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Can the Taylor Rule Describe the Monetary Policy in China?

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Abstract

The Taylor Rule effectively describes the relationship among nominal interest, inflation rate and output gap in the United States, assuming the country has a closed economy. This paper positively analyzes the efficiency of the Taylor Rule in China through historical analysis. I evaluate the responsiveness and effectiveness by estimating the Taylor Rule and its modifications, using quarterly data in the period 1987Q1 to 2015Q3. The original Taylor Rule does not work well based on the current Chinese monetary policy. However, adding a lagged nominal interest rate in the previous period can help the model to work better. The nominal interest rate responds actively to both the inflation rate and the output gap. Using a specific information set can help to forecast the change in the nominal interest rate. The exchange rate also plays an important role in improving the model.

Keywords: Taylor Rule, monetary policy, China, exchange rate, open economy

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I. Introduction

There is an increasing amount of research about the Taylor Rule in developed countries, such as the United States and Canada. However, only a few researchers mention the Taylor Rule based on monetary policy conditions in China. Could the Taylor Rule effectively describe the monetary policy in China? How should the Taylor Rule react to the change from closed economy to open economy? Could the monetary policy in China be implemented and predicted by the Taylor Rule? Following previous models and literature, this paper answers these questions.

Based on the models in developed countries, the central banks have been using the interest rates and money supply as their main tools to implement monetary policies. I analyze how the nominal interest rate responds to GDP, inflation, exchange rates, et cetera. Moreover, I also test the McCallum Rule which is regarded as an alternative to the Taylor Rule. At this part, the central bank of China wants to target the money supply growth rate rather than the interest rate. Using the money supply rate and the exchange rate also helps to analyze the monetary policies in China. Also, I use the HAC (Bartlett kernel, Newey-West) method to calibrate models to avoid having significant problems with heteroscedasticity and autocorrelation.

Firstly, what is the Taylor Rule? In 1993, Taylor advanced a general form of the Taylor rule based on a closed economy. The rule is a monetary policy model that stipulates how much the central bank should change the nominal interest rate in response to changes in inflation, output, or other economic conditions. Taylor (1993) also tries to use this rule to foster price stability and full employment by systematically reducing uncertainty and increasing the credibility of future actions by the central bank.

Taylor (1993) examines the application of econometric evaluation research on monetary policy rules in the United States, the United Kingdom, Canada, and some other countries. However, these examinations have a common assumption: Every country has a closed economy. Ball (1999) tries to add exchange rates into the original Taylor Rule to adjust the equation for an open economy. Taylor (2001) concludes that monetary policy rules that react directly to the exchange rate do not work better in stabilizing inflation and real output, and sometimes work worse than policy rules that do not react directly to the exchange rate.

My results indicate that the original Taylor Rule does not work well based on current monetary policy in China, because the original Taylor Rule is built on the United States, assuming it has a closed economy. However, the change of nominal interest rate significantly depends on the previous period's nominal interest rate. Only part of the inflation rate and the output gap can influence the change of the nominal interest rate. In other words, the central bank tries to decrease the effects of the inflation rate and the output gap to the change of the nominal interest rate.

Also, the role of the exchange rate is unstable in the model, but the indirect effects of the exchange rate can help the model work better than the direct effect of the exchange rate. Using the information set can help to forecast the change of the nominal interest rate, but the forecasting model may not perform perfectly, because the model of forecasting the inflation rate may not fully work in the real world. Simply put, only using the inflation rate, the output gap and the exchange rate cannot fully explain the monetary policy in China.

The purpose of this paper is to test whether the Taylor Rule and its extensions could effectively describe the monetary policies in China. Section 2 begins to give brief reviews of the previous literature on the evaluation of the Taylor Rule based on different conditions. Then, it provides information about China’s monetary background. This is followed by summary statistics and graphs in section 3, which also provide detailed data and variable information relating to monetary policies in China. Section 4 presents the results of testing the monetary policies, using different hypotheses. A thorough analysis of the results and the corresponding effects is outlined in Section 5. Section 6 concludes the entire paper, and some tables, figures and references relating to the paper will be included in section 7.

II. Background

A. Literature Review

In 1993, Taylor explores the original model of monetary policy based on data from the United States, United Kingdom, Canada and other developed countries.

This is the original model built by Taylor:

$$r_t = r^* + \pi_t + c(1) * (y_t - y^*) + c(2) * (\pi_t - \pi^*) \tag{1}$$

In this function, $c(1)$ and $c(2)$ are coefficients, r_t is the central bank's target short-term nominal interest, r^* is the assumed equilibrium real interest, π_t is the inflation rate measured by the GDP deflator, π^* is the target inflation rate, y_t is the real output or the logarithm of real GDP, and y^* is the logarithm of potential output. In other words, this function helps to build the relationship among the nominal interest rate, r_t, target interest rate, r^*, inflation rate gap, $\pi_t - \pi^*$, and output gap, $y_t - y^*$.

Initially, Taylor (1993) wishes to create a formal rule to stipulate the monetary policy made by the central bank in the United States; so he makes a rule that depicts the monetary policy sufficiently based on data from the United States, considering only the closed economy. However, after 1993, an increasing number of economists, whose research field is Macroeconomics, have applied the Taylor Rule to open economies in different countries. For example, they find that the Taylor Rule with real exchange rates performs well in France and Italy, but not in Germany (Taylor, 2001).

The Taylor rule is the fundament of this paper, in which running hypothesis tests for it will help to analyze its efficiency of depicting monetary policy in China. With several small changes to the original Taylor rule, the model fits the monetary policy in China well.

Mervyn King (2000) claims that the Taylor rule ignores interest rate smoothing. Taylor uses both inflation and output as exogenous variables, responding to the early changes of interest rate, but King argues that both inflation and output should be considered as endogenous variables.

At the beginning of the 21st century, Clarida et al. (2000) make a forward-looking prior interest rate rule, based on the Taylor Rule:

(2) $$r_t^* = r^* + \beta\left(E\left\{\pi_{t,k}\middle|\Omega_t\right\} - \pi^*\right) + \gamma E\{x_{t,k}|\Omega_t\}$$

In this equation, β and γ are coefficients, r_t^* denotes the target rate for the nominal Federal Funds rate in period t, $\pi_{t,k}$ denotes the percent change in the price level between periods t and $\mathrm{t+k}$, π^* is the target for inflation, $x_{t,k}$ is a measure of the average output gap between period t and $\mathrm{t+k}$, r^* is the desired nominal rate when both inflation and output are at their target levels, E is the expectation operator, and Ω_t is the information set at the time the interest rate is set.

Clarida et al. (2000) estimates a simple forward-looking policy reaction function which nests the Taylor rule as a special case. They test whether lagged inflation or a linear combination of lagged inflation and the output gap is a sufficient statistic for forecasting future inflation. On the other hand, this specification allows the central bank to consider a broad array of information to form beliefs about future economic conditions.

Equation (2) also plays an important role in this paper, because it helps to forecast the monetary policy in the future, based on current conditions. The information set helps to make the model more realistic than the original one, since I am testing the model based on an open economy, consisting of more monetary variables, such as the exchange rate.

B. China's Monetary Background

Zhang et al. (2007) also talks about the use of the Taylor Rule in China. They extend the forward-looking formula to estimate the effectiveness in China:

(3) $$r_t^* = r^* + \pi_{t-1} + \alpha_1(E\{\pi_t|\Omega_{t-1}\} - \pi^*) + \alpha_2 E\{y_t|\Omega_{t-1}\} + \alpha_3 M_{t-1}$$

In this equation, M_{t-1} is the lagged growth rate of money, which is the only one target controlled by the central bank in China. Other variables are built based on the previous model set by Clarida et al (2000). Adding the growth rate of money in the forward-looking formula could make the model more realistic.

Li et al. (2010), introduces several extended equations of the original Taylor Rule. Taylor (1993) initially sets up the equation based on the closed economy, so that these extended equations add exchange rates, lagged interest rates, or expected inflation to test the equation in China. They use this to analyze the effectiveness of the Taylor Rule, based on the monetary-policy in China over the 1994 to 2006 period.

Fan et al. (2010) talks about both the Taylor rule and the McCallum rule. The McCallum rule is an alternative to the Taylor rule, and it performs better during crisis periods. As an alternative rule, the McCallum rule adds the real exchange rate to the Taylor rule:

(4) $$m_t = b_c + b_y(y_t - y^*) + b_\pi(\pi_t - \pi^*) + b_e e_t$$

In this equation, b_c is the intercept of this equation (constant), b_y, b_π, and b_e are coefficients, m_t is the target growth rate of the real money supply, $y_t - y^*$ is the output gap, $\pi_t - \pi^*$ is the inflation gap, and e_t is the real effective exchange rate. When they build the model, they use lagged value as an additional dependent variable. The authors believe that using both rules will help to find whether the monetary policy responds to and has some effects on the economic growth, the inflation rate, and the real effective exchange rate in China, as in Western countries.

Chen et al. (2009) writes about monetary policy in Taiwan during the period from 1981 to 2008, estimating the money growth rule (McCallum Rule) and the interest rate rule (Taylor Rule). Also, Chen et al. (2009) makes a conjecture of Chinese monetary policy rule about Chinese monetary conditions, estimating both the Taylor and the McCallum Rule.

In the late 1970's, China began its economic reforms: the open-door policy. A large amount of investments entered the Chinese market, which prompted economic growth. Up to 2014, the highest real GDP growth rate occurs in 1995 with 126.94 percent and the lowest occurs in 1999 with negative 77.22 percent. Overall, the real GDP growth rate on average is about 35.45 percent each year. The highest inflation rate appears in 1994 with 350.00 percent, and the lowest inflation rate occurs in 1999 with negative 178.95 percent. Also, the lowest rate of change of the real exchange rate from Dollar to Renminbi is negative 805.73 percent in 2004, while the highest rate of change of the real exchange rate is 4897.11 percent in 2014.

From 1987-2015, the People's Bank of China becomes the central bank, which stimulates economic growth and maintains stability in commodity prices. Given the reform in China, the fluctuations of economic factors provide a good opportunity to study the Taylor Rule, which explains the responsiveness of different economic variables. How does the Taylor Rule help to depict and forecast monetary policy in China?

III. Data

I use quarterly observations of these variables. The nominal interest rate, $inter\_loan$, is the average of the seasonal deposit or lending rate, which is also defined by banks as the official inter-bank loan rate. The nominal interest rate is the dependent variable in almost every model, except for the McCallum model, in this paper. This whole paper tests the dependent variable as it responds to the changes of other independent variables, which reflects the monetary policy in China.

The following variables are independent variables. Firstly, the inflation rate, $inflation$, is calculated by using the quarterly observations of the Consumer Price Index (CPI). The Real Gross Domestic Product (GDP) also plays an important role in the model, which is calculated by using the [nominal GDP/CPI]. After that, I use the Hodrick–Prescott filter (HP-Filter) to calculate the potential GDP, because the HP-Filter can help to remove the cyclical component of a time series from raw data, and gain smoothed-curved representation of potential GDP. Figure 1 shows how the HP-Filter works and the comparison between real GDP and potential GDP. Furthermore, I calculate the output gap, $output\_gap$, by using the equation: [(real GDP – potential GDP)/potential GDP].

Another important economic factor is the exchange rate, which is significant in an open economy, as it reflects change of the value of currency based on cross-country monetary conditions. Initially, I collect the nominal exchange rate (Dollar per Renminbi), $exch\_nominal$. In this paper, the real exchange rate, $exch\_real$, is defined by using the [nominal exchange rate

* CPI (China) / CPI (USA)]. Using the data, I also calculate the rates of change of the nominal exchange rate and the real exchange rate, which are no more non-stationary but stationary.

In general, the McCallum Rule is regarded as an alternative to the Taylor Rule, which explains the response of money growth rate to inflation rate, output gap, and real effective exchange rate. In this way, I also collect the M2 growth rate and the rate of change of the M2 growth rate, which may indicate the changes of inflation, output gap, and real effective exchange rate.

I collect all the data from the Federal Reserve Economic Data (FRED) and the National Bureau of Statistics of China. Inflation rate and Consumer Price Index are published since 1987Q1 to 2015Q3; nominal GDP and real GDP are from 1992Q1 to 2015Q3; M2 growth rate is from 1999Q1 to 2015Q3; nominal interest and real interest rate are from 1997Q3 to 2014Q4; nominal exchange rate and real exchange rate are from 1987Q1 to 2015Q3.

As it is shown in Table 1,2 &3, I calculate the rates of change of these variables and show the descriptions of these rates of change. The original data (time series) are non-stationary, but the rates of change of these variables are stationary. Also, some of them have missing observations, so that I build regressions based on at least 67 observations.

Figure 2 and 3 show the time-series plots of eight variables and the rates of change of these variables. These two graphs show the economic fluctuations in China, which also provides a first glimpse at how monetary policy corresponds to the changes of economic variables. However, because some data have missing values, these plots are not based on the same range of years.

Further, based on the target inflation rate published by China's Government Work Report, I choose 4 percent as the ideal value for target inflation rate. Also, Xie et al. (2003) calculates that the target inflation is 4 percent in China. In 2009, Li et al. (2009) also uses 4% as the target inflation rate. On the other hand, some other research papers choose 4% as the target inflation in China. In this way, I believe 4% is an appropriate target inflation rate.

IV. Method

The original Taylor Rule is defined as equation (1) in section II, which is also the most essential model for this paper. However, based on collected data, there are strong correlations between the variables in (1); such that, the model is modified as:

$$r_t = c(1) * (y_t - y^*) + c(2) * (\pi_t - \pi^*) + c(3) \tag{5}$$

In this equation, $c(3)$ is the constant, which replaces $r^* + \pi_t$ in equation (1). If we run the regression test, the change in the model will not affect the results of coefficients, $c(1)$ and $c(2)$. In this way, based on the monetary condition in China, changing the variables in the equation may help the model to be more reasonable.

Taylor (1993) sets coefficients $c(1)$ and $c(2)$ as 0.5 to fit the model into the United States' closed economy, in which Taylor tries to decrease the influence of output gap and inflation gap towards the nominal interest rate. In general, these two coefficients are supposed to be less than one. However, implementing the model into China's economic condition may change the values of the coefficients, because China is an open economy, and China may not have the same monetary policy as the United States. So, the hypothesis is to test whether these two coefficients are significant.

Furthermore, after analyzing the original Taylor Rule, adding lagged nominal interest as one of the independent variables will help to capture the behaviors of the central bank, because the central bank may change the nominal interest rate based on last period nominal interest rate. To study the model in an open economy, checking the correlation through time is important, such that:

$$r_t = c(1) * (y_t - y^*) + c(2) * (\pi_t - \pi^*) + c(3) + c(4) * r_{t-1} \tag{6}$$

In this equation, r_{t-1} is the lagged nominal interest rate (the exactly previous period), and the meaning of the rest of the variables follows equation (5). After running the hypothesis test for this equation, the correlation between the current interest rate and the past period interest rate may be obvious, which may help to find a model.

On the other hand, as China has an open economy, adding the exchange rate as one additional, dependent variable may help the model to be more realistic, because the exchange rate is supposed to influence the change of the nominal interest rate. However, at this time, it is hard to decide whether to use the nominal exchange rate or the real exchange rate. In this way, there are at least two models that needed to be tested:

(7) $$r_t = c(1) * (y_t - y^*) + c(2) * (\pi_t - \pi^*) + c(3) + c(4) * r_{t-1} + c(5) * e_n$$

In this equation, e_n denotes the nominal exchange rate, and the meaning of the rest of the variables is as equation (6).

(8) $$r_t = c(1) * (y_t - y^*) + c(2) * (\pi_t - \pi^*) + c(3) + c(4) * r_{t-1} + c(5) * e_r$$

The only difference between equation (7) and equation (8) is that e_r replaces e_n. e_r is the real exchange rate, which is calculated by using [nominal exchange rate * CPI (China) * 100 / CPI (USA)].

After testing the significance of the nominal and the real exchange rate as independent variables, it may be helpful to include the rates of change of nominal and real exchange rates. There are two ways to add the variable: using the rate of change of exchange rate to replace the exchange rate, or including both variables into the model.

As an alternative to the Taylor Rule, the McCallum Rule is also worth testing, which shows the change of money supply growth rate with in response to the inflation gap, the output gap and the real effective exchange rate. This rule is built in equation (4). The rule expresses the monetary policy from another aspect, using money growth rate to replace the nominal interest rate. In general, a stabilizing rule for money supply should be counter-cyclical, in which b_y and b_π are supposed to be smaller than zero.

Following the original McCallum rule, adding the lagged money growth rate may let the model work better.

(9) $$m_t = b_c + b_y(y_t - y^*) + b_\pi(\pi_t - \pi^*) + b_e e_t + b_5 * m_{t-1}$$

However, there may be unexpected inflation components in the money supply, which are not controlled by the central bank. In this way, the sign of b_5 is hard to determine, but this coefficient needs to be significant.

The last model is the forward-looking model, which uses information set in the previous period to predict current inflation rate and output gap. It then uses the two predictive variables to build the Taylor Rule:

(10) $$r_t = c(1) * (E\{\pi_t|\Omega_{t-1}\} - \pi^*) + c(2) * E\{y_t|\Omega_{t-1}\} + c(3) * r_{t-1} + c(4)$$

Equation (10) is modified based on equation (2) and (3). This model uses a previous period information set to get expectations of inflation rate and output gap. It is supposed to have similar coefficient values as equation (6). By using on this model, it will be easy to forecast future interest rate in China, based on current information.

V. Results

First, I test the most essential model, equation (5), which is modified by using a constant term to replace target interest rate and inflation rate. The hypothesis is to test the significances of dependent variables. Based on the results in table 4 column 1, the R-squared for this hypothesis test is 0.047, which indicates that this model actually does not explain the change in nominal interest rate. In other words, using output gap and inflation gap just helps to explain 4.71% of the change of the nominal interest rate. On the other hand, the Durbin-Watson stat is 0.12, which is far less than 2, in which indicates that there is big problem with autocorrelation. In this way, this model does not work well based on the monetary policy in China.

However, even though equation (5) does not give good results, adding a lagged independent variable as another dependent variable may help a lot. As it is shown in equation (6), I add a lagged nominal interest rate as a dependent variable. As in the previous hypothesis test, the goal is to test the significance of the dependent variables. In table 4 column 2, the R-squared is 0.91, which indicates that this model is better than the previous one. Also, based on the t-stats, the coefficients for three dependent variables are significant; such that these three variables efficiently explain the change of nominal interest rate. Further, in table 5, the p-value for the Breusch-Godfrey Serial Correlation LM test is 0.18. The null hypothesis of this test is that there is no serial correlation up to lag order 2, and the results strongly fail to reject the null of no serial correlation. The coefficient of the output gap is 0.27, which indicates that the central bank wants to decrease the influence of the output gap, but the nominal interest rate will still increase when the output gap increases. The coefficient of the inflation rate is 0.11, which shoes that the central bank also wants to decrease the influence of the inflation rate. When the inflation rate increases, the nominal interest rate will increase a little. The coefficient of the lagged nominal interest rate is 0.85, which means that the central bank change the current nominal interest rate based on the previous period's nominal interest rate a lot.

Based on the results, the short-run response of the central bank to an increase in inflation is small, but in the long run it is close to 1, which indicates the response is really important. Also, the long-run response of the central bank to an increase in output gap is bigger than 1 , which is also significant.

After testing the lagged variable for the previous period, testing the lagged nominal interest rate for the previous two periods may give better estimations:

(11) $r_t = c(1) * (y_t - y^*) + c(2) * (\pi_t - \pi^*) + c(3) + c(4) * r_{t-1} + c(5) * r_{t-2}$

In table 4 column 3, the R-square is 0.90, which is smaller than the R-square in the previous test. Also, the t-stats for the additional variable is -1.57, which indicates that the variable is not necessary to include in this model. Table 6 shows the p-value for the Breusch-Godfrey Serial Correlation LM test is 0.47. The null hypothesis of this test is that there is no serial correlation up to lag order 2, and the results strongly fail to reject the null of no serial correlation. Also, the coefficients of the output gap and inflation rate do not change a lot. In this way, the model should only contain the lag order one period nominal interest rate instead of more than one lagged nominal interest rates in the model.

After testing these two models, it is shown that the current nominal interest rate significantly depends on the previous nominal interest rate. The lagged one period nominal interest rate plays an important role in building the model, which indicates that the rest of models are supposed to contain the variable. However, it is not necessary to build the model based on more lagged nominal interest rates.

Adding nominal exchange rate as one of the dependent variables may help to adjust the model to fit the monetary condition in China based on an open economy. The results of testing equation (7) are shown in table 7 column 2, the R-squared for this model is 0.91, which is almost the same as the R-squared in the test of equation (6). The t-stats for the nominal exchange rate is -0.64, which indicates that the variable, the nominal exchange rate, is not significant in this model.

On the other hand, based on equation (7), I add the rate of change of the nominal exchange rate, rather than the nominal exchange rate, as an additional dependent variable.

(12) $$r_t = c(1) * (y_t - y^*) + c(2) * (\pi_t - \pi^*) + c(3) + c(4) * r_{t-1} + c(5) * \Delta e_n$$

In equation (12), Δe_n represents the rate of change of the nominal exchange rate. The hypothesis is to test the significance of the variables in the model. Table 7 column 3 shows the results of the hypothesis test. The t-stats for the additional variable is -1.31, which indicates that the rate of change of nominal exchange rate is not significant in the model.

After testing the nominal exchange rate, I believe it may be useful to test the significance of the real exchange rate, equation (8). Table 10 column 1 shows that the t-stats for real exchange rate is 1.05, which indicates that the real exchange rate of China is not significant to help improve the model.

The first three model do not work well based on open economy, and the exchange rate coefficients are not significant in any of the first three models. In this way, the next model with the rate of change of real exchange rate is more important.

I modify equation (8) as follows:

$$(13) \qquad r_t = c(1) * (y_t - y^*) + c(2) * (\pi_t - \pi^*) + c(3) + c(4) * r_{t-1} + c(5) * \Delta e_r$$

In this equation, Δe_r is the rate of change of the real exchange rate based on the Chinese monetary policy (a positive Δe_r means real appreciation). The coefficient of the rate of change of real exchange rate is -0.85, which is consistent with results got by Ball (1999). The coefficient of the rate of change of real exchange rate is expected to be negative, because the appreciation has a contractionary effect on aggregate demand. Then the appreciation makes foreign goods cheaper, thereby reducing net exports (Taylor, 2001). Table 10 column 2 shows the t-stat for Δe_r is -1.68, which is close to -2. In this way, based on the one-tail test, the rate of change of the real exchange rate is significant in this model, which will help to improve the model. In table 11, the p-value for the Breusch-Godfrey Serial Correlation LM test is 0.12. The null hypothesis of this test is that there is no serial correlation up to lag order 2, and the results fail to reject the null of no serial correlation. Other coefficients are consistent with the values in previous models, so that adding the additional variable does not change the roles of other variables in the model. As a result, the rate of change of real exchange can affect the change in the nominal interest rate based on the Chinese monetary policy.

Additionally, table 10 column 3 shows the results for testing equation (13) with one more dependent variable, lagged rate of change of exchange rate.

(14) $r_t = c(1) * (y_t - y^*) + c(2) * (\pi_t - \pi^*) + c(3) + c(4) * r_{t-1} + c(5) * \triangle e_r + c(6) * \triangle e_{r-1}$

In this model, $\triangle e_{r-1}$ is the lagged rate of change of real exchange rate. The t-stat is 1.0425, which shows that this variable is not significant, so that the lagged rate of change of the real exchange rate is not supposed to be included in the model.

After testing the models with exchange variables, the results show that only the rate of change of the real exchange rate may help to improve the model efficiently. Direct effects of exchange variables may cause the model to function worse. Also, the rate of change of the real exchange rate does help to explain the change of the nominal interest rate. Besides testing the model with exchange variables, testing the McCallum Rule may give some important information.

Table 12 shows the results of testing equation (9). The goal is to test the significance level of each variable and to check the efficiency of the model. The R-squared is 0.37, which indicates that these dependent variables do not actually explain the change of the nominal interest rate. Also, the coefficients of the inflation and output gaps are negative, which are supposed to be positive. The inflation gap is also not significant in the model, based on the t-stats. In table 13, the p-value for the Breusch-Godfrey Serial Correlation LM test is 0.22, which indicates that there is no serial correlation up to lag order 2. However, the model still indicates that using the growth rate of money supply as an indicator instead of the nominal interest rate cannot reflect the conditions based on the Chinese monetary policy.

Another way to test the Taylor Rule is to forecast the inflation rate and output gap by using the information set. Table 14 shows how to calculate $E\{\pi_t|\Omega_{t-1}\}$, and the results of building this expectation. I use 6 variables and 1 constant in the previous period to forecast the current inflation. As it is shown in table 14, the R-squared is 0.90, which indicates that these variables explain most of the change of inflation. In table 15, the p-value for the Breusch-Godfrey Serial Correlation LM test is 0.15, which indicates that there is no serial correlation up to lag order 2. Figure 4 shows the comparison between the original inflation rate and the forecasting inflation rate.

After forecasting the inflation rate based on the previous period information set, I use the same method to forecast the output gap, $E\{y_t|\Omega_{t-1}\}$. Table 16 shows the results of building forecasting function. In this function, I also use seasonal terms to help forecast the current output based on the previous one period output. The R-squared is 0.99, which means this model is very effective to forecast the future output gap. In table 17, the p-value for the Breusch-Godfrey Serial Correlation LM test is 0.21, which indicates that there is no serial correlation up to lag order 2. Figure 5 shows the comparison between the original output gap and the forecasting output gap.

Moreover, I use these two forecasting variables to test the change of the nominal interest rate. Table 18 shows the results of testing equation (6) and (10). Using forecasting variables, the coefficient of the inflation gap becomes less significant than the coefficient in testing equation (6). The coefficients of the output gap and the previous period nominal interest rate do not change a lot for both values and significance levels. However, the R-squared does not decrease a lot, about less than 2%, which indicates that it is possible to use the forecast variables to forecast the future nominal interest rate. Also, all three variables in the model are significant, based on the t-stats. Figure 7 shows the comparison between the nominal interest rate in the real world and the forecasting nominal interest rate over time.

It is also possible to use this model to explain and create monetary policy in China. However, the difference between the real nominal interest rate and the forecasting nominal interest rate may be caused by the differences of forecasting the inflation rate. Also the R-squared, about 90%, indicates that the model cannot forecast the change of nominal interest rate perfectly. As a result, the forecasting model works well and helps to use the Taylor Rule to describe the monetary policy in China.

VI. Conclusion

The original Taylor Rule, which is built based on closed economy, does not work in modern China. The previous period nominal interest rate plays an important role in deciding the current nominal interest rate. Using the information set to forecast the variables can help to forecast the change of the nominal interest rate in China. As the results show from table 4 to table 18, the central bank tries to decrease the effects of the inflation rate and the output gap to the change of the nominal interest rate. However, in the long run, the response of the central bank to an increase in inflation and output gaps is important, because the long-run effects are bigger or close to 1.

Although the modifications of the Taylor Rule work well based on Chinese monetary policy, the McCallum Rule cannot help to describe the monetary conditions in China. In other words, the growth rate of money supply may not a good indicator for the monetary conditions in China.

The role of exchange rates may play an unimportant role in improving the model to predict the change of the nominal interest rate. However, the indirect effects of the real exchange rate assuredly have some advantages compared with the direct effects of the real exchange rate.

More research is needed to see if containing some special dependent variables will help to improve the efficiency of describing the monetary policy in China. To some extents, the modifications of the Taylor Rule do help to describe and forecast the change of the nominal interest rate in China.

VII. Appendix

A. Tables

Table 1

	RATE_OF_NOMINAL_GDP	RATE_OF_REAL_GDP	RATE_OF_POTENT_GDP
Mean	0.353807	0.354496	0.041170
Median	0.553001	0.538137	0.035045
Maximum	1.248701	1.269366	0.168623
Minimum	-0.773677	-0.772163	0.019246
Std. Dev.	0.694105	0.694924	0.025897
Skewness	-0.615778	-0.612287	2.781318
Kurtosis	2.100028	2.099396	11.59330
Jarque-Bera	9.112824	9.050118	410.4189
Probability	0.010500	0.010834	0.000000
Sum	33.25789	33.32265	3.869951
Sum Sq. Dev.	44.80565	44.91152	0.062370
Observations	94	94	94

Table 2

	RATE_OF_CPI	RATE_OF_INFLATION	OUTPUT_GAP	M2_RATE
Mean	-0.000137	0.075919	0.000378	0.039118
Median	0.001463	0.031056	0.034141	0.037712
Maximum	0.077356	3.500000	0.799629	0.094899
Minimum	-0.075100	-1.789474	-0.649236	0.004176
Std. Dev.	0.018826	0.671097	0.466667	0.018019
Skewness	-0.347626	1.571391	0.061891	0.687764
Kurtosis	7.725528	10.08678	1.707390	3.587359
Jarque-Bera	108.3664	282.9689	6.674397	6.245152
Probability	0.000000	0.000000	0.035536	0.044044
Sum	-0.015577	8.578815	0.035924	2.620875
Sum Sq. Dev.	0.040051	50.44161	20.47111	0.021430
Observations	114	113	95	67

Table 3

	RATE_OF_INTER_LOAN	RATE_OF_EXCH_NOM	RATE_OF_EXCH_REAL
Mean	0.005827	-0.003731	0.338020
Median	-0.018223	2.42E-05	-0.071971
Maximum	0.491373	0.038357	48.94112
Minimum	-0.519593	-0.333899	-8.057315
Std. Dev.	0.182160	0.037410	5.067455
Skewness	0.292243	-7.065165	8.141576
Kurtosis	3.785099	58.75239	77.74117
Jarque-Bera	2.754264	15712.98	27306.46
Probability	0.252301	0.000000	0.000000
Sum	0.402090	-0.425381	37.85827
Sum Sq. Dev.	2.256403	0.158141	2850.380
Observations	69	114	113

Table 4

Eq Name:	REG_ORI_1	REG_ORI_LAG1	REG_ORI_LAG2
Dep. Var:	INTER_LOAN	INTER_LOAN	INTER_LOAN
OUTPUT_GAP	0.4091 (0.2495) [1.6394]	0.2724 (0.0946)** [2.8790]**	0.2910 (0.0953)** [3.0554]**
INFLATION	0.1430 (0.1250) [1.1439]	0.1087 (0.0236)** [4.6033]**	0.0840 (0.0220)** [3.8181]**
INTER_LOAN(-1)		0.8469 (0.0301)** [28.1332]**	1.0297 (0.1175)** [8.7610]**
INTER_LOAN(-2)			-0.1740 (0.1105) [-1.5752]
Observations:	70	69	68
R-squared:	0.0471	0.9101	0.8971
F-statistic:	1.6542	219.2312	137.2719
Prob(F-stat):	0.1990	0.0000	0.0000

The number in () is standard error. The number in [] is t-statistics.

Table 5

Breusch-Godfrey Serial Correlation LM Test (REG_ORI_LAG1):			
F-statistic	1.787582	Prob. F(2,63)	0.1757
Obs*R-squared	3.705380	Prob. Chi-Square(2)	0.1568

Table 6

Breusch-Godfrey Serial Correlation LM Test (REG_ORI_LAG2):			
F-statistic	0.764730	Prob. F(2,61)	0.4699
Obs*R-squared	1.663268	Prob. Chi-Square(2)	0.4353

Table 7

Eq Name:	REG_ORI_LAG1	REG_W_EXCH_NOM	REG_W_EXCH_NOM_RATE
Dep. Var:	INTER_LOAN	INTER_LOAN	INTER_LOAN
INTER_LOAN(-1)	0.8469 (0.0301)** [28.1332]**	0.8418 (0.0327)** [25.7120]**	0.8494 (0.0302)** [28.1257]**
OUTPUT_GAP	0.2724 (0.0946)** [2.8790]**	0.2685 (0.0947)** [2.8361]**	0.2585 (0.0979)* [2.6409]*
INFLATION	0.1087 (0.0236)** [4.6033]**	0.0985 (0.0254)** [3.8752]**	0.0814 (0.0245)** [3.3216]**
EXCH_NOMINAL		-0.0642 (0.1005) [-0.6389]	
EXCH_RATE			-12.2986 (9.3954) [-1.3090]
Observations:	69	69	69
R-squared:	0.9101	0.9110	0.9123
F-statistic:	219.2312	163.6941	166.4651
Prob(F-stat):	0.0000	0.0000	0.0000

The number in () is standard error. The number in [] is t-statistics.

Table 8

Breusch-Godfrey Serial Correlation LM Test (REG_W_EXCH_NOM):			
F-statistic	1.689223	Prob. F(2,62)	0.1931
Obs*R-squared	3.565590	Prob. Chi-Square(2)	0.1682

Table 9

Breusch-Godfrey Serial Correlation LM Test (REG_W_EXCH_NOM_RATE):			
F-statistic	2.238061	Prob. F(2,62)	0.1152
Obs*R-squared	4.646065	Prob. Chi-Square(2)	0.0980

Table 10

Eq Name:	REG_EXRE_ORI_LAG1	REG_EXRE_ORI_RATE	REG_EXRE_ORI_RATE_L1
Dep. Var:	INTER_LOAN	INTER_LOAN	INTER_LOAN
INTER_LOAN(-1)	0.8519 (0.0291)** [29.3109]**	0.8452 (0.0306)** [27.5769]**	0.8486 (0.0300)** [28.2422]**
OUTPUT_GAP	0.3701 (0.1489)* [2.4855]*	0.2433 (0.0974)* [2.4986]*	0.2516 (0.0989)* [2.5432]*
INFLATION	0.1008 (0.0264)** [3.8183]**	0.1103 (0.0240)** [4.5998]**	0.1051 (0.0240)** [4.3729]**
REAL_EXCH	1.0507 (0.9972) [1.0536]		
RATE_REAL_EXCH		-0.8500 (0.5046) [-1.6844]	-0.8094 (0.4997) [-1.6197]
RATE_REAL_EXCH(-1)			1.0910 (1.0465) [1.0425]
Observations:	69	69	69
R-squared:	0.9129	0.9111	0.9129
F-statistic:	167.6936	164.0331	132.0591
Prob(F-stat):	0.0000	0.0000	0.0000

Table 11

Breusch-Godfrey Serial Correlation LM Test (REG_EXRE_ORI_RATE):			
F-statistic	2.239078	Prob. F(2,62)	0.1151
Obs*R-squared	4.648034	Prob. Chi-Square(2)	0.0979

Table 12

Dependent Variable: M2_RATE
Method: Least Squares (Gauss-Newton / Marquardt steps)
Date: 03/13/16 Time: 21:35
Sample (adjusted): 1999Q2 2015Q1
Included observations: 64 after adjustments
HAC standard errors & covariance (Bartlett kernel, Newey-West fixed bandwidth = 4.0000)
M2_RATE = C(1)*(INFLATION-0.04) + C(2)*OUTPUT_GAP + C(3) *M2_RATE(-1) + C(4)*EXCH_REAL + C(5)

	Coefficient	Std. Error	t-Statistic	Prob.
C(1)	-0.001017	0.001080	-0.941586	0.3502
C(2)	-0.024097	0.004329	-5.566213	0.0000
C(3)	-0.002669	0.172508	-0.015474	0.9877
C(4)	-0.000263	0.000351	-0.748189	0.4573
C(5)	0.042713	0.005847	7.305178	0.0000

R-squared	0.372123	Mean dependent var	0.039439
Adjusted R-squared	0.329555	S.D. dependent var	0.017895
S.E. of regression	0.014653	Akaike info criterion	-5.533475
Sum squared resid	0.012667	Schwarz criterion	-5.364812
Log likelihood	182.0712	Hannan-Quinn criter.	-5.467030
F-statistic	8.741870	Durbin-Watson stat	1.731123
Prob(F-statistic)	0.000013	Wald F-statistic	14.25598
Prob(Wald F-statistic)	0.000000		

Table 13

Breusch-Godfrey Serial Correlation LM Test:

F-statistic	1.543673	Prob. F(2,57)	0.2224
Obs*R-squared	3.288382	Prob. Chi-Square(2)	0.1932

Table 14

Dependent Variable: INFLATION
Method: Least Squares (Gauss-Newton / Marquardt steps)
Date: 03/13/16 Time: 22:33
Sample (adjusted): 1997Q4 2015Q1
Included observations: 70 after adjustments
HAC standard errors & covariance (Bartlett kernel, Newey-West fixed bandwidth = 4.0000)
INFLATION = C(2) * INFLATION(-1) + C(3) * INTER_REAL(-1) + C(4) *GDP_REAL(-1) + C(5)*GDP_POTENT(-1) +C(6)*INFLATION(-2) +C(7)*EXCH_REAL_RATE(-1)+C(8)

	Coefficient	Std. Error	t-Statistic	Prob.
C(2)	1.311398	0.118586	11.05863	0.0000
C(3)	-0.084452	0.026882	-3.141620	0.0026
C(4)	0.000101	0.000849	0.118526	0.9060
C(5)	0.001796	0.001333	1.347609	0.1826
C(6)	-0.578296	0.114044	-5.070797	0.0000
C(7)	0.035781	0.007149	5.005166	0.0000
C(8)	0.330285	0.174541	1.892304	0.0630

R-squared	0.901455	Mean dependent var	1.877714
Adjusted R-squared	0.892069	S.D. dependent var	2.341174
S.E. of regression	0.769141	Akaike info criterion	2.407554
Sum squared resid	37.26939	Schwarz criterion	2.632404
Log likelihood	-77.26440	Hannan-Quinn criter.	2.496867
F-statistic	96.05004	Durbin-Watson stat	2.310476
Prob(F-statistic)	0.000000	Wald F-statistic	138.5407
Prob(Wald F-statistic)	0.000000		

Table 15

Breusch-Godfrey Serial Correlation LM Test:			
F-statistic	1.966154	Prob. F(2,61)	0.1488
Obs*R-squared	4.239208	Prob. Chi-Square(2)	0.1201

Table 16

Dependent Variable: OUTPUT_GAP
Method: Least Squares (Gauss-Newton / Marquardt steps)
Date: 02/18/16 Time: 13:44
Sample (adjusted): 1997Q4 2015Q1
Included observations: 70 after adjustments
HAC standard errors & covariance (Bartlett kernel, Newey-West fixed bandwidth = 4.0000)
OUTPUT_GAP = C(2) * OUTPUT_GAP(-1) + C(3) * INTER_REAL(-1) + C(4)*GDP_REAL(-1) + C(5)*GDP_POTENT(-1) +C(6) *OUTPUT_GAP(-2)+C(7)*INFLATION(-1) + C(8) +C(9)*@SEAS(1) +C(10)*@SEAS(2)+C(11)*@SEAS(3)

	Coefficient	Std. Error	t-Statistic	Prob.
C(2)	0.132595	0.112929	1.174146	0.2450
C(3)	0.010731	0.002630	4.079764	0.0001
C(4)	-1.76E-05	3.04E-05	-0.580787	0.5636
C(5)	3.61E-05	4.48E-05	0.804506	0.4243
C(6)	-0.261825	0.134476	-1.946998	0.0562
C(7)	0.006842	0.001899	3.602295	0.0006
C(8)	0.520221	0.023413	22.21910	0.0000
C(9)	-1.202371	0.091894	-13.08431	0.0000
C(10)	-0.515452	0.077586	-6.643584	0.0000
C(11)	-0.487926	0.095828	-5.091695	0.0000

R-squared	0.998078	Mean dependent var	0.002727
Adjusted R-squared	0.997790	S.D. dependent var	0.474634
S.E. of regression	0.022313	Akaike info criterion	-4.635763
Sum squared resid	0.029871	Schwarz criterion	-4.314549
Log likelihood	172.2517	Hannan-Quinn criter.	-4.508173
F-statistic	3462.474	Durbin-Watson stat	1.964992
Prob(F-statistic)	0.000000	Wald F-statistic	3147.663
Prob(Wald F-statistic)	0.000000		

Table 17

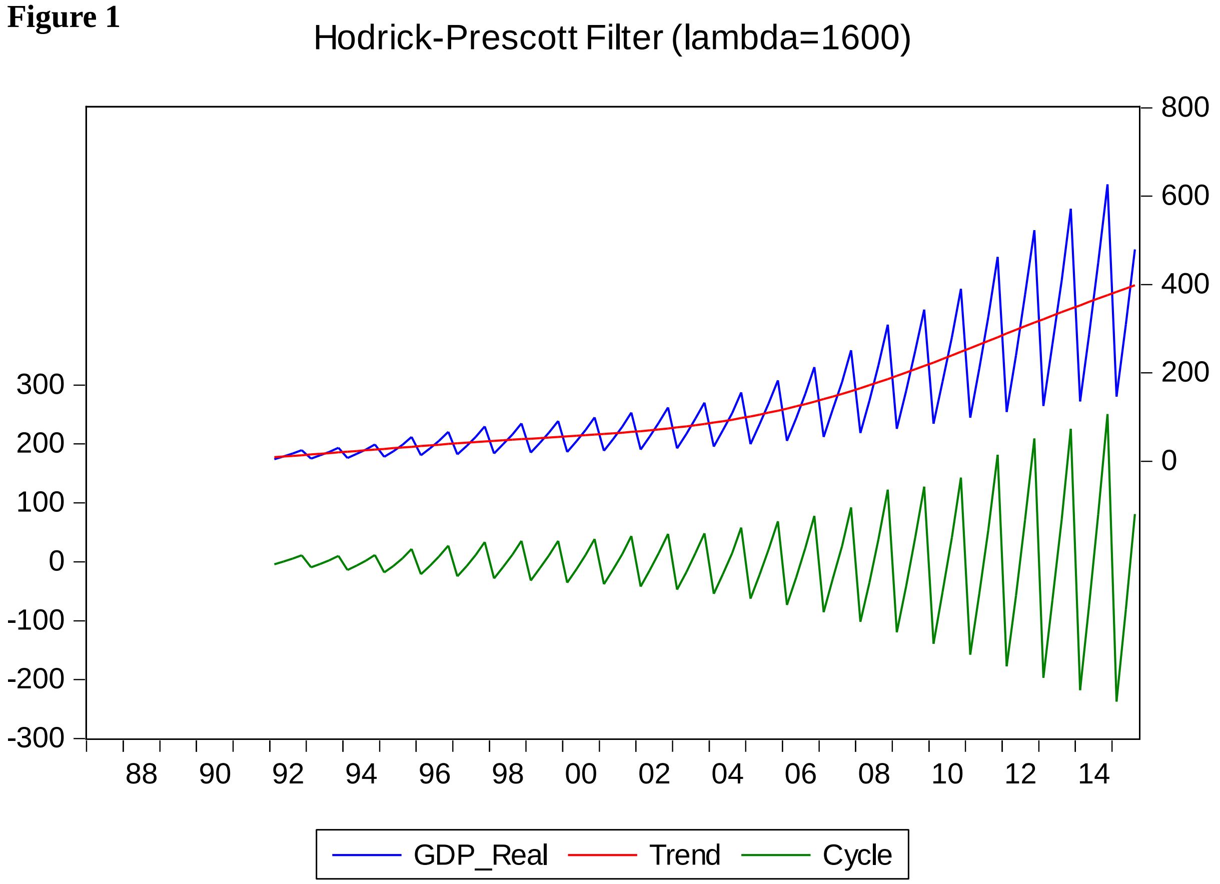
Breusch-Godfrey Serial Correlation LM Test:			
F-statistic	1.586398	Prob. F(2,58)	0.2134
Obs*R-squared	3.630628	Prob. Chi-Square(2)	0.1628

Table 18

Eq Name:	REG_ORI_LAG1	REG_FORE_BOTH
Dep. Var:	INTER_LOAN	INTER_LOAN
INTER_LOAN(-1)	0.8469 (0.0301)** [28.1332]**	0.8657 (0.0278)** [31.1819]**
OUTPUT_GAP	0.2724 (0.0946)** [2.8790]**	
INFLATION	0.1087 (0.0236)** [4.6033]**	
OUTPUT_GAPF		0.2646 (0.1038)* [2.5504]*
INFLATIONF		0.1005 (0.0565) [1.7795]
Observations:	69	69
R-squared:	0.9101	0.8935
F-statistic:	219.2312	181.7005
Prob(F-stat):	0.0000	0.0000

B. Figures

Figure 1



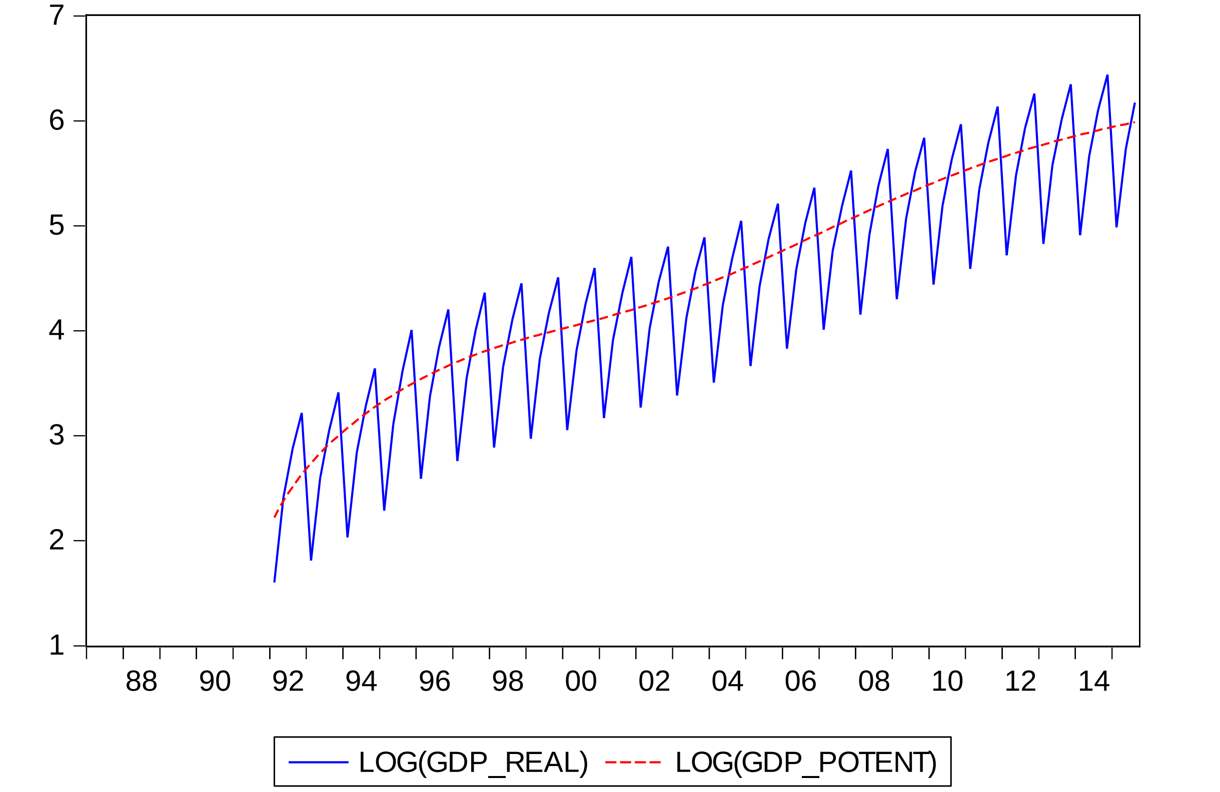


Figure 2


Inter_loan
10
9
8
7
6
5
4
3
2
1
88 90 92 94 96 98 00 02 04 06 08 10 12 14
Inflation
28
24
20
16
12
8
4
0
-4
88 90 92 94 96 98 00 02 04 06 08 10 12 14
Nominal GDP
70,000
60,000
50,000
40,000
30,000
20,000
10,000
0
88 90 92 94 96 98 00 02 04 06 08 10 12 14
Real GDP
700
600
500
400
300
200
100
0
88 90 92 94 96 98 00 02 04 06 08 10 12 14
Potential GDP
500
400
300
200
100
0
88 90 92 94 96 98 00 02 04 06 08 10 12 14
Nominal Exchange Rate
.28
.26
.24
.22
.20
.18
.16
.14
.12
.10
88 90 92 94 96 98 00 02 04 06 08 10 12 14
Real Exchange Rate
.004
.003
.002
.001
.000
-.001
-.002
-.003
-.004
-.005
88 90 92 94 96 98 00 02 04 06 08 10 12 14
M2
1.4E+14
1.2E+14
1.0E+14
8.0E+13
6.0E+13
4.0E+13
2.0E+13
0.0E+00
88 90 92 94 96 98 00 02 04 06 08 10 12 14

Figure 3

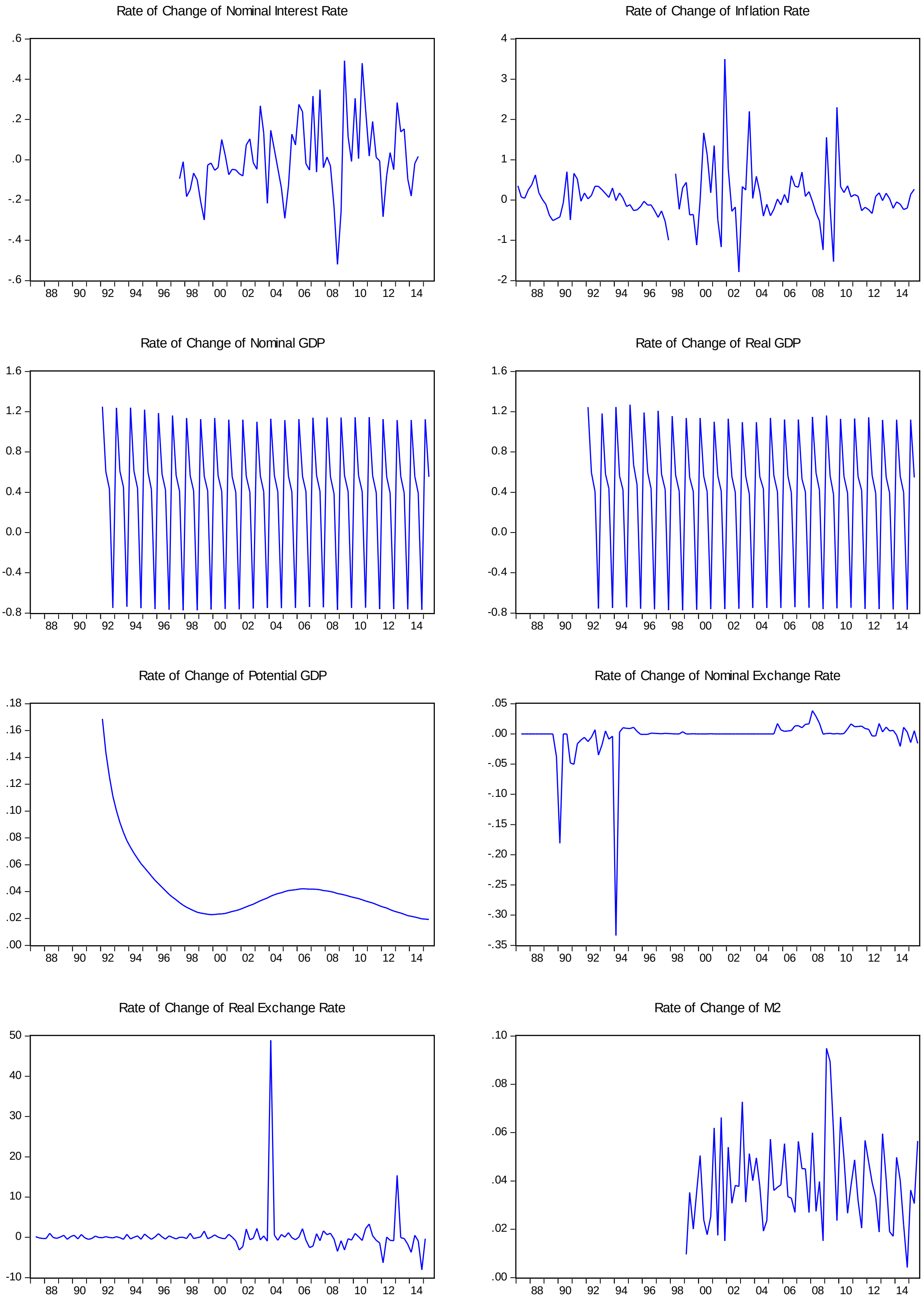

Rate of Change of Nominal Interest Rate
.6 .4 .2 .0 -.2 -.4 -.6
Rate of Change of Inflation Rate
4 3 2 1 0 -1 -2
Rate of Change of Nominal GDP
1.6 1.2 0.8 0.4 0.0 -0.4 -0.8
Rate of Change of Real GDP
1.6 1.2 0.8 0.4 0.0 -0.4 -0.8
Rate of Change of Potential GDP
.18 .16 .14 .12 .10 .08 .06 .04 .02 .00
Rate of Change of Nominal Exchange Rate
.05 .00 -.05 -.10 -.15 -.20 -.25 -.30 -.35
Rate of Change of Real Exchange Rate
50 40 30 20 10 0 -10
Rate of Change of M2
.10 .08 .06 .04 .02 .00
88 90 92 94 96 98 00 02 04 06 08 10 12 14

Figure 4

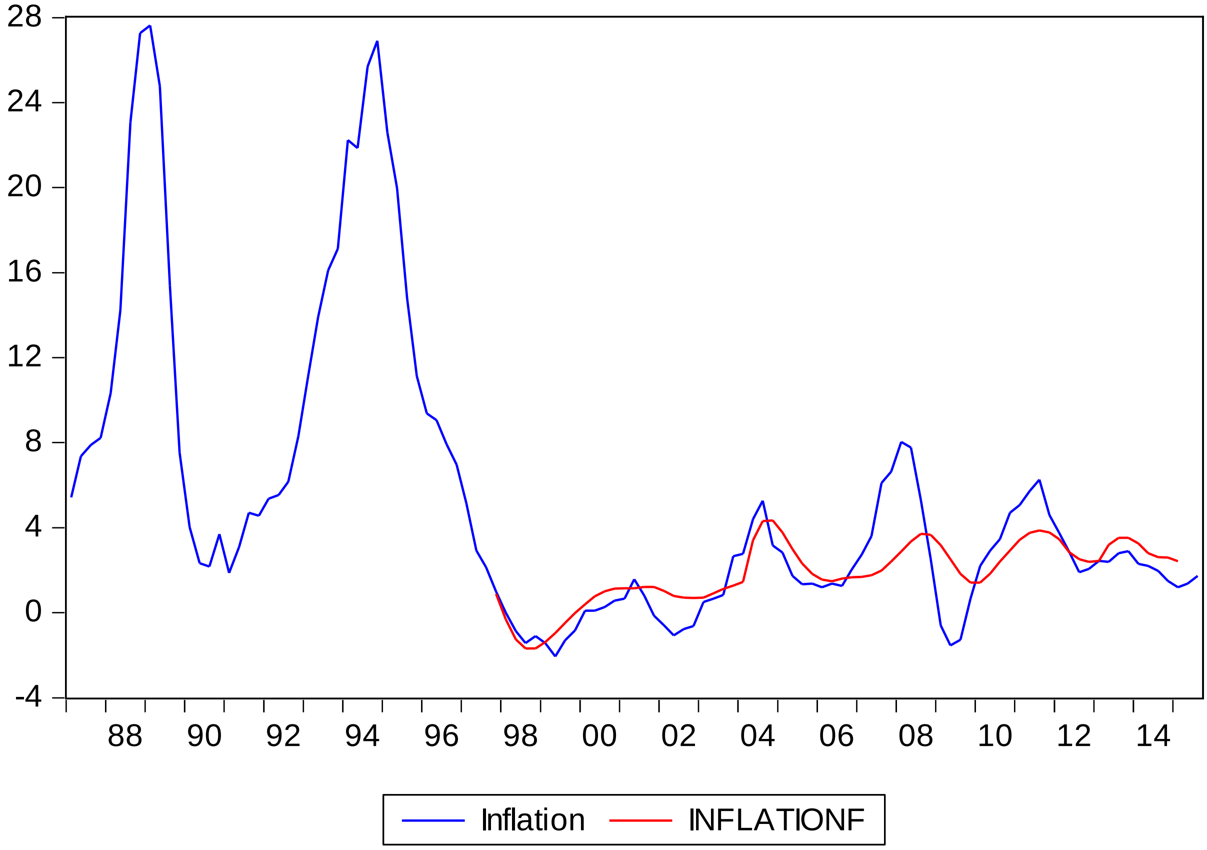


Figure 5

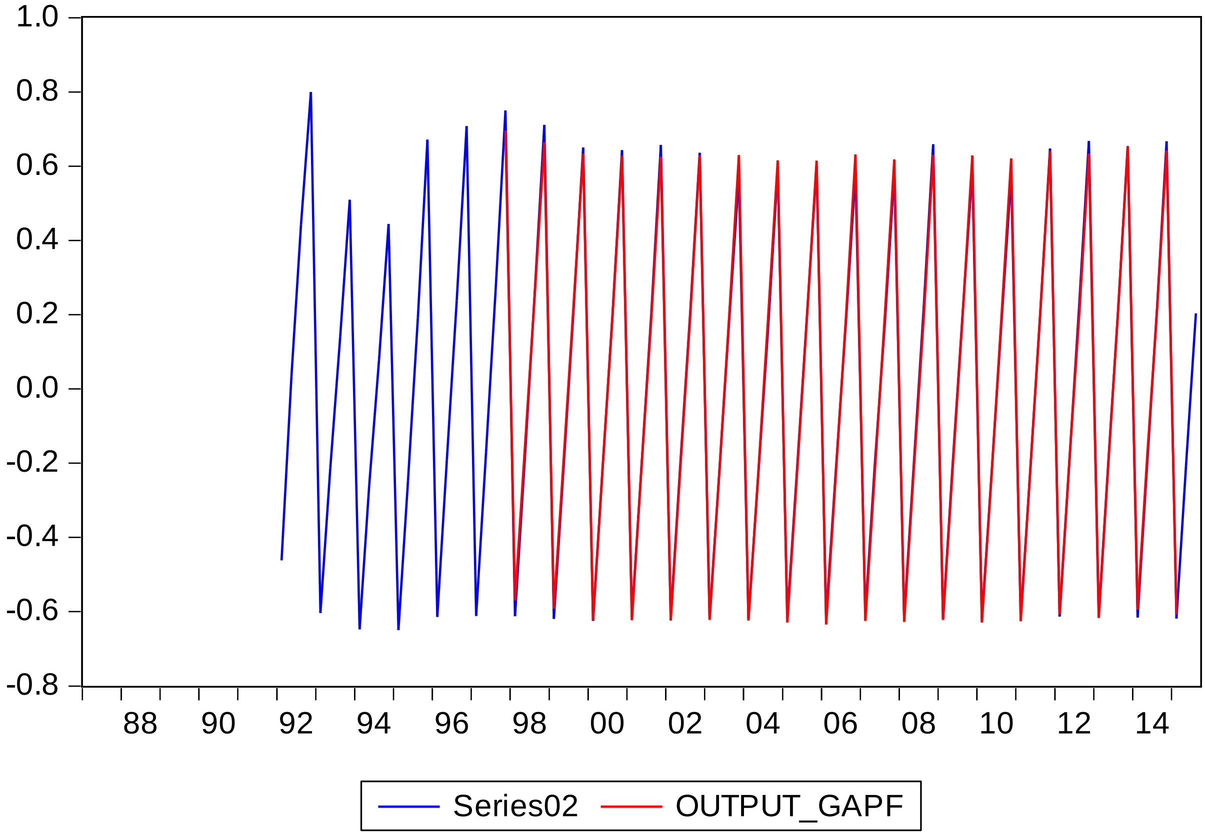
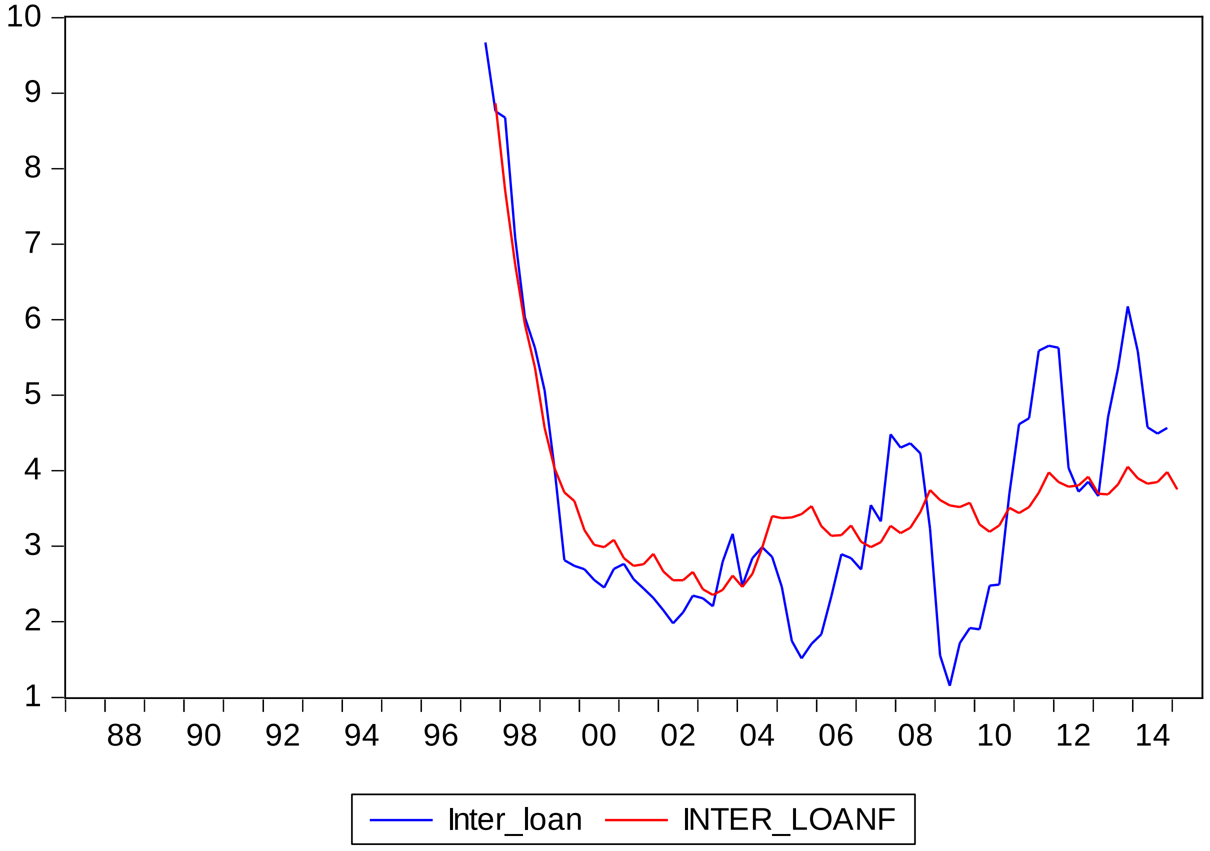


Figure 6


10
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92
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02
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08
10
12
14
Inter_loan
INTER_LOANF

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