

Dynamic Analysis of Time Series Data Based on State Space Model

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Abstract

The state space model is effective on analyzing non-stationary time series data, especially in adapting better to the dynamic variation analysis of the time series data and forecasting demand, by replacing fixed parameters with the variable ones. This article elaborates the constructing process of state space model by the measurement equation and state equation. This article also selects M0 money supply, M1 money supply, M2 money supply as the characterize variables of monetary policy, selects the national housing climate Index as characterize variables of real estate development, status regression model with stronger dynamic analysis capabilities as empirical analysis tool, with 2005 to 2012 monthly data of relevant variables as empirical analysis object, carry out the empirical study of relationship between the development of China's real estate industry and the amount of the three currencies. The empirical results show that the amount of three currencies elastic influence for real estate development are positive, M2 money supply impact of greater intensity. Among, M0 money supply influence gradually weakened, M1 and M2 money supply influence gradually increased.

Keywords: *State space model; national housing climate index; M0 money supply; M1 money supply; M2 money supply*

1. Introduction

Time series analysis is an important method and application research field based on the stochastic process theory and mathematical statistics. According to the statistic characteristics, time series can be classified into two kind: stationary time series and non-stationary time series. Most series we meet in real life-especially for the ones reflecting the social or economic phenomenon-is usually not steady. Therefore, it is significant to do reasonable modeling and dynamic analysis on these data [1-2].

In the process of study on the method of time series data analysis, the BJ model method and the ARIMA model method first appeared, which can both achieve the prediction of stationary time series data, for non-stationary time series data, we can turn them into the stationary ones by taking differencing, logarithm or other transformation operations and then do the processing [3-4]. Afterwards, stochastic model method got constructed, in order to improve the polyfit effects of the time series data values [5]. As the Bayes theory matured gradually, processing methods based on the Bayes model appeared in the time series analysis [6]. In recent years, an analysis method based on state space model was applied to the time series data, as a result, the Kalman filtering was introduced into the dynamic analysis process of series data successfully. Such method is close to the Bayes method on performance, but the calculation is greatly reduced [7].

This article focuses on the research of analyzing time series data based on state space model, and tries to apply it to analyze and predict the monetary policy tools to adjust the real

estate industry. In the various tools of monetary policy, money supply has the greatest influence on the real estate industry development [8]. The relationship between monetary policy and the real estate industry development has obvious dynamic characteristic, so choosing the model within the stronger dynamic analysis capability can obtain a greater advantage. Therefore, in this paper, we select three currencies M0, M1, M2 as the variable characterization of monetary policy, and explore the relationship between the real estate industry development and them with the support of the state space model theory.

2. Construction of State Space Model

In the existing variables analysis methods of economic data, a considerable number of analysis methods are the expansion and extension on the basis of the regression model constructed. General regression model as shown in Equation (1).

$$y_t = x_t' \beta + u_t \quad (1)$$

Here, y_t represents the dependent variable, x_t represents $m \times 1$ step of explanatory variables,

β indicates that the requested $m \times 1$ step of unknown parameters, u_t represents disturbance term.

The regression model shown in the formula (1), the general assumption is that the required solution of unknown parameters within the estimated time range is fixed, so you can use least squares method and other means to solve, that formed OLS regression.

However, since reform and opening-up, China's economic structure have constantly changing and restructuring, constantly withstand external shocks and adjust their own, regression model with fixed parameters clearly unable to accurately estimate the dynamic changes in the economic structure. At this time, the analysis model using variable parameters will undoubtedly have greater advantage. State space model is a typical model for dynamic analysis that can be used, especially its form of variable parameters for economic issues has good applicability, and its detailed description as formula (2).

$$y_t = x_t' \beta_t + z_t' \gamma + u_t \quad (2)$$

Compared with regression model with fixed parameters shown in the formula (1), state-space model use β_t which can change over time substitution of β , which can be more truly reflect the changes of relationship between the explanatory variables x_t and y_t the dependent variable, effectively explain certain dynamics changes of economic structure, or changes in economic laws. If β_t use AR (1) to be described, then:

$$\beta_t = \phi \beta_{t-1} + \varepsilon_t \quad (3)$$

Here, β_t is unobservable variables, need the help of observable variables y_t, x_t to be estimated. Therefore, equation (2) is called the measurement equation, equation (3) is called a state equation.

u_t and ε_t are disturbance terms of the measurement equation and the equation of state, in the case of obedience to AR (1), they satisfy:

$$(u_t, \varepsilon_t)' \sim N \left(\begin{pmatrix} 0 \\ 0 \end{pmatrix}, \begin{pmatrix} \sigma^2 & 0 \\ 0 & Q \end{pmatrix} \right) \quad (4)$$

Equation (4) shows that, u_t and ε_t are independent of each other, and likewise obedience to normal distribution with mean 0 and variance σ^2 , covariance ρ .

3. Selection of Time Series Data

For monetary policy, Money supply is commonly used as characterize variables, are widely used during the study in all the economic laws. China's relevant central bank issued the monetary aggregates, is divided into M0 money supply, M1 money supply, M2 money supply.

The so-called M0 money supply, is sum of cash of the various units outside the banking system and cash in the hands of residents, therefore, is seen as the total amount of cash in circulation.

The so-called M1 money supply, is based on the M0 money supply, plus totally demand deposits of various units outside of the banking system.

The so-called M2 money supply, is really based on the M1 money supply, plus total time deposits of various units outside the banking system as well as rural residents' deposits and securities margin.

In the past, on the research of relationship between real estate development and monetary policy, the amount of M2 is widely used. This article use M0 money supply, M1 money supply, M2 money supply at the same time as the characterize scalar representation of monetary policy and its trying to via differences among and different impact on the real estate industry, from a deeper level excavate the relationships of money supply and real estate industry.

For real estate development, we have chosen national housing climate index as characterize variables. National housing climate index formulated by the National Bureau of Statistics, publishing monthly basis since 1997, it is currently the accepted most objective evaluation index for trend of real estate development.

Through the implementation of monetary policy in the regulation of the real estate industry, after 2005 began to increase. Thus the selection of the empirical data starting from 2005, according to monthly, statistics to the end of 2012. As used herein, all of the data comes from national aggregate net and China Statistical Yearbook, the natural logarithm of the original data are as shown in Table 1.

Table 1. Variable Data of Various Economic

| time | House Index (R) | M0 | M1 | M2 |
|---------|-----------------|----------|----------|----------|
| 2005.01 | 4.632785 | 10.08645 | 11.48328 | 12.45958 |
| 2005.02 | 4.626834 | 10.02871 | 11.43836 | 12.46596 |
| 2005.03 | 4.623992 | 9.963592 | 11.45893 | 12.48593 |
| 2005.04 | 4.623305 | 9.983525 | 11.45735 | 12.49498 |
| 2005.05 | 4.621536 | 9.943265 | 11.47004 | 12.50336 |
| 2005.06 | 4.623599 | 9.945050 | 11.49884 | 12.52738 |
| 2005.07 | 4.623599 | 9.960397 | 11.48939 | 12.53165 |
| 2005.08 | 4.620748 | 9.968880 | 11.50668 | 12.54714 |
| 2005.09 | 4.616110 | 10.01113 | 11.52252 | 12.56876 |
| 2005.10 | 4.615912 | 9.993921 | 11.53029 | 12.56930 |
| 2005.11 | 4.619665 | 10.01724 | 11.55335 | 12.58571 |
| 2005.12 | 4.621142 | 10.08713 | 11.58319 | 12.60738 |
| 2006.01 | 4.623697 | 10.28570 | 11.58292 | 12.62337 |
| 2006.02 | 4.634049 | 10.10569 | 11.55557 | 12.62648 |
| 2006.03 | 4.639668 | 10.06356 | 11.57812 | 12.64591 |
| 2006.04 | 4.637734 | 10.09228 | 11.57486 | 12.65620 |
| 2006.05 | 4.636087 | 10.06328 | 11.60111 | 12.66574 |
| 2006.06 | 4.638605 | 10.06344 | 11.62931 | 12.68465 |

| | | | | |
|---------|----------|----------|----------|----------|
| 2006.07 | 4.643621 | 10.07545 | 11.63207 | 12.68853 |
| 2006.08 | 4.617296 | 10.11137 | 11.65548 | 12.69774 |
| 2006.09 | 4.631325 | 10.15376 | 11.66834 | 12.71248 |
| 2006.10 | 4.637831 | 10.12520 | 11.68149 | 12.71514 |
| 2006.11 | 4.640827 | 10.14750 | 11.70886 | 12.72933 |
| 2006.12 | 4.644391 | 10.20628 | 11.74432 | 12.75305 |
| 2007.01 | 4.648996 | 10.23814 | 11.76356 | 12.76996 |
| 2007.02 | 4.653865 | 10.32967 | 11.74608 | 12.79013 |
| 2007.03 | 4.660983 | 10.21786 | 11.75886 | 12.80517 |
| 2007.04 | 4.668990 | 10.23329 | 11.75727 | 12.81401 |
| 2007.05 | 4.651290 | 10.19347 | 11.77741 | 12.82050 |
| 2007.06 | 4.645064 | 10.19918 | 11.81929 | 12.84221 |
| 2007.07 | 4.638025 | 10.21560 | 11.82215 | 12.85810 |
| 2007.08 | 4.635505 | 10.23360 | 11.85647 | 12.86671 |
| 2007.09 | 4.628496 | 10.27611 | 11.86774 | 12.88182 |
| 2007.10 | 4.622814 | 10.25125 | 11.88207 | 12.88462 |
| 2007.11 | 4.616605 | 10.27463 | 11.90503 | 12.89861 |
| 2007.12 | 4.601965 | 10.32138 | 11.93531 | 12.90779 |
| 2008.01 | 4.589650 | 10.50980 | 11.95034 | 12.94280 |
| 2008.02 | 4.569128 | 10.38759 | 11.91958 | 12.95048 |
| 2008.03 | 4.552402 | 10.32329 | 11.92416 | 12.95526 |
| 2008.04 | 4.551136 | 10.33493 | 11.92963 | 12.96994 |
| 2008.05 | 4.551347 | 10.31458 | 11.94044 | 12.98591 |
| 2008.06 | 4.563723 | 10.31498 | 11.95002 | 13.00164 |
| 2008.07 | 4.570061 | 10.33160 | 11.95113 | 13.00889 |
| 2008.08 | 4.585070 | 10.33694 | 11.96330 | 13.01444 |
| 2008.09 | 4.605970 | 10.36486 | 11.95600 | 13.02342 |
| 2008.10 | 4.615912 | 10.35194 | 11.96524 | 13.02394 |
| 2008.11 | 4.625267 | 10.36114 | 11.96925 | 13.03603 |
| 2008.12 | 4.632591 | 10.44054 | 12.02105 | 13.07142 |
| 2009.01 | 4.641116 | 10.62333 | 12.01500 | 13.11461 |
| 2009.02 | 4.658427 | 10.46714 | 12.02064 | 13.13569 |
| 2009.03 | 4.662401 | 10.42663 | 12.08131 | 13.18181 |
| 2009.04 | 4.591071 | 10.44165 | 12.09074 | 13.20022 |
| 2009.05 | 4.595019 | 10.42108 | 12.11190 | 13.21451 |
| 2009.06 | 4.595625 | 10.42350 | 12.17116 | 13.25149 |
| 2009.07 | 4.613238 | 10.44113 | 12.18530 | 13.25882 |
| 2009.08 | 4.621831 | 10.44600 | 12.20804 | 13.26508 |
| 2009.09 | 4.634146 | 10.51292 | 12.21458 | 13.28006 |
| 2009.10 | 4.641984 | 10.48375 | 12.24311 | 13.28217 |
| 2009.11 | 4.643814 | 10.50078 | 12.26667 | 13.29565 |
| 2009.12 | 4.639088 | 10.55179 | 12.30139 | 13.31501 |
| 2010.01 | 4.640634 | 10.61542 | 12.34405 | 13.34648 |
| 2010.02 | 4.641695 | 10.66583 | 12.32068 | 13.36307 |
| 2010.03 | 4.640827 | 10.57338 | 12.34321 | 13.38465 |
| 2010.04 | 4.660226 | 10.58804 | 12.36269 | 13.39477 |
| 2010.05 | 4.654627 | 10.56238 | 12.37369 | 13.40506 |
| 2010.06 | 4.654532 | 10.56887 | 12.39081 | 13.42087 |
| 2010.07 | 4.651290 | 10.58515 | 12.39116 | 13.42106 |
| 2010.08 | 4.645448 | 10.5947 | 12.40632 | 13.44083 |
| 2010.09 | 4.639765 | 10.64195 | 12.40419 | 13.45378 |
| 2010.10 | 4.640248 | 10.63697 | 12.44238 | 13.45852 |
| 2010.11 | 4.636669 | 10.65141 | 12.46620 | 13.47350 |
| 2010.12 | 4.622912 | 10.70612 | 12.49359 | 13.49510 |
| 2011.01 | 4.623796 | 10.96930 | 12.47520 | 13.50611 |
| 2011.02 | 4.633758 | 10.76364 | 12.46536 | 13.50916 |
| 2011.03 | 4.634535 | 10.71097 | 12.49221 | 13.53861 |
| 2011.04 | 4.636572 | 10.72523 | 12.49413 | 13.53763 |
| 2011.05 | 4.636669 | 10.70555 | 12.50354 | 13.54555 |
| 2011.06 | 4.622519 | 10.70275 | 12.52330 | 13.56810 |
| 2011.07 | 4.620059 | 10.71848 | 12.50820 | 13.55794 |
| 2011.08 | 4.616308 | 10.73150 | 12.51867 | 13.56814 |
| 2011.09 | 4.609262 | 10.76099 | 12.49573 | 13.57650 |
| 2011.10 | 4.607867 | 10.74891 | 12.53016 | 13.61319 |

| | | | | |
|---------|----------|----------|----------|----------|
| 2011.11 | 4.603869 | 10.76463 | 12.54759 | 13.62374 |
| 2011.12 | 4.594008 | 10.83464 | 12.57711 | 13.65486 |
| 2012.01 | 4.585070 | 10.99911 | 12.50622 | 13.65991 |
| 2012.02 | 4.583844 | 10.84834 | 12.50733 | 13.67299 |
| 2012.03 | 4.573886 | 10.81166 | 12.53537 | 13.70521 |
| 2012.04 | 4.560382 | 10.82376 | 12.52447 | 13.69853 |
| 2012.05 | 4.552824 | 10.80039 | 12.53773 | 13.71020 |
| 2012.06 | 4.550820 | 10.80537 | 12.56907 | 13.73754 |
| 2012.07 | 4.549340 | 10.81388 | 12.55352 | 13.73112 |
| 2012.08 | 4.550080 | 10.82447 | 12.56284 | 13.73744 |
| 2012.09 | 4.547435 | 10.88619 | 12.56650 | 13.75755 |
| 2012.10 | 4.549235 | 10.84871 | 12.58899 | 13.74980 |
| 2012.11 | 4.561323 | 10.86651 | 12.60109 | 13.75876 |
| 2012.12 | 4.560068 | 10.90962 | 12.64013 | 13.78937 |

Corresponding to the data in Table 1, a graph shown in Figure 1.

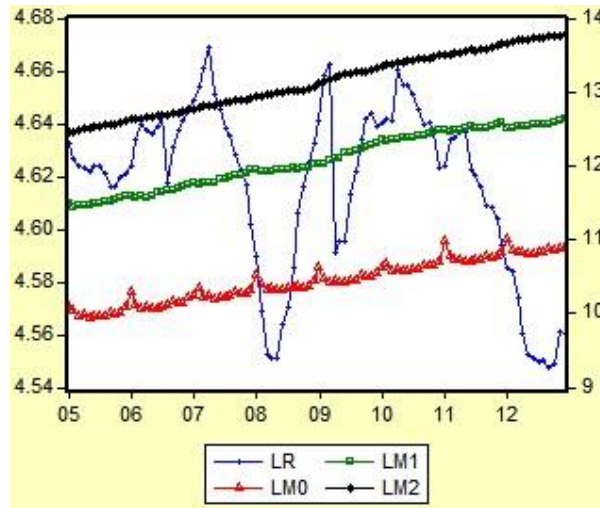


Figure 1. Graphs of the Economic Variables

In Figure 1, LR curves represent the national housing climate index trend from 2005 to 2012, LM0 curves represent M0 money supply trend from 2005 to 2012, LM1 curve represents the trend of M1 from 2005 to 2012, LM2 curve represents M2 money supply trend from 2005 to 2012.

As can be seen, estate climate index started rising from 2005, and reached highs at April 2007; later affected by the relevant control policies, began to decline dramatically; in April 2008 reached lows; Then, in order to address the financial crisis, China promulgated a series of loose control policies, the real estate industry rose again. In April 2010 and May 2011, estate climate index has twice reached highs; later, in order to control high prices, China has promulgated a series of control policies which are the most stringent policies in the history, making estate climate index in September 2012 reached lows. Seen that, estate climate index curves is basically consistent with the actual situation of real estate development.

Three kinds of money supply curve, from 2005 to 2012 showed a rising trend all the way, which is also coincide with the actual situation of China's economic development.

4. Experiment and Analysis

According to construction theory of the state-space model, we should first determine regression models of each variable, so we use LR as the dependent variable, LM0, LM1, LM2 as explanatory variables, using OLS regression methods get the following equation:

$$LR = 0.027 LM_0 + 0.375 LM_1 + 0.36 LM_2 - 5.099 \quad (5)$$

On this basis, further build this measurement equation of four variable are as follows:

$$LR = sh_0 * LM_0 + sh_1 * LM_1 + sh_2 * LM_2 - 5.099 \quad (6)$$

Three state equation are as follows:

$$\begin{cases} sh_{0t} = 0.027 sh_{0(t-1)} \\ sh_{1t} = 0.027 sh_{1(t-1)} \\ sh_{2t} = 0.027 sh_{2(t-1)} \end{cases} \quad (7)$$

The measurement equation shows in equation (6) and the state equation shows in equation (7), used the relevant data of various variables in Table 1, further testing three elastic's dynamic measurement: sh0, sh1, sh2, respectively obtained the results shows as Figure 2, Figure 3, Figure 4.

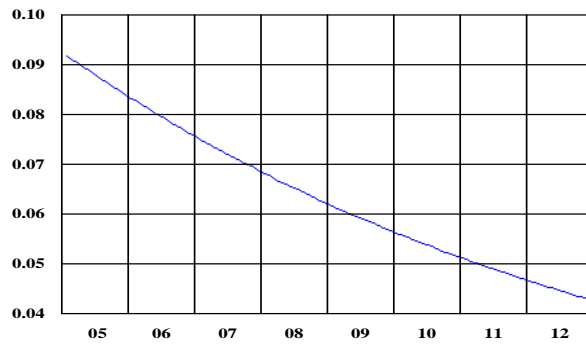


Figure 2. Dynamic Measurement of M0 Money Supply Elasticity for Real Estate Development

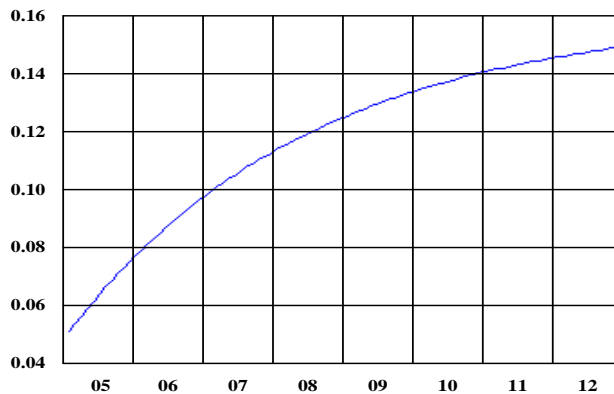


Figure 3. Dynamic Measurement of M1 Money Supply Elasticity for Real Estate Development

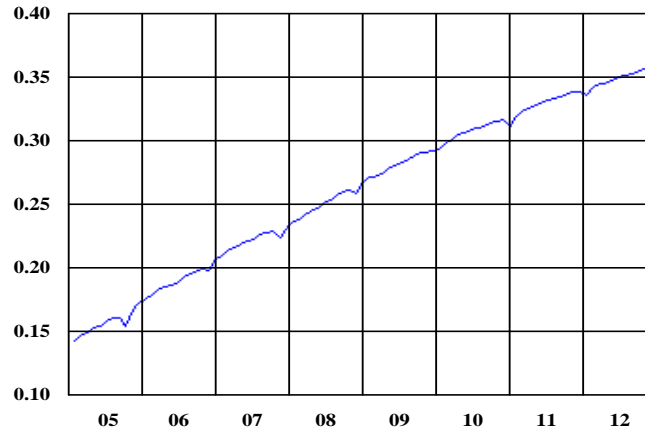


Figure 4. Dynamic Measurement of M2 Money Supply Elasticity for Real Estate Development

As can be seen from Figure 2, M0 money supply characterized by sh0 has a positive impact on the flexibility for the national housing climate index, that explains the increase of M0 money supply is conducive to the development of the real estate industry, and thus shows the growth of the total amount of cash circulating in the country will stimulate the purchasing power of the public for housing. But another fact is that from 2005 to 2012, elastic effects of M0 money supply for the national housing climate index have decreased from 0.09 to 0.04, and this downward trend is consistent. This shows that the growth of the total amount of cash in circulation has gradually lost its role in enhancing the purchasing power of public for housing.

As can be seen from Figure 3, M1 money supply characterized by sh1 has a positive impact on the flexibility for the national housing climate index, that explains the increase of M0 money supply is conducive to the development of the real estate industry, and thus shows the growth of the total amount of cash circulating in the country coupled with the growth of total demand deposits will stimulate the purchasing power of the public for housing. And, from 2005 to 2012, elastic effects of M1 money supply for the national housing climate index have rose from 0.05 to 0.15. Combined with the analysis results of M0 money supply, we can see an increase in total demand deposits, it will further enhance the public's desire and confidence to purchase houses.

As can be seen from Figure 4, M2 money supply characterized by sh2 has a positive impact on the flexibility for the national housing climate index, that explains the increase of M0 money supply is conducive to the development of the real estate industry, and thus shows the growth of the total amount of cash circulating in the country coupled with the growth of total demand deposits and total time deposits will stimulate the purchasing power of the public for housing. And, from 2005 to 2012, elastic effects of M1 money supply for the national housing climate index have rose from 0.15 to 0.35. Combined with the analysis results of M0 money supply and M1 money supply, we can see an increase in total deposits, and it will greatly enhance the public's desire and confidence to purchase houses.

As can be seen from the results of elastic impacts through comprehensive consideration of Figure 2, Figure 3, Figure 4, M0, M1, M2, the increase of this three currencies has a positive impact for real estate development, but the impact of M0 money supply is gradually weakened, the impact of M1 money supply, M2 money supply are growing. This also indirectly shows that in recent years, China's economic developed rapid, improved the income

of each units, increased the demand deposits and time deposits of general public, making their desires about buy a house becomes possible, which is important reason of promoting rapid development of the real estate industry.

5. Conclusion

This article analyzes the requirements of dynamic time series data processing by beginning with the general regression model. Then expounds the state space model construction deeply, and finally confirms the applicability and effectiveness of such model for analyzing dynamic changes of the time series data, by replacing fixed parameters with the variable ones.

In this paper, use three currencies as characterize variables of monetary policy, with the state-space model as a tool for empirical analysis, select monthly data of relevant variables from 2005 to 2009, launched research about the relationship between real estate development and the amount of three currencies. This line of thought fully considered the dynamic effect of the money supply about real estate development, and changed the previous studies' mindset which focus only on the amount of M2 money.

The analysis process and results of empirical shows that, money supply as an important tool of monetary policy indeed has a significant role in promoting the develop of real estate industry. See from the elasticity changes of the amount of three currencies' impacts about real estate development, the impact of M0 money supply are gradually weakened, while the impact of M1 and M2 money supply are gradually increased. In which, the increased M2 money supply have more effective incentive effect for real estate development.

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