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).

$$y_t = x_t'\beta + u_t \tag{1}$$

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).

$$y_t = x_t'\beta_t + z_t'\gamma + u_t \tag{2}$$

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:

$$\beta_t = \phi\beta_{t-1} + \varepsilon_t \tag{3}$$

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:

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

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 Q .

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.
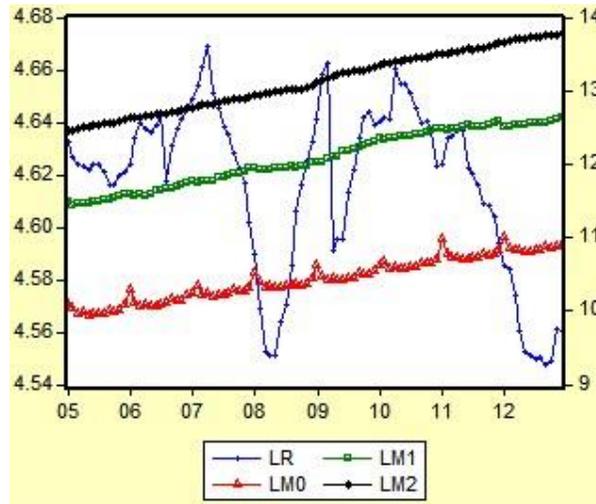
Figure 1. Graphs of the Economic Variables

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:

$$LR = 0.027\ LM_0 + 0.375\ LM_1 + 0.36\ LM_2 - 5.099 \tag{5}$$

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

$$LR = sh_0 * LM_0 + sh_1 * LM_1 + sh_2 * LM_2 - 5.099 \tag{6}$$

Three state equation are as follows:

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

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.
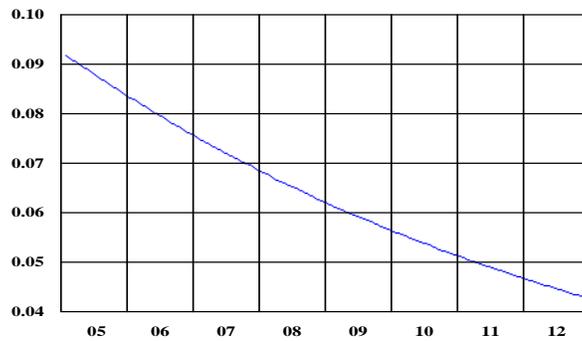

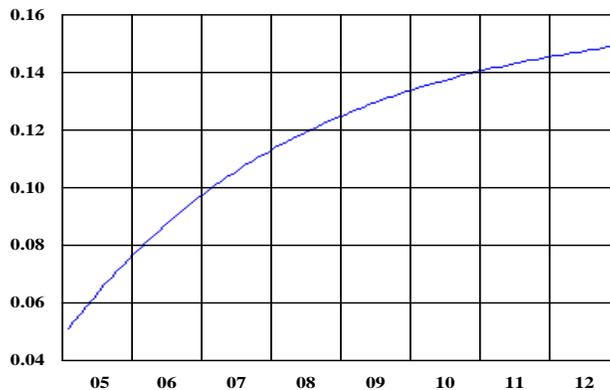**Figure 2. Dynamic Measurement of M0 Money Supply Elasticity for Real Estate Development**

Figure 3. Dynamic Measurement of M1 Money Supply Elasticity for Real Estate Development
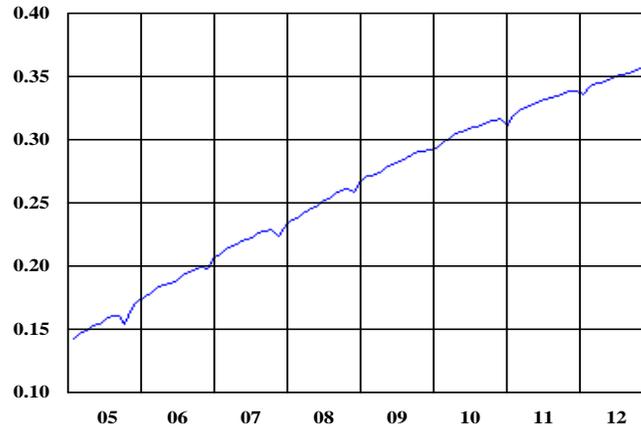
Figure 4. Dynamic Measurement of M2 Money Supply Elasticity for Real Estate Development

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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