nominal GDP. $\Delta x^* - \Delta x_{t-1}$ is the nominal GDP growth rate deviation.

In terms of inflation target framework, base-money-growth-rate rule can also be understood as a kind of inflation targeting framework. If $\Delta x^* - \Delta x_{t-1}$ is regarded as the pressure on the inflation, when nominal GDP growth rate is bigger than the target, that is, the economy is overheated, the growth rate of base money will reduce. Therefore, McCallum rule can provide an automatic stabilizer for the macro economy.

4

3.3 Modified Taylor Rule

Frankly to say, both the seminal forward-looking Taylor rule and seminal McCallum have some problems. For Taylor rule, since the long-run equilibrium real rate and output gap, which the policy rule heavily rely on, are unobservable, there exists great uncertainty about the computation. Different methods do lead to different results. At present, there is no uniform international standard to compute the potential output, even in U.S:, there is no consensus on the computation of potential output. On the other hand, due to the same adjustment direction of the endogenous and exogenous interest rate, the dynamic relationship between nominal interest rate and inflation might increase the difficulty to utilize this rule. Generally, increasing interest rate can reduce demand and inflation pressure. However, from the perspective of long run, high interest rate is the inevitable result of high inflation. Therefore, it will increase the difficulty for monetary authority to judge the effectiveness of interest rate rule.

In order to solve the uncertainty problem of output gap, referring to McCallum rule that utilizes the observable nominal *GDP* growth rate, also referring to McCallum (2000) and Rudebusch (2002), I utilize $\Delta x^* - \Delta x_{t-1}$ to replace the output gap y and change eq. (5) into eq. (7),

$$i_t = (1-\rho)\alpha + (1-\rho)\beta\pi_{t+1} - (1-\rho)\gamma(\Delta x^* - \Delta x_{t-1}) + \rho i_{t-1} \qquad (7)$$

Eq. (7) indicates that when nominal output growth rate is bigger than the nominal growth rate, the interest rate in the left-hand side should increase in order to loosen the inflation pressure. When inflation rate increases, the interest rate should also increase and automatically adjust the economic inflation. The merit of this augmented Taylor rule is that all variables in the rule are observable. Therefore, it has great operationality.

3.4 Modified McCallum Rule

In McCallum rule, there is only one target variable – nominal *GDP* growth rate. In terms of target variables, the rule does not reflect that base money responds to inflation directly, although Fisher Equation and lots of empirical studies indicate that money supply and inflation have high correlation coefficient (Romer,2000; Walsh, 2003).

In order to solve the problem that McCallum rule does not reflect price stability reaction directly, referring to Taylor rule which reacts to price stability explicitly and McCallum (2000) and Orphanides (2003), also based on the recognition that money supply and price level moves at the same direction, I modify eq. (6) as follows.

$$\Delta b_t = \Delta x^* - \Delta V_t^a + \beta(\pi^* - \pi_{t-1}) + \gamma(\Delta x^* - \Delta x_{t-1}) \qquad (8)$$

Equation (8) indicates that when nominal output growth rate is greater than nominal growth rate target, the base money should be decreased in order to reduce the overheat pressure. Similarly, when inflation rate is greater than inflation rate target,

money supply should be decreased in order to adjust the overheated economy.

4. Estimation of Monetary Policy Rule for China

There are two methods to estimate the reaction coefficients of the monetary policy rule. One is calibration, that is, choosing different figures and testing which figures are the best to fit the actual interest rate or money growth movements. Both seminal Taylor rule and seminal McCallum rule utilize this method. The other is to use the econometric analysis methods such as GMM, OLS and so on to estimate the response parameters. For example, the widely cited forward-looking Taylor rule proposed by Clarida et al.(2000) is conducted by GMM method.

In this paper, I utilize the methods of GMM and OLS to estimate four monetary policy rules mentioned in section 3. The data period is 1994:1-2006:4. There are two reasons why I choose data from 1994. One is data availability. The other is that China conducts lots of market-based financial system reforms from 1993 and it makes the economic environment more market-oriented.

4.1 Data

The estimated variables include interest rate, base money growth rate, nominal *GDP* growth rate, inflation rate and velocity of money. The data of nominal *GDP* in 1994:1-2001:4 is from *China Quarterly Gross Domestic Product Estimates 1992-2001* which is edited by China Statistics Bureau. All raw data except the explanation of data source is from *Quarterly Report of People's Bank of China*, website of China Statistics Bureau and website of People's Bank of China. Next I explain the data in details.

Interest rate (i). Because China's deposit and lending rates are still largely administratively determined now, I utilize the interbank rate, which is determined by market mechanism, as the indicator of interest rate. Since the 7-days interbank trading volume accounts for most proportion of interbank trades, I choose 7-days interbank rate as the indicator of interest rate. The 7-days interbank rate of 1994 and 1995 is the weighted average interbank rate of all terms of Shanghai Financing Center (cited from Xie and Luo (2002)). Due to data availability, the interest rate terms in 1994-1995 and 1996-2006 do not match. However, since the interbank rates of different terms of Shanghai Financing Center have no big differences, the inconsistency of terms does not have greater effects on the econometric test.

Although the deposit and lending rates are administratively determined in China, with the development of market economy, the formation mechanism of deposit and lending rates relies on the market mechanism more and more, the correlation relationship between deposit rate, lending rate and interbank rate becomes stronger and stronger. Therefore, interbank rate can also reflect the trend of deposit and lending rates. Figure 1 plots one-year deposit rate and interbank rate. Form this figure, we can see that these two rates have strong correlation relationship.

Figure1 Interbank Rate and One-Year Deposit Rate in 1994–2006 Period
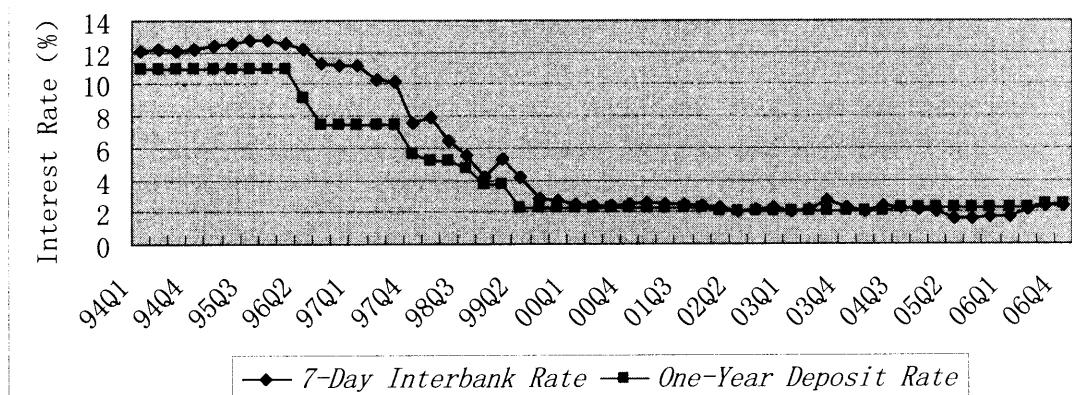
Potential Output (GDP^p) and Output Gap (y).   In China, there is no official

statistics about the potential output and output gap. Therefore, I have to compute the potential output and output gap before estimating monetary policy rules.

The potential output is the output that is produced when all factors are fully

employed. The computation formula is $y = \dfrac{GDP - GDP^p}{GDP^p} \approx \ln GDP - \ln GDP^p$.

In this formula, GDP is real GDP , GDP^p is potential GDP . Usually there are two

methods to estimate potential output. One is production function method. The other is to linear time trend method.

Referring to Xie and Luo（2002）, I employ the linear time trend method to estimate Chinese potential output. First I give the regression equation (9) of real GDP. I add three season dummies to eliminate the seasonal in this equation. Real GDP = Nominal GDP /(1+CPI). The potential output can be computed based on eq. (9).

$$D_1 = \begin{cases} 1 \\ 0 \end{cases} \quad D_2 = \begin{cases} 1 \\ 0 \end{cases} \quad D_3 = \begin{cases} 1 \\ 0 \end{cases}$$

$$\ln RGDP = 9.52 + 0.028T - 0.39D1 - 0.27D2 - 0.24D3 \tag{9}$$

$$R^2 = 0.978 \quad D.W. = 2.3$$

AR(1) = 0.754   To eliminate the first-order autocorrelation.

According to eq. (9), the potential output can be expressed as follows.

$$POTENGDP = EXP(9.52 + 0.028T - 0.39D1 - 0.27D2 - 0.24D3) \tag{10}$$

Figure 2 plots real GDP and potential GDP. Figure 3 is the bar graph of output gap and the trend of output gap is in line with the macroeconomic trend in the sample period.
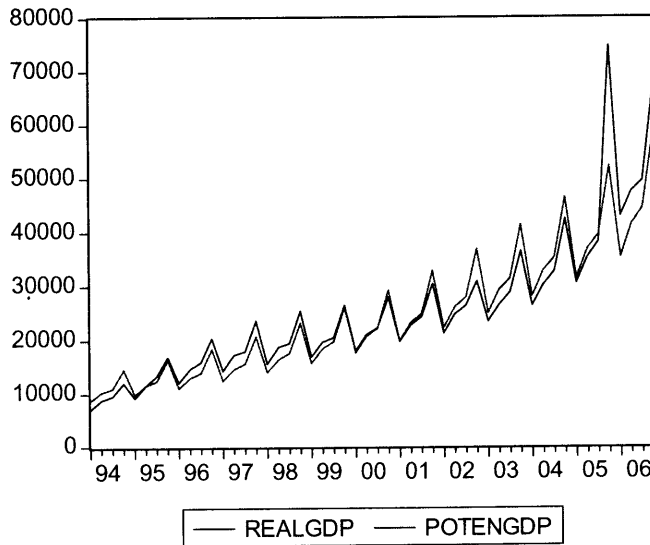
7

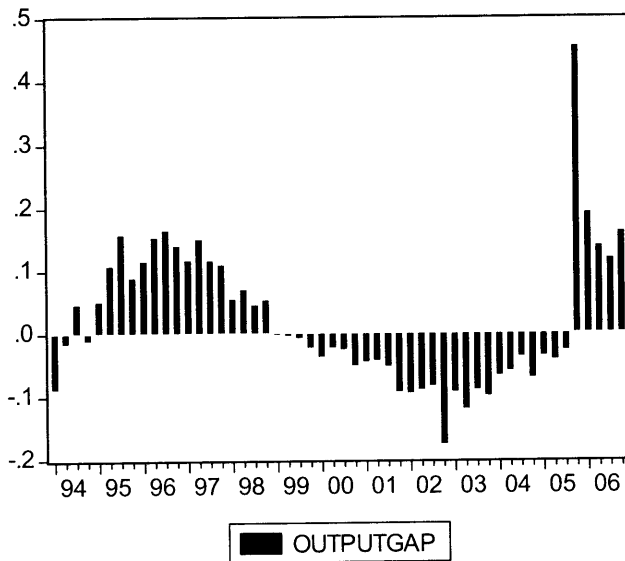Figure2   Real Output and Simulated level of Potential Output

Figure3   Bar Graph of Chinese Output Gap

Base Money Growth Rate (Δb). Base money growth rate takes the form of log

difference. $\Delta b_t \approx \ln b_t - \ln b_{t-1}$. From 1994, China begins to compile the statistics of

base money. According to the People's Bank of China (PBOC) , the definition of base money is as follows. Base money =Vault money of financial institutions + Cash in the circulation + Special deposits of financial institution + Postal savings deposits + Deposits of institutions and societies in PBOC. In January 2002, PBOC adjusted the contents of balance sheet of monetary authority and utilized the concept of reserve money. According to the PBOC, the reserve money is the same as the base money and the statistics is consistent.

Velocity of Money (ΔV_t^a). Based on Fisher equation $MV = PT$, the calculation

of velocity can be obtained, that is $V = PT / M$. Because PT can be replaced with

8

nominal *GDP* , the formula of velocity of money can be changed into $V = \text{nominal GDP} / M$. The velocity of money in this paper is the velocity money of base money.

Inflation rate (π). The inflation rate is measured by consumer price index *CPI* . From 1994, China begins to compile and publish *CPI* data officially. However, the data is year-on-year index, not year-to-year index. China starts to compile and publish year-to-year *CPI* from 2000 (2000 = base year) officially. In order to get a longer and relatively reliable time series, I employ year-on-year *CPI* as the proxies of year-to-year *CPI* .

Inflation Target (π^*). The data of inflation target is from *Report on the implementation of the **** Plan for National Economic and Social Development and on the **** Draft Plan for National Economic and Social Development* of various years, which is compiled by State Development and Reform Commission of China. The targets of 1994-1997 are in form of RPI while 1998-2006 target values are in form of *CPI* (See Table 1). Since quarterly data is utilized in this paper, the quarterly targets of each year are equal to the annual targets.

Table1   Inflation Target Published by Chinese Government in 1994-2006

Year	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006
CPI	N.A.	N.A.	N.A.	N.A.	5%	4%	4%	1-2%	1-2%	1%	3%	4%	3%
RPI	10%	15%	10%	6%	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.

Nominal *GDP* Growth Rate (Δx). Nominal *GDP* growth rate takes the form of nominal *GDP* log difference. $\Delta x \approx \ln x_t - \ln x_{t-1}$.

Nominal *GDP* Growth Rate Target (x^*). The nominal GDP growth target equals to the sum of inflation target and long-run average real GDP growth rate. Since quarterly data of real GDP growth rate is available in China, I use the real GDP growth rate as the long-run average real GDP growth rate. Therefore, the nominal GDP growth rate target can be obtained by summing up the quarterly inflation target and quarterly real GDP growth rate.

4.2 Unit Root Test and Cointegration Test

In order to avoid spurious regression, I conduct the unit root test and cointegration test first. I conduct *ADF* test for five variables – interest rate (i), inflation rate (π), output gap (y), base money growth rate (Δb), nominal *GDP* growth rat e (Δx). Table 1 is the empirical results of ADF test. The results indicate that at the 1% and 5% level, the level series of i, π, y are unstationary. However, first difference of these three series are stationary. The level of Δb and Δx are stationary.

9

Table 2 Empirical Results of Unit Root Test

Variable	Test Type (c,t,k)	ADF Test Value	1% Critical Value	5% Critical Value	Stationarity
i	(c,0,1)	-1.46	-3.57	-2.92	No
Δi	(c,0,1)	-3.58	-3.57	-2.92	Yes
π	(c,0,1)	-2.78	-3.57	-2.92	No
$\Delta \pi$	(c,0,1)	-5.05	-3.57	-2.92	Yes
y	(c,0,1)	-2.87	-3.57	-2.92	No
Δy	(c,0,1)	-9.83	-3.57	-2.92	Yes
Δb	(c,0,1)	-7.997	-3.57	-2.92	Yes
Δx	(c,0,1)	-12.8	-3.57	-2.92	Yes

Since i , π, y are I(1) variable, the cointegrating relationship between these three variables need to be tested. This paper conducts the cointegration test by utilizing the method proposed by Johansen-Juselius (1990). Table 3 reports the results of cointegration test. The test results show that at the 5% critical level, there exists three cointegration equations among these three variables. This indicates that these three variables (i , π, y) has long-run cointegrating relationship. Therefore, the regression conducted by these three variables is not spurious.

Table 3 Results of Johansen Cointegration Test
Unrestricted Cointegration Rank Test (Trace)

Hypothesized No. of CE(s)	Eigenvalue	Trace Statistic	0.05 Critical Value	Prob.**
None *	0.391496	41.05012	29.79707	0.0017
At most 1 *	0.193206	16.21252	15.49471	0.0389
At most 2 *	0.103774	5.478154	3.841466	0.0192

Trace test indicates 3 cointegrating eqn(s) at the 0.05 level

4.3 The Estimation of Four Monetary Policy Rules With Chinese data

After finishing unit root test and cointegration test, I will estimate monetary policy rules in form of eqs. (5),(6),(7) and (8). The purpose of this empirical study is to estimate reaction coefficients of the instrument variables to the inflation and output gap and measure the fitness of rule to the actual monetary policy behavior.

4.3.1. Taylor Rule (Eq. (5))

$$i_t = (1-\rho)\alpha + (1-\rho)\beta\pi_{t+1} + (1-\rho)\gamma y_{t+1} + \rho i_{t-1} + \varepsilon_t$$

Just like Clarida et al. (2000), this paper also utilizes GMM method to estimate the vector $[\beta,\gamma,\rho,\alpha]$. The instrument variable set (u_t) include one–period lagged

output gap, inflation, interest rate and real GDP growth rate (y_{t-1}, $\pi_{t-1}, i_{t-1}, g_{t-1}$).

Table 4 reports the estimates of Taylor rule in form of (5). The reaction coefficient of inflation deviation is greater than that of output gap.

Table 4   Estimates of Rule (5)

β	γ	ρ	α	$\overline{R}^2$
0.549*	0.159**	0.887*	0.015***	0.985
(4.28)	(1.97)	(29.61)	(1.33)	

Note: *, ** and *** are 1%, 5% and 10% level respectively.

Figure 3 indicates time paths predicted by forward-looking Taylor rule and the actual interbank rate. We can see that the fitness is good, the trends of rule and actual data are consistent. Only in 1997Q3, 1998Q1 and 1999Q1, there is significant difference between the actual and fitted values.
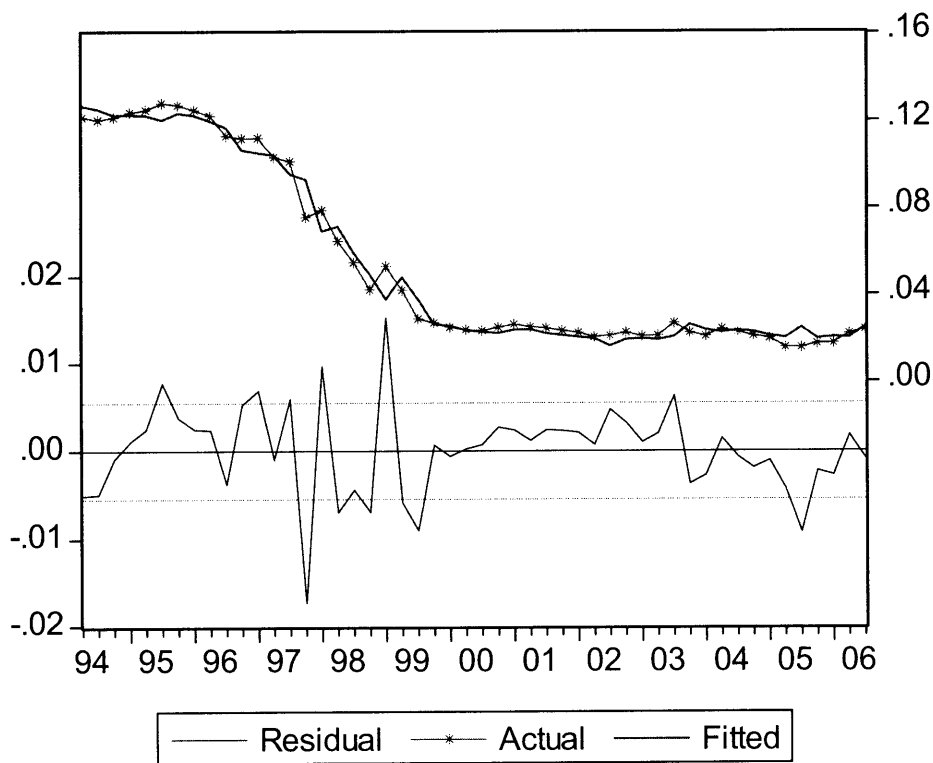

Figure 3   Taylor Rule (5) and Actual Interbank Rate

4.3.2 Modified Taylor rule (Eq. (7))

$$i_t = (1-\rho)\alpha + (1-\rho)\beta\pi_{t+1} - (1-\rho)\gamma(\Delta x^* - \Delta x_{t-1}) + \rho i_{t-1}$$

I also employ GMM method to estimate modified Taylor rule. Table 5 reports the estimation results.

Table 5   Modified Taylor rule (7) and Taylor rule (5)

	β	γ	ρ	α	$\overline{R}^2$
Modified	0.767*	0.0368	0.924*	0.008	0.984
Taylor rule	(3.66)	(-1.02)	(44.49)	(0.876)	

11

Taylor rule	0.549^{*}	0.159^{**}	0.887^{*}	0.015^{***}	0.985
	(4.28)	(1.97)	(29.61)	(1.33)	

Figure 4 shows the modified Taylor rule and the actual interbank rate. Similar to Figure 5, the fitness of modified Taylor rule is good and the actual interbank rate is in line with the rule's predictions. Only in 1997Q3, 1998Q1 and 1999Q1, there is great residual (interest rate gap).　Compared with figure 4, there is no significant change in Figure 5.
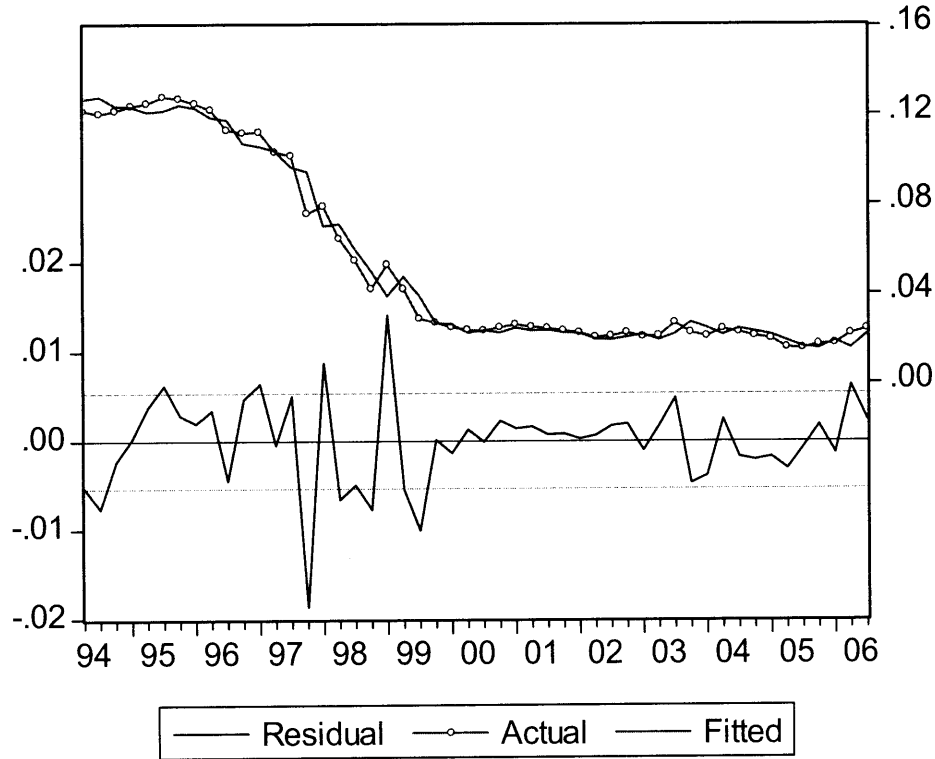

Figure 4　Modified Taylor Rule (7) and Real Interbank Rate

4.3.3. McCallum Rule (Eq.(6))

$$\Delta b_t = \Delta x^{*} - \Delta V_t^{a} + \lambda(\Delta x^{*} - \Delta x_{t-1})$$

Different from McCallum who utilizes calibration method to analyze (6) in many papers, I utilizes OLS method to estimate eq. (6). For convenience, $\Delta V_{t-1} = \Delta V_t^{a}$ is assumed. Therefore, Eq.(6) can be changed into following form.

$$\Delta b_t = \theta \Delta x^{*} - \delta \Delta V_{t-1} + \lambda(\Delta x^{*} - \Delta x_{t-1})$$

The regression result is as follows,

$$\Delta b_t = 0.07\Delta x^{*} - 0.059\Delta V_{t-1} - 0.13(\Delta x^{*} - \Delta x_{t-1})$$

$$(0.43) \qquad (1.61)^{***} \qquad (-4.2)^{*}$$

12

$$\overline{R}^2 = 0.27 \qquad DW = 2.14$$

（*, *** is 1% and 10% level respectively）

The regression result presents that the reaction coefficient of base money growth rate to nominal GDP growth rate deviation is negative (-0.13) and statistically significant, at least at the 10% level. It seems that this is conflicted with the principle that the reaction coefficient of McCallum rule should be positive. The minus coefficient means that when nominal GDP growth rate is bigger than GDP growth rate target, ceteris paribus, the growth rate of base money will increase and this will facilitate the increase of nominal GDP growth rate. In this sense, McCallum rule is indeterminitic in China. The reason why this problem happens is that base money is unstable with the development of financial innovation and financial reform. It is difficult to make statistics of money supply precisely nowadays.

Figure 5 plots McCallum rule and actual base money growth rate. Form this figure, we can see that the former fit the latter basically. Compared with the simulated value, the volatility of actual base money growth rate is significant. However, it fluctuates around the fitted value.
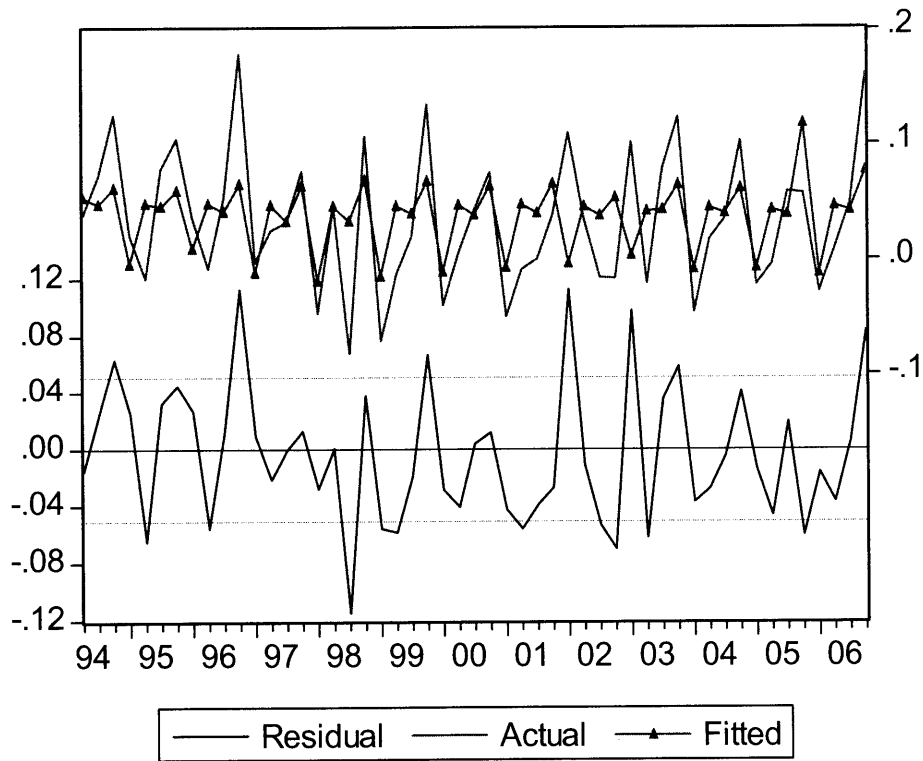

Figure 5   McCallum Rule and Actual Base Money Growth Rate

4.3.4. Modified McCallum Rule (Eq.(8))

$$\Delta b_t = \Delta x^* - \Delta V_t^a + \beta(\pi^* - \pi_{t-1}) + \lambda(\Delta x^* - \Delta x_{t-1})$$

Similar to 4.3.3, for convenience, the modified McCallum rule can be changed into the following form.

$$\Delta b_t = \theta \Delta x^* - \delta \Delta V_{t-1} + \beta(\pi^* - \pi_{t-1}) + \lambda(\Delta x^* - \Delta x_{t-1})$$

Utilizing the OLS method, the regression results can be obtained.

$$\Delta b_t = -0.045 - 0.087\Delta V_t - 0.24(\pi^* - \pi_{t-1}) - 0.14(\Delta x^* - \Delta x_{t-1})$$

$$(-0.253) \quad (2.128)^{**} \quad (-1.48)^{***} \quad (-4.44)^{*}$$

$$\overline{R}^2 = 0.29 \qquad DW = 2.15$$

（*, **,*** is 1% , 5% and 10% level respectively）

The regression results indicate that reaction coefficient of base money growth rate to the nominal GDP growth rate deviation is negative (-0.14). The reaction coefficient of base money growth rate to the inflation is also negative (-0.24). Similar to the unmodified McCallum rule, we can also conclude that modified McCallum rule tends to be destablizing in China. From the perspective of absolute value, in line with two kinds Taylor rule mentioned in 4.3.1 and 4.3.2, the reaction of Chinese monetary policy to inflation is bigger than that to output.

Figure 6 plots modified McCallum rule and actual base money growth rate. Form this figure, we can see that the former fit the latter basically. Compared with the fitted value, the volatility of actual base money growth rate is significant. However, it fluctuates around the rule.
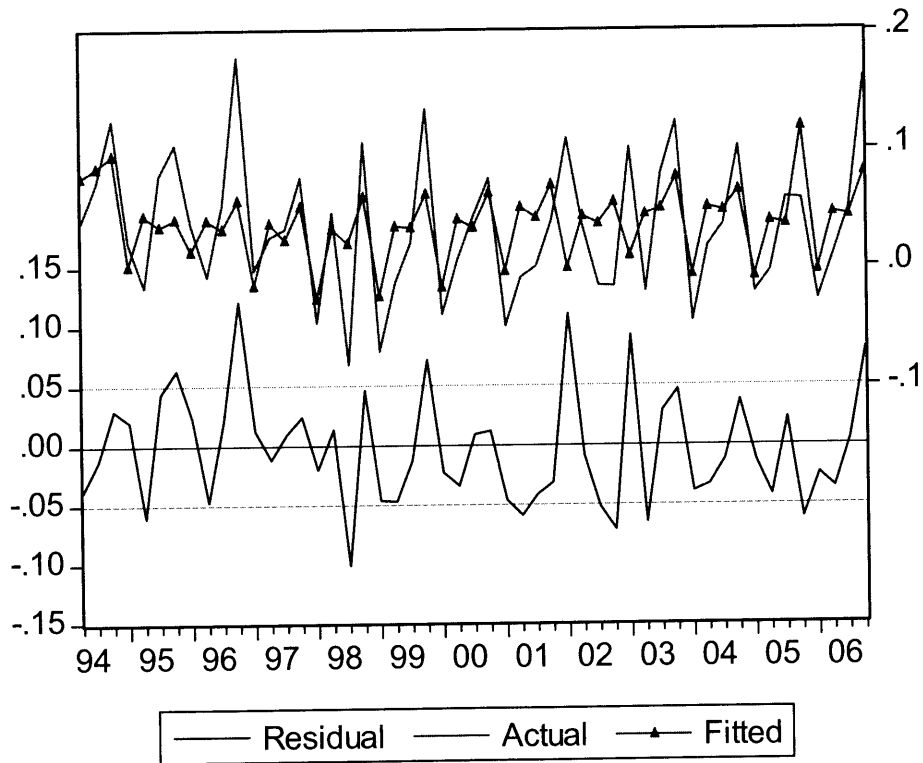

Figure 6 Modified McCallum rule and actual base money growth rate

4.4 Comparison of four kinds of estimated monetary policy rules

Table 6   Estimates of Four Monetary Policy Rules

	β	γ	λ	$\overline{R}^2$
Taylor Rule	0.549[*] (4.28)	0.159[**] (1.97)		0.985
Modified Taylor Rule	0.767[*] (3.66)	0.0368 (-1.02)		0.984
McCallum Rule			-0.13[*] (-4.2)	0.27
Modified McCallum Rule	-0.24[***] (-1.48)		-0.14[*] (-4.44)	0.29

Table 6 indicates the estimates of four kinds of monetary policy rule. The results of Taylor rule and the modified Taylor rule show that the reaction of interest rate to the inflation is greater than that to the output. According to Clarida et al. (2000), the rule tends to be stabilizing if $\beta > 1$, the rule tends to be destablizing if $\beta < 1$. The rule tends to be stabilizing if $\gamma < 0$ while it is likely to be stabilizing if $\gamma > 0$. In this paper, the β estimates of Taylor rule (5) is smaller than 1 and γ is smaller than 0.

These coefficients mean that the reaction of interest rate to the inflation makes the rule be destabilizing while the reaction of interest rate to output makes the rule be stablizing. However, the response of interest rate to inflation is bigger than that to output, Taylor rule (5) tends to be destabilizing in some degree. Modified Taylor rule also has same problem.

Why do Taylor rule and Modified Taylor rule generate the destabilizing results in China? How to explain it ? In terms of macroeconomic practice, China experiences inflation-deflation-inflation alternatively after 1994. Especially after the East Asian Crisis, the rare phenomenon of deflation occurred. After 2004, the price level increased quickly. Under this condition, Chinese monetary authority adjusts interest rate frequently to stabilize the price fluctuation. Since 1996, Chinese monetary authority has reduced interest rate 8 times and increased interest rate 7 times consecutively. In some cases, the adjustment is just adaptive, the timing and degree of adjustment has some problems. This might lead to the destabilizing property of two estimated Taylor rules. What's more, although the dominated interest rate- deposit and lending rate and market-based interbank rate has strong correlation relationship, the fact that deposit and lending rate is still administratively determined also leads to the destabilizing property of rule in some degree.

Although there exist the destabilizing properties, there is no doubt that these two Taylor rules have good fitness of actual interbank interest rate. In a sense, the Taylor rules can be treated as the guidelines of Chinese monetary policy. It can provide lots of useful information for PBOC to design and manipulate monetary policy and behave in a time-consistent manner.

In terms of McCallum rule, the empirical results indicate that the reaction of base money growth rate to the output is very small. In the Modified McCallum rule, the reaction of Chinese monetary policy to the price is bigger than that to the output. This is consistent with two Taylor rules. In addition, the reaction coefficients of two estimated McCallum rules are minus, conflicting with the property of automatic stabilizer of McCallum rule. This indicates that McCallum rule tends to be destabilizing in China.

In terms of fitness, two estimated McCallum rules basically reflect the trend of actual base money growth rate. Compared with the simulated value, the volatility of actual values is bigger. Why does the base money growth rate fluctuate so significantly? The most important reason is that Chinese base money supply is largely passively affected by its increasing foreign exchange after the reform in 1994. Chinese monetary authority has to conduct the open market operations to influence the money supply. Although the two McCallum rules tend to be destabilizing and the fitness is not good as that of Taylor rules, under the condition that deposit and lending rates are still administratively determined and money supply is still the intermediate target of Chinese monetary policy framework, it is very useful to utilize the McCallum rule as the guidelines of Chinese monetary policy.

5. Concluding Remarks

The research focus of this paper is to apply Taylor rule, Modified Taylor rule, McCallum rule and Modified McCallum rule to China and attempt to find which type is better to describe Chinese central bank behavior. The estimation results show that two types of Taylor rule are better to fit Chinese actual monetary policy stance than two types of McCallum rule. Although these four rules tend to be destabilizing in terms of stabilizing properties, these four rules can be treated as guidelines of Chinese monetary policy in terms of fitness. With the development of market-oriented reforms of interest rate system and the improvement of money supply statistics, both Taylor rule and McCallum rule can describe the stance of Chinese monetary policy in a better way. Considering Taylor rule is the mainstream of theoretic research and more and more countries utilize the interest rate to conduct the monetary policy, it can be expected that Taylor-type rule will become the main guidelines of future Chinese monetary policy.

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