An Extended Taylor Rule and its Applicability in China — An Empirical Analysis Based on Time-Varying Parameters State-Space Model

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Abstract — This paper conducts an extending study on the traditional Taylor rule under the opening conditions in China, and uses the time-varying parameters state-space model to conduct an empirical analysis of its feasibility to be applied in China. Research finds that the interest rate shows a time-varying aspect to the inflation rate, the output gap, the currency supply and the exchange rate; while with the advent of the 21st century it is much more stable. This suggests that China has been equipped with basic conditions to apply the extended Taylor rule. At the end of this paper, the author suggests that China should accelerate the interest rate market-oriented reform and gradually adjust the intermediate variable for monetary policy operation from currency supply to interest rate.

Keywords - taylor rule; empirical analysis; state-space model

I. INTRODUCTION

It has been a controversy for a long time about whether the monetary policy should follow contingency decision-making or single rules. Contingency decision-making refers to choosing policies according to flexible changes of economic operations so as to reach the optimum of monetary policies. At the first sight, it is more flexible and more logical. This might be the reason why monetary authorities in many countries (including China) still adopt the monetary policy planning. However, Kydland and Prescott (1977) raised the issue of “time inconsistency” in their classic paper, Rules Rather Than Discretion: The Inconsistency of Optimal Plans. According to their research, monetary authorities might formulate a monetary policy for the moment of “t+n” according to the principle of optimization at the moment of “t,” but the policy might not be the optimal policy at the moment of “t+n.” Therefore, they thought that single currency rules are superior to contingency decision-making. Barro and Gordon (1983) also pointed out that, under the contingency decision-making model, social output might not achieve a systematic improvement, but the public suffers a relatively high inflation.

Against the backdrop of new economic normal and supply-front reform, the demand-driven economic development mode relying on expansionary momentary policies has been the past. In September 2014, Premier LI Keqiang said in Davos World Economic Forum that, “Since the currency in the pool has been too much, we can no longer stimulate economic growth by increasing currency issuance.” Thus, it can be seen that China’s future monetary policies should proceed from the interest rate rather than the currency supply. Under the condition, there is no need to maintain the previous fuzzy robust positioning, but to guide the public expectation through increase of currency issuance. The implementation effect of monetary policies is largely decided by the communication between the central bank and the social public. In other words, the expectation of the social public largely decides the implementation effect of monetary policies. The difficulty in measuring the currency supply has caused many disputes. The social public can hardly achieve an agreement about it. Besides, the contingency decision-making operation style can easily plunge the social public into uncertainty, making it hard to lead the formation of desirable social public expectation.

Currently, there have been some domestic scholars studying the issue. Generally speaking, researches in the early period mainly focused on verifying the feasibility of applying the traditional Taylor rule in China. Later, researches were gradually conducted from the perspective of interest rate smoothness, forward-looking or time-varying parameters to achieve a more elaborate analysis. With the deepening of researches in this field, scholars’ understanding of the issue also deepens. However, it should be noted that the traditional Taylor rule requires monetary policies to have dual objectives, namely price stabilization and promotion of economic growth. Though Law of the People’s Bank of China stipulates that the ultimate objective of China’s monetary policies is to “keep stability of the currency value to boost economic growth,” most of China’s monetary policies have, in fact, diversified objectives rather than the two stated above. Under the condition of multiple objectives, the prerequisites to apply the traditional Taylor rule should be re-studied. Since China is now in a transformational period and coupled with China’s special...
national conditions, China’s central bank is not so independent like its Western counterparts. Therefore, the ultimate objective of China’s monetary policies is not just to serve economic growth, but also to conform to government’s periodical policy objectives. The trade surplus accumulated over recent years has given rise to a heavy burden of RMB appreciation. To respond to the problem, the central bank has passively increased the monetary base, causing a huge influence on independence of China’s monetary policies. It is apt to say that the issue of exchange rate in China is an issue monetary policies cannot steer clear of. Even if China’s monetary policy operations adhere to certain rule, the rule must take the issue of exchange rate into consideration.

II. METHODOLOGY

Taylor (1993) put forward a simple interest rate rule for monetary policies, and proved the rule could well explain the interest rate trend of Federal Funds FROM 1987 TO 1992. The rule is later called the “Taylor rule.” It can be expressed as below:

\[ i_t = r^* + \pi_t + \alpha (\pi_t - \pi^*) + \beta \gamma_t \]  

(1)

Where, \( i_t \) stands for the interest rate of Federal Funds; \( r^* \) stands for the real balanced interest rate of Federal Funds; \( \pi_t \) stands for the average inflation rate in the former four quarters; \( \pi^* \) stands for the target inflation rate; \( \gamma_t \) stands for the output gap, namely the percentage of deviation of the actual GDP from the potential GDP. Under the rule, if the actual inflation rate increases to be higher than the target inflation rate or the actual GDP is higher than the potential one, the interest rate of Federal Funds should increase to inhibit the trend. Otherwise, it should decrease. When the practical inflation rate equals to the target inflation rate or the actual GDP equals to the potential one, the interest rate of Federal Funds should in principle equals to the sum of the real balanced interest rate of Federal Funds and the target inflation rate. Based on the exchange factor and the currency supply under the opening conditions, the Taylor rule model is expanded into the following one:

\[ i_t = r^* + \pi_t + \alpha (\pi_t - \pi^*) + \beta \gamma_t + \gamma \bar{e}_t + \delta m_t \]  

(2)

Where, \( \bar{r}_t \) is not the real interest rate but the suggested interest rate according to the Taylor rule; \( r^* \) stands for the RMB effective exchange rate under the indirect quotation; \( m_t \) stands for the supply growth rate of M2. In order to avoid dramatic fluctuations of the financial market and the macro-economy caused by one adjustment of the interest rate to the target one, the central bank will generally not adopt a large-scale adjustment for once, but several minor adjustments. In this way, the interest rate changes are smooth. Considering the smoothness characteristic of the interest rate changes, it is assumed the dynamic changes of the interest rate meet the following condition:

\[ i_t = (1 - \rho) \bar{r}_t + \rho \bar{r}_{t-1} + \xi_t \]  

(3)

Where, \( \rho \in [0, 1] \) is the smoothness coefficient; \( \xi_t \) is the random disturbance term. Put Eq. (2) into Eq. (3), then:

\[ i_t = (1 - \rho) [r^* + \pi_t + \alpha (\pi_t - \pi^*) + \beta \gamma_t + \gamma \bar{e}_t + \delta m_t] + \rho \bar{r}_{t-1} + \xi_t \]  

(4)

Compared with the traditional Taylor rule model, Model (4) can reflect characteristics of China’s monetary policies better. From the perspective of the practice process, China’s monetary policies are not like those of developed countries, the latter of which often adopts a single objective and a single tool. Currently, China’s monetary policies still feature combinations of multiple objectives and tools. Apart from price stabilization, China’s monetary policies should also allow for economic growth, full employment, balance of international payment, etc.

Economic rules are not so stable like social science. Along with economic reforms, policy changes and various impacts, they will undergo progressive structural changes. The traditional OLS and other fixed parameter estimation methods cannot reflect the progressive structural changes of economic rules. Under the condition, the time-varying state-space model should be adopted. In this paper, it is assumed that the inflation rate, the output gap, the exchange rate gap, the monetary supply growth gap and the interest rate smoothness coefficient are time-varying. Then, expand Model (4), and make \( \alpha = (1 - \rho)(1 - \alpha') \), \( \beta = (1 - \rho) \beta' + \gamma = (1 - \rho) \gamma' \) and \( \delta = (1 - \rho) \delta' \), then:

\[ i_t = \alpha + \rho \bar{r}_{t-1} + \alpha \pi_t + \beta (\gamma_t - \gamma_t') + \gamma e_t + \delta m_t + \xi_t \]  

(5)

Here, \( \alpha \) stands for the reaction coefficient of the true value of the nominal interest rate to the inflation rate in the short term; \( \beta' \) stands for the reaction coefficient of the true value of the nominal interest rate in the short term to the output gap; \( \gamma' \) stands for the reaction coefficient of the true value of the nominal interest rate to the exchange rate; \( \delta' \) stands for the reaction coefficient of the nominal interest rate to the inflation rate to the monetary supply growth rate. Considering the time-varying parameters of the expanded Taylor rule model, Model (5) can be set into the following form:

\[ i_t = \alpha_e + \alpha \pi_t + \beta (\gamma_t - \gamma_t') + \gamma e_t + \delta m_t + \xi_t \]  

(6)

It should be noted that \( \rho \bar{r}_{t-1} \) is abandoned. The reason is that the measurement equation of the time-varying parameter state-space model cannot contain the current period and future value of any measurement variables. In order to reduce the spatial dimensions of parameters to be estimated, the time-varying process of all parameters is set into a random walk form, namely \( \alpha = \alpha_{t-1} + \mu_\alpha \); \( \beta = \beta_{t-1} + \mu_{\beta} \); \( \gamma = \gamma_{t-1} + \mu_\gamma \); \( \delta = \delta_{t-1} + \mu_\delta \).

III. RESULTS AND DISCUSSION

A. Variable Selection and Data Specification

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This paper collects 75 samples from the quarterly data from the first quarter of 1997 to the third quarter of 2015. The data sources include China Macro-Economic Database developed by GTA Information Technology Co., Ltd., official website of the People’s Bank of China, Bank for International Settlements Database and Statistical Quarterly Report of the People’s Bank of China.

1). Interest rate

As is known to all, China has not yet fully realized marketization of the interest rate. However, the intermediate target of China’s monetary policies is not the interest rate. Therefore, it is necessary to choose an already marketized interest rate as the substitutional variable of the nominal interest rate. In order to test the feasibility of the Taylor rule in China, it should be assumed that the substitutional variable is a tool variable of China’s monetary policies. Theoretically speaking, the treasury bond rate of a country can well reflect market theories. However, China’s treasury market is a late-starter and small in scale, which cannot well guide the trend of the market interest rate in China. Comprehensively considering various interest rates in China, the marketization degree of interbank rate is the highest. Therefore, this paper chooses the interbank rate as the substitutional variable of the marketized nominal interest rate. The data are from official website of the People’s Bank of China and Statistical Quarterly Report of the People’s Bank of China.

2). GDP, potential GDP and output gap

The GDP data in this paper are from China Macro-Economic Database developed by GTA Information Technology Co., Ltd. However, the data in the Database are quarterly accumulated amount, while quarterly GDP refers to the accrual of the current quarter. Therefore, the annual accumulated amount of the current quarter is used to subtract that of the last quarter. In order to eliminate the influence of inflation, the nominal quarterly GDP is used to subtract that of the last quarter. In order to eliminate the influence of inflation, the nominal quarterly GDP is used to subtract the CPI of the current CPI so as to transform the nominal quarterly GDP into an actual one.

In fact, there has not yet been an agreement about the estimation of the potential GDP, because the concept of the potential GDP has been a controversy itself. Methods to estimate the potential GDP can be divided into two categories: 1) Decompose the time sequence of the actual GDP, and decompose the actual GDP into the potential GDP and the fluctuation element, of which the fluctuation element is the output gap; 2) Adopt the production function to estimate the potential GDP. The second kind of methods has its theoretical basis, and has been adopted by many researchers. However, in China, there are great difficulties in estimating full employment capacity and capital stock, and current estimation methods have many defects. Therefore, this paper has no alternative but to choose the first kind. In other words, the linear trend method is adopted to decompose the time sequence of GDP. Since quarterly data are adopted, the dummy variable of three quarters is introduced during the practical operation process so as to avoid the influence of quarterly fluctuations.

\[
D_1 = \begin{bmatrix} 1 \\ 0 \\ \vdots \end{bmatrix} \text{ Others} \quad D_2 = \begin{bmatrix} 0 \\ 1 \\ \vdots \end{bmatrix} \text{ Others} \quad D_3 = \begin{bmatrix} 0 \\ 0 \\ \vdots \end{bmatrix} \text{ Others}
\]

Conduct regression of the logarithm of the actual GDP, the time trend term and the seasonal dummy variable to obtain the output gap. The estimation equation is shown below, and the estimation results are shown in Table 1:

\[
\begin{align*}
\ln GDP_t &= \alpha_0 + \alpha_1\text{Trend} + \alpha_2D_1 + \alpha_3D_2 + \alpha_4D_3 + \mu_t \\
\end{align*}
\]

The calculation equation for the output gap is:

\[
\text{Potential GDP} \times 100\% = \text{Actual GDP - Potential GDP} / \text{Potential GDP}
\]

3). Inflation rate

Indexes used to measure the inflation rate include producer price index (PPI), consumer price index (CPI) and retail price index (RPI). Among them, the influence of CPI is the greatest, and the inflation rate index receiving the greatest attention. It covers the service price and can more comprehensively reflect fluctuations of the price level, compared with the other two. Therefore, this paper adopts the year-on-year CPI as the substitutional index to measure the inflation rate. The CPI data issued on Statistical Quarterly Report of the People’s Bank of China are monthly data. Thus, this paper conducts a simple calculation of the CPI data of three months in a quarter to get the average quarterly CPI data.

4). Broad monetary supply growth rate

This paper adopts the broad monetary supply growth rate, M2, from the official website of the People’s Bank of China, adopts the year-on-year monetary supply growth rate as the substitutional variable and the average of the growth rate over three months as the quarterly data.

5). Exchange rate

This paper adopts the RMB real effective exchange rate (REER) as the substitutional variable of the exchange rate. The effective exchange rate is a weighted average exchange rate, which generally adopts the foreign trade proportion as the weight. During the specific use process, researchers usually divide the effective exchange rate into two kinds, namely the nominal effective exchange rate and the actual effective exchange rate. The former refers to the weighted average of the bilateral nominal rate of the currency of one country with all of its trading partners, which can efficiently and comprehensively reflect the external value and the relative purchasing power of the domestic currency. The rise of the effective exchange rate means appreciation of the relative value of the domestic currency; otherwise, it means depreciation. During the calculation process, the actual effective exchange rate data come from Bank for International Settlements Database.

B. Estimation and Analysis of Time-varying
Parameters

In order to reflect the possible progressive structural changes of the economic relationship, this paper adopts the time-varying parameter state-space model for estimation. The time-varying process of all parameters is assumed to be progressive. The estimation results are shown in Table 2.

Table II Results of the Time-Varying Parameter State-Space Model

<table>
<thead>
<tr>
<th>Coefficient</th>
<th>Std.Error</th>
<th>Z-Statistic</th>
<th>Prob.</th>
</tr>
</thead>
<tbody>
<tr>
<td>C(1)</td>
<td>0.013372</td>
<td>0.001994</td>
<td>6.706872</td>
</tr>
<tr>
<td>C(2)</td>
<td>7.472472</td>
<td>0.061776</td>
<td>120.9600</td>
</tr>
<tr>
<td>C(3)</td>
<td>12.99436</td>
<td>0.191312</td>
<td>67.92240</td>
</tr>
<tr>
<td>C(4)</td>
<td>8.864967</td>
<td>0.00432</td>
<td>20527.42</td>
</tr>
<tr>
<td>C(5)</td>
<td>10.64556</td>
<td>0.010138</td>
<td>1049.994</td>
</tr>
<tr>
<td>C(6)</td>
<td>8.720959</td>
<td>0.28049</td>
<td>3.095761</td>
</tr>
<tr>
<td>C(7)</td>
<td>22.92285</td>
<td>0.004504</td>
<td>5089.046</td>
</tr>
<tr>
<td>C(8)</td>
<td>125.2250</td>
<td>0.001496</td>
<td>83710.64</td>
</tr>
</tbody>
</table>

From Table 2, it can be seen that the corresponding P value of the estimate of parameters in either the measurement equation or the state equation should be smaller than 0.01, suggesting that the state variable of the measurement equation is significant.

The reaction coefficient of the interest rate to the inflation rate: Fig. 1 provides the reaction coefficient of the interest rate to the inflation rate. From the time-varying trend chart state, it can be seen that the fluctuation of the time-varying parameters in the late 20th century is extremely dramatic. With the advent of the 20st century, the time-varying parameters gradually decreased and tended to be smooth. During 1997~1998, affected by the Southeast Asian Financial Crisis, China was faced with deflation. The CPI quarterly growth rate was under zero for a period of time. Under the condition, the People’s Bank of China immediately promoted investment and economic growth through lowering of the interest rate so as to alleviate the aggravating deflation trend. When the interest rate was lowered at the very beginning, the deflation rate also continued to decrease. This resulted in the dramatic enhancement route of time-varying parameters during 1997~1998 in Fig. 1. When the continuously decreasing interest rate stopped the inflation, the time-varying parameters started decreasing. The whole process was actually a typical contingency decision-making. Since the advent of the 21st century, China’s monetary policy implementation has been increasingly mature. In the American Subprime Mortgage Crisis in 2008 which influenced the whole world, the reaction coefficient of the interest rate to the inflation rate in China was not so dramatic like that during the Southeast Asian Financial Crisis. On the contrary, it was quite stable. Thus, it can be seen that China’s monetary policies have been more regulated in the 21st century. In terms of quantity, the reaction of the interest rate to the inflation rate is positive at most times and is quite stable.
Fig. 2 shows the reaction coefficient of the interest rate to the output gap. From the time-varying trend chart, it can be seen that in the late 20th century, the time-varying parameters of the interest rate to the output gap changed dramatically. Affected by the Southeast Asian Financial Crisis, during 1997–1998, China’s output gap kept on widening. At the moment, the central bank stimulated output through huge lowering of the interest rate. This explained why the time-varying parameters of the interest rate to the output gap decreased so dramatically. When the interest rate stimulus brought benefits, the increase of output resulted in narrowing of the output gap. Therefore, the time-varying parameters of the interest rate to the output gap from 1998 to 1999 picked up quickly. The process was a typical contingency decision-making. With the advent of the 21st century, the reaction of the interest rate to the output gap was not so dramatic as before in terms of the time-varying parameters. Even affected by the American Subprime Mortgage Crisis in 2008 and that China showed obvious deflation in 2009, the time-varying parameters during the period showed no dramatic fluctuations. It can be seen that China’s monetary policies are not significantly asymmetric in coping with inflation and deflation. Besides, China’s monetary policies have been increasingly regulated in response to the output gap. Based on a careful observation of the time-varying path, it can be seen that, over the past one decade or so, the reaction of the interest rate to the output gap has not been stable, alternating negative with positive in different periods of time. This exactly suggests that, during the period, China’s monetary policies still adhere to the contingency decision-making mode. Under the multi-objective contingency decision-making model, the production output is not the only focus. This explains why the time-varying parameters are now positive and now negative. On the other hand, though China has long stuck to the contingency decision-making, the slightly changing time-varying parameters also indicate that China’s monetary policies have been growingly stable.

Reaction coefficient of the interest rate to the monetary supply growth rate: Fig. 3 shows the reaction coefficient of the interest rate to the monetary supply. From the time-varying parameters trend chart, it can be seen that, in the late 20th century, the time-varying parameters underwent turbulent fluctuations. After the 21st century, these parameters fluctuated slightly, and tended to be stable. During 1997–1998, in order to cope with the impact of the Southeast Asian Financial Crisis, the People’s Bank of China adopted the expansionary monetary policies and increased the monetary supply. During the period, the interest rate plummeted. Due to that, the reaction coefficient of the interest rate to the monetary supply kept increasing and decreased considerably after the fading impact of the Financial Crisis. With the advent of the 21st century, the trend of the time-varying parameters tended to be stable. Quantitatively, the reaction coefficient of the interest rate to REER is mostly positive and is very stable in the 21st century.
IV. Conclusion

Due to the multi-objective characteristic of China’s monetary policies, the traditional Taylor rule is obviously not applicable to China. In this paper, the monetary supply and the exchange rate under the opening conditions are introduced to expand the traditional Taylor rule. The time-varying parameters state-space model is adopted for an empirical study. Research findings suggest that the influence of various variables on the interest rate showed significant time-varying characteristic, especially, during the Southeast Asian Financial Crisis from 1997 to 1998. With the advent of the 21st century, the time-varying parameters of various variables tended to be stable and showed slight fluctuations. To put it specifically, the empirical results of this paper show that the reaction of the interest rate to the inflation rate in the 21st century was positive and stable, and that there was no asymmetry in China’s monetary policies in coping with inflation and deflation. Based on the reaction of the interest rate to the output gap, the time-varying parameters were now positive and now negative. This exactly indicates that China’s monetary policies have long stuck to the contingency decision-making model. Based on the reaction of the interest rate to REER, the reaction of the interest rate to REER was mostly positive and was quite stable in the 21st century. Though China’s monetary policies over the past years show a significant contingency decision-making characteristic, the implementation of monetary policies and the reaction of the interest rate to various variables are stable generally speaking. Thus, it can be concluded that, though the Taylor rule after expansion cannot fully reflect the trend of China’s interest rate, China has been equipped with conditions to implement the Taylor rule. Therefore, this paper suggests that China should accelerate the interest rate marketization reform and adjust the intermediate variable of the monetary policy operation from the monetary supply to the interest rate gradually.

REFERENCES