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The Research on the Operating Situation of China's Real Interest Rate Based on the Three Regimes Markov-switching Model

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Abstract. Since Chinese government implemented interest rate liberalization reform, the level of interest rate has aroused widespread concern from all walks of life. In this paper, we divide the state of China's real interest rate into three different regimes: low level interest rate regime, medium level interest rate regime and high level interest rate regime. Then we apply three regimes Markov-switching Model to explore the operating situation of China's real interest rate. The result of empirical research indicates that low level interest rate and high level interest rate are not significant in our country and medium level interest rate is significant and has a long period of duration.

1. Introduction

In June 1996, the People's Bank of China loosed the restriction in China inter-bank offered interest rate, which became a turning point in China's interest rate liberalization reform. Analyzing the operating situation of real interest rate under the background of interest rate liberalization reform and evaluating the effect of interest rate liberalization promote the maturity and stability of the financial market, improve the operating efficiency of the financial market as well as accelerates the development of national economy.

A majority of experts and scholars do researches on the operating situation of China's real interest rate from many different perspectives. GARCH model are in widespread use in the research concerning interest rate. For example, by formulating a GARCH model based on SHIBOR with terms of overnight, three months and a year, the author analyzed the fluctuation of interest rate and drew the conclusion that short term SHIBOR had the characteristic of agglomeration property while long term SHIBOR didn't have this kind of characteristic (Mengze He, 2013). After taking monetary policy into account and setting a GARCH-JUMP model with the factor of the change of monetary policy, we can draw the conclusion that the change of monetary policy is a reason for the extreme change and sudden jump in SHIBOR (Honghuai Liu, Zhiguo Wang, Hengfu Zou, 2016).

From the perspective of the relationship between fluctuation of interest rate and the monetary policy, many scholars build error correction model with two variables to explore the long term and short term relationship between SHIBOR and the interest rate of central bank bill. They conclude that



there is a long-term co-integration relationship between SHIBOR and the central bank bill interest rate. What's more, long term SHIBOR are affected more severely than short term SHIBOR (Yonggang Ye, Bote Chen, 2012). Some other scholars formulate interest rate model with monetary policy transmission, using SHIBOR as intermediate variable. They use this model to research the difference between the transmission of monetary policy within and out of political system. By empirical research, they found that the loaning rate of state-owned enterprises is sensitive to the change of monetary policy while the loaning rate of private enterprises is not that sensitive. Their loaning rate is steady at a rather high level (Xuesong Qian, Li Du, Wentao Ma, 2015). Some scholars introduce two-channel system of interest rate and the prosperity of informal finance into the new Keynesian dynamic stochastic equilibrium model and analyze the effect of credit policy through impulse response and transmission system (Kun Yang, Hui Cao, Ninghua Sun, 2015).

From the respective of the term structure, some scholars get long term、medium term and short term factors which reflect the term structure of interest rate by formulating a Nelson-Siegel model. They use this model to estimate the influence that the predicted change of macroeconomic variables have to the structure of interest rate. They also use this model to explore the periodical characteristics which are endogenous in the term structure of the interest rate itself (Zhiguo Ding, Decai Xu, Langan Chen, 2014). However, formulating factors may lead to the problem of ambiguous meaning. The factors may also have the problem of overlapped information. In order to solve these problems, some scholars optimize the factors model by restraining the loading of factors and orthogonalizing the factors in order to make their meanings easier to explain. The optimized dynamic model can be applied to the research of dynamic interest rate term structure. They draw the conclusion that short term impulse of interest rate has no significant influence on medium and long term interest rate and medium term interest rate has significant influence on long term interest rate, which indicate that the transmission of interest rate in China is not fluent and the transmission system needs to be further optimized (Genxiang Shen, Zhaowen Shuai, 2017). Other scholars use factors with clear economic meanings such as interest rate of one year central bank bill, the liquidity of funds and risk premium factors to build the Affine interest rate model. They reveal how these factors with clear meaning affect interest rate with different terms (Jing Qiang, Xin Hou, Longzhen Fan, 2018).

Markov Regimes Switching model is in widespread use in the regime transformation of interest rate because it fits the regime switching of financial time series well. It can be used to analyze the regime transformation of real interest rate in China and explore the periodically steady characteristic of the interest rate (Jie Xie, 2011). Some scholars divide SHIBOR into three state: low level of fluctuation, medium level of fluctuation and high level of fluctuation. They explore the correlation between SHIBOR and LIBOR with Markov-switching Model (Pingping Song, Hao Sun, Shengdong Shi, 2017). Some use Markov-switching Model with two variables to explore the correlation between interest rate and exchange rate (Deying Wang, 2015).

Most of the research on interest rate now uses the nominal interest rate, ignoring the influence of inflation. Hence, they cannot reflect the real level of interest rate, which will significantly weaken the judgement of the situation of economy and the state of the monetary policy. In this paper, we combine real interest rate data with Three Regimes Markov-switching Model to investigate the operating situation of real interest rate in China.

2. Model and Solution

In order to investigate the operating state of real interest rate in China, we divide China's real interest rate into three regimes: low level interest rate, medium level interest rate and high level interest rate. Then, we formulate a Three Regimes Markov-switching Model and only account for lags of two orders. The specific setting of model is as follows:

$$x_t - \mu_{s_t} = \phi_1(x_{t-1} - \mu_{s_{t-1}}) + \phi_2(x_{t-2} - \mu_{s_{t-2}}) + \varepsilon_t \quad (1)$$

$$\varepsilon_t \sim N(0, \sigma_{s_t}^2) \quad (2)$$

$$\mu_{s_t} = \mu_1 S_{t1} + \mu_2 S_{t2} + \mu_3 S_{t3} \quad (3)$$

$$\sigma_{S_t}^2 = \sigma_1^2 S_{t1} + \sigma_2^2 S_{t2} + \sigma_3^2 S_{t3} \quad (4)$$

$$S_{ij} = 1 \quad \text{if } S_t = j \quad \text{otherwise } S_{ij} = 0 \quad j = 1, 2, 3 \quad (5)$$

$$p_{ij} = \Pr\{S_t = j | S_{t-1} = i\} \quad (6)$$

The meanings of the variables are as follows. x_t is the real interest rate in China. S_t is the discrete variables of state, indicating the low, medium and high level of interest rate separately. μ_{s_t} is the average of interest rate at the state S_t . $\sigma_{S_t}^2$ is the variance of the state S_t . p_{ij} is the Markov transition probability. The Markov transfer matrix is as follows:

$$\begin{pmatrix} p_{11} & p_{12} & p_{13} \\ p_{21} & p_{22} & p_{23} \\ p_{31} & p_{32} & p_{33} \end{pmatrix} \quad (7)$$

According to the equation (1), when $S_t = 1$, the conditional probability density of x_t is

$$f(x_t | S_t = 1; t-1; \alpha) = \frac{1}{\sqrt{2\pi}\sigma} \exp \left\{ -\frac{\left[(x_t - \mu_{S_t}) - \phi_1(x_{t-1} - \mu_{S_{t-1}}) - \phi_2(x_{t-2} - \mu_{S_{t-2}}) \right]^2}{2\sigma^2} \right\} \quad (8)$$

where $t = (x_t, x_{t-1}, L, x_1)$, $\alpha = (\mu_1, \mu_2, \mu_3, \phi_1, \phi_2, \sigma_1^2, \sigma_2^2, \sigma_3^2)$.

According to the non-linear filter probability methodology propose by Hamilton (1989), the likelihood function of x_t is

$$f(x_T, x_{T-1}, L, x_2) = \prod_{t=3}^T f(x_t | x_{t-1}, x_{t-2}, L, x_0) \quad (9)$$

The filter probability at time t is

$$p(S_t = j | x_t, x_{t-1}, L, x_0) = \sum_{i=1}^3 \sum_{k=1}^3 p(S_t = j, S_{t-1} = i, S_{t-2} = k | x_t, x_{t-1}, L, x_0) \quad j = 1, 2, 3 \quad (10)$$

3. Empirical Analysis

3.1. Data Description

This paper choose monthly data from January 2001 to March 2008 to do the analysis. The capacity of the sample is 207. The inter-bank offered rate is the core interest rate of the currency market. Thus, we choose the weighted average of China inter-bank offered interest rate with the term of one month as our data. Real interest rate is calculated from deducting inflation rate from nominal interest rate. The inflation rate in this paper is calculated from the month-on-month national consumer price index data. All of our data is from CElet statistics database.

3.2. Estimation of the Existence of Unit Root

When fitting stable time series, AR (p) model is one of the most widespread use models. The Markov Regimes Switching Model we built in this paper is based on the form of AR (2). We need to estimate whether the time series data is stable or not before we use the model to do the analysis. That is to say, we need to estimate the existence of unit root.

We use STATA 12.1 to do the ADF estimation and estimate whether there is a unit root according to AIC criterion. The result of the estimation is shown in Table 1. From Table 1, we know that nominal interest rate, inflation rate and real interest rate are all stable under the significance level of 5%

and there are no unit roots. Hence, these three variables are all stable and it is suitable to apply AR (p) model to do the analysis of time series.

Table 1. The Estimation of the Existence of Unit Root

Variable	Horizontal Estimation		
	ADF	1% significance	5% significance
Nominal interest rate	-3.591	-4.005	-3.436
Inflation rate	-9.418	-4.005	-3.436
Real interest rate	-5.203	-4.005	-3.436

3.3. The Result of Empirical Estimate

We combine the real interest rate data with Three Regimes Markov Switching Model to estimate the parameters. The estimated result is shown in Table 2.

Table 2. The Result of Three Regimes Markov-switching Model

Parameters	Estimation	Standard Error
p_{11}	0.4081	0.4200
p_{12}	0.5919	0.4200
p_{21}	0.0059	0.0067
p_{22}	0.8862	0.0558
p_{31}	0.0000	0.0000
p_{32}	0.9999	0.0040
ϕ_1	0.7311	0.0816
ϕ_2	0.1189	0.0812
σ_1^2	1.6312	2.0909
σ_2^2	0.3922	0.0589
σ_3^2	1.7032	0.7311
μ_1	0.3467	0.9085
μ_2	3.0437	0.3269
μ_3	4.1121	0.4747
Log likelihood		-243.8439

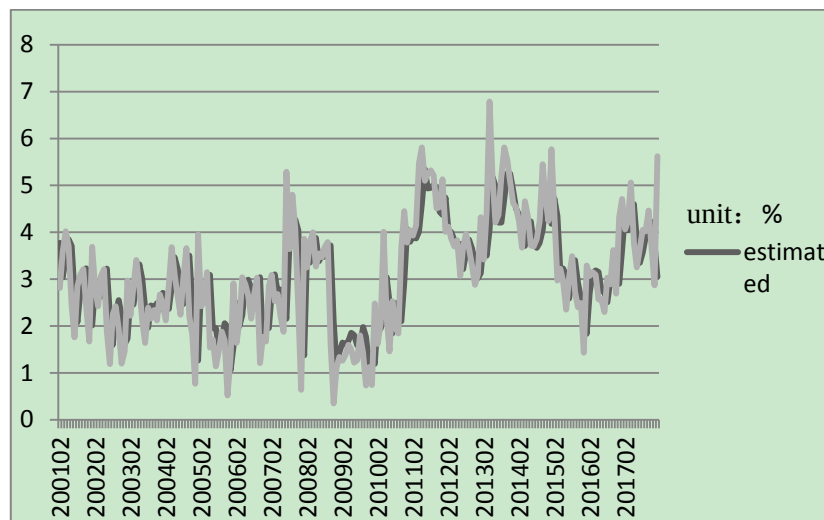


Figure 1. The Actual Operating Situation and Prediction of Real Interest Rate

According to the estimated results given in Table 2, we can get the operating situation of real interest rate in China (as is shown in Figure1). From Figure 1, we know that the actual real interest rate has the same trend as the predicted real interest rate estimated from the model, which means that the model's prediction effect is rather good.

We can also learn from the Figure 1 that China's real interest rate fluctuate from a certain level from January 2001 to March 2018. From November 2005 to September 2007, our country's real interest rate showed a trend of increasing steadily with some small fluctuations, which was closely related with the act that the People's Bank of China loosed the restriction on inter-bank deposit rate for financial institutions. The real interest rate was also in growth from August 2008 to June 2011. The financial crisis erupted in 2008 depressed the consumers' demand in the American Market and shocked the Chinese export market. The rapid of the increase of Chinese value of export slowed down and the growth of economy turned to depend on domestic needs. In this period, our country's inflation rate was under zero continuously. With steady nominal interest rate and negative inflation rate, the real interest rate was bound to present a trend of increase.

Another increase trend which began in December 2012 was due to the reform of parity quotation mechanism between RMB and dollar at August 11, 2015. After this reform, RMB depreciated against dollar. The liquidity in domestic market tightened and the bond market were not in a favored situation. As we all know, RMB is not yet a international reserve currency. It could not maintain depreciating and low interest rate at the same time by quantitative easing like dollar did. Hence, it's no wonder that the real interest rate presented a trend of increasing under the background of RMB depreciating.

According to the estimated results shown in Figure 2, we divide our country's real interest rate into three regimes: low level interest rate, medium level interest rate and high level interest rate. p_{11} indicates the probability that the real interest rate stays at the low level and it remains at low level at next period. Its estimated value is 0.4081. μ_1 is the average of low interest rate level, whose estimated value is 0.3457%. σ_1^2 is the variance of the low interest level, whose estimated value is 1.6312. As is shown in Figure 2, the estimated value of p_{11} , μ_1 and σ_1^2 are all not significant. Thus, we will not analyze the filer probability of low level interest rate regime any more. p_{33} is not shown in the output of GAUSS software. We can calculate it with the equation $p_{33} = 1 - p_{31} - p_{32}$. Its estimated value is 0.0001. However, p_{31} is not significant and that leads to the insignificance of p_{33} and high interest rate level.

p_{22} indicates the probability that the real interest rate stays at the medium level and it remains at medium level at next period. Its estimated value is 0.8862. μ_2 is the average of medium interest rate

level, whose estimated value is 3.0437%. σ_2^2 is the variance of the low interest level, whose estimated value is 0.3922. The estimated value of p_{22} , μ_2 and σ_2^2 are all significant. The duration of medium level interest rate is $1/(1-0.8862)=8.79$.

According to the calculation of duration mentioned above, the duration of medium level interest rate is very long, which is in line with the reality.

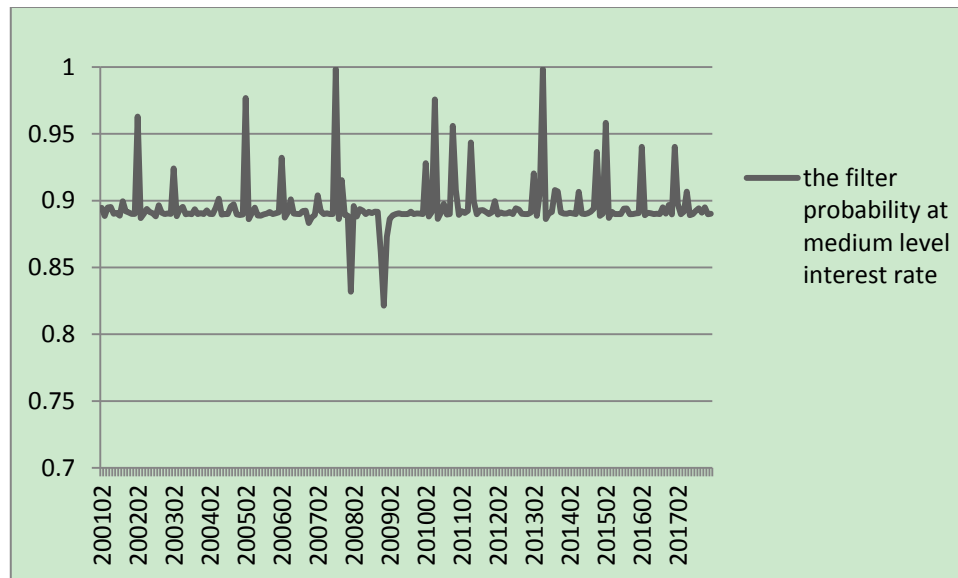


Figure 2. The Filter Probability at Medium Level Interest Rate

We can further get the filter probability figure at medium level interest rate (as is shown in Figure 2). The filter probability at medium level is significantly above 0.5 from January 2001 to March 2018, which indicates that our country stays at the medium level regime during this period.

Figure 2 also indicates that the filter probability is steady as a whole. It only dropped obviously at January 2008 and December 2008. The reason for this kind of drop was that there were downward pressure for the economy and prediction for deflation.

According to loanable fund theory, the equilibrium of market interest rate is determined by the equality of supply and demand of funds. Real economy and financial system affect the level of interest rate at the same time. Although monetary market interest rate such as government bonds and corporate bonds has been liberalized, our country's reform of interest rate liberalization is not mature yet. Restricted interest rate such as loan and deposit interest rate are still based on the core interest rate. Interest rate liberalization needs to solve the problem of the double channel interest rate system. A systematical and authoritative interest rate indicator system is still on the way.

4. Conclusion

By combining Three Regimes Markov-switching Model and real interest rate data, we can learn that our country's real interest rate is not significant on the low and high level interest rate regime and it is significant on the medium level interest rate regime. Our country's real interest rate keeps steady at medium level regime and the fluctuation amplitude is rather slim, which is in close relationship with the fact that China's interest rate liberalization reform is still at the stage of transition and restricted loan and deposit interest rate as well as liberalized monetary interest rate coexist.

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