

The Superposition of Markov Chain and the Prediction of Consumer Price Index

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Abstract—Using China's consumer price index historical data and the methods of Superimposed Markov chain to forecast the CPI of the year 2016 is a new channel in the CPI forecast. Firstly, according to the relationship between China's consumer price index and inflation, divided the CPI into five states; Secondly, using C-K methods to compute the order transition probability matrix; Thirdly, according to the CPI of 2009-2013 to forecast the situation of 2014, the CPI of 2010-2014 to forecast the situation of 2015; Fourthly, compared with the actual situation, it is confirmed that the method of basing on the superposition of markov chain to forecast consumer price index is accurate. Finally, using the data from 2011-2015 to forecast CPI this year to provide theoretical basis for the government's macroeconomic regulation and the policymaking.

Keywords —Consumer Price Index; markov chain; inflation Introduction

I. INTRODUCTION

CPI is an important macroeconomic indicator that reflects the changes in the price level of consumer goods and services related to the life of the residents. It is also an important indicator of macroeconomic analysis and decision-making as well as national economic accounting. Generally speaking, the level of CPI directly affects the issue and the efforts of the state's macroeconomic measures, such as whether the central bank pranayama, whether or not to adjust the deposit reserve rate etc. At the same time, CPI also affect the capital market (such as stock market, futures market, capital market, financial market) changes indirectly.

At present, in our country, there have been many scholars using different approaches to predict the CPI. There are 790 records whose theme is "CPI"+"prediction" from CNKI academic journals. CI, EI, core journals, CSSCI source. However, most of the 790 records concentrated in time series, neural network, support vector machine etc. I only find 7 records which themed "CPI"+"Markov".

Five papers use Markoff theory to explain the intrinsic mechanism and features of the price. For example, Zhu Peijin (2015) [1] construct a Markov transition autoregressive (MS-AR) model, using the CPI and PPI index from January 1997 to December 2014 to analyze the nonlinear characteristics and the inner mechanism of price index. Liu Weijiang and Li Yingqiao (2015) [2] used the double stage Markov switching model to identify and analyze the

internal transfer mechanism about the consumer confidence and price fluctuation in the dynamic process, the results show that the fluctuation of the growth of CCI is stronger than CPI's; Tong Di and Zhang Wenbin (2015) [3] used variable coefficient Markov regime transformation model proves that Wenzhou City financial institutions loans volatility and inflation had obvious area of asymmetric effect to private lending rate. Restrictive Monetary Policy and high inflation lead the rate of folk lending rate at the high interest rate area improved significantly; Liang Zhixiong and Liang Jian (2010) [4] use VAR method to study the long-term relationship among the price level, economic growth and monetary policy. The results show that there is a cointegration relationship among the price level, monetary policy and economic growth. In this paper, the prediction of CPI based on these internal mechanisms and methods.

There are only three papers based on Markov method to predict the trend of economic. Ren Xiaotao, Teng Tengfei, Yi Zhuoxi (2014) [5] use Markov chain model to analyze the monthly consumer price index (CPI) since 2002 when China joined the World Trade Organization (WTO). They also construct the two order transition matrix with the changing trend based on the fixed base relative data of CPI, the third order transition matrix based on the CPI compared. Yangchun (2010) [6] used discretized CPI to estimate the state transfer matrix and probability matrix, based on the estimation to build HMM model to predict the CPI. The experiment results show that the presented algorithm is effective. This paper also gives some help to macroeconomic analysis forecast. Hou Zengyan (2008) [7] use the consumer price index (CPI) and some other price index, based on the Markov forecast model, to make an empirical analysis about the fluctuation characteristics of the consumer price index (CPI) and the short and long term trend. The result shows that the rise of price is a structural rise. In the near future, monthly CPI will continue to maintain a high growth, but long-term CPI growth benefit from the low level of growth. The biggest advantage of this paper is easy to operate. It adopt the most easily acquired data and the simplest method to give a high accuracy prediction of CPI.

Markov process has no aftereffect, namely, the future state only related to current state, it doesn't have relationship with the past. Obviously, CPI is a random process that vary with time. It's a good idea to determine whether the number of CPI has the Markov mathematical nature with chi square, and then predict its future trends by Markov chain.

II. SUPERIMPOSED MARKOV THEORY

Markov chain model was first posed by Andre Markoff (A.A.Markov, 1856-1922) who is a famous Russian mathematician in the paper of large numbers on the expansion of dependent variables in 1906. In the following one hundred years, Markov chain model was applied to different fields, such as economic, education, physics, genetics, computer and so on, and achieved fruitful results. Compared with other models, Markov chain model doesn't have too high requirements for historical data, it is also unnecessary to look for the relationship among the factors from the complex predictors. We only need to calculate the state transition probability by the history itself state with gradient characteristics, to predict CPI.

A. The Definition of Markov chain

A random sequence $\{X(n); \text{state space } n = 0\}$ S (discrete), if the n in \dots . In S , $P(X(0) = i, \dots, X(n) = j | X(0) = i, \dots, X(n-1) = j) = P(X(n) = j | X(n-1) = j)$ is called $\{X(n); n = 0\}$ Markov chain. Inflation rate is a continuous variable, in this paper the use five segments division method discretization, to obtain the state space $S = \{1, 2, 3, 4, 5\}$. In 1989 with the sample data of 27 years from 2015 to that frequency matrix of each state is obtained.

B. The Definition of Transition Matrix and Transition Probability

Let $\{X(n); n = 0\}$ for the Markoff chain, the state space is S . For I, J and S , called $P\{X(n) = j | X(n-1) = i\}$ $\{X(n); n = 0\}$ step transition probability. If the transfer probability is independent of N , called $\{X(n); n = 0\}$ for homogeneous Markov chain. By using the transfer matrix formula, one step transition probability matrix of CPI is obtained.

$P(n) = (p_{ij}(n))$ for the M step transfer matrix. M step transfer matrix satisfies the following properties: $(n) = 0$ $\sigma(n) = 1$ (I, J, S).

C. Karl Kampmann Kolmogoroff Equation

Let $\{x(n), n \in \mathbb{N}\}$ for homogeneous Markov chain, $P(n)$ is its transition matrix, then for any I, j in $s, m, R, m+r \in \mathbb{N}$: $(n) = \sum_k P(n) P(r)$ $(n + m)$. By using the C-K equation and one step transition probability matrix, the two step, three step, four step, five step transition probability matrix are obtained、和.

D. Markov Theorem

Homogeneous Markov chain $\{X(n); n \geq 0\}$ as state space of finite order s , if there exists a positive integer, so that for all I, j in $s, >$, is called its ergodicity, and limit distribution $\lim_{n \rightarrow \infty} P(n) = (\pi_1, \pi_2, \dots, \pi_s)$. Among them, $\lim_{n \rightarrow \infty} P(n) = \lim_{n \rightarrow \infty} P(n) * P$ equations, namely $= \sum_j \pi_j P_{ij} = \pi_i$, $j=1, 2, \dots, N$ to meet the conditions of >0 , $\sum \pi_j = 1$, the only solution $=1$, where $\lim_{n \rightarrow \infty} P(n)$ is the stationary distribution of Markov chain. The use of chi square test, test inflation rate range of the data is consistent with the Markoff.

E. Superposition of Mark off Theorem

The nearly five years of data and 1-5 step probability transition matrix for the year CPI was five times forecast, five times forecast the probability of superposition, the maximum probability of state is most likely to occur determined to predict the CPI, according to the state division according to the control back to the original zone CPI, which predicts the end of.

III. CPI DATA SELECTION

I can monitor the function of the national economy. It's also an important indicator when the government make monetary policy, fiscal policy, consumption policy, wage policy, social security policy and The consumer price index colligates urban and rural consumer price index, which reflect the changes of price about goods and services which is related to our life. It reflects the trend and degree of changes in prices of consumer goods and services by urban and rural households during a given period. It is an important indicator, which account national economic.

Therefore, it has important practical significance to analyze the consumer price index and make a short-term forecasting.

A. The Description of CPI Data

Since our country makes reform and opening policy in 1979, our party transferred her work center to the socialist modernization. The rapid growth of macroeconomic, a surge of the investment scale and the tremendous ramp-up of spending resulted in serious fiscal deficits, the imports escalation bring about trade deficit, foreign exchange reserves was close to zero quickly.

This serious domestic deficit bring the first currency inflation.

During 1984-1985, the essence of aggregate demand is greater than the total social supply because of the enlargement of scale of fixed assets. The wage growth is faster than labour productivity caused cost-push inflation. Along with the expansion of the scale of infrastructure construction, the demand of social consumption and credit. We cannot avoid an overheating of the economy. The second inflation came to our life;

When the tightening policy adopted by the central authorities during 1984-1985 cannot work for the inflation completely, every policy muffled in 1986. This is the factor that increases aggregate demand. Maybe it is also the reason for large scale panic purchasing in 1988. The third inflation came to the society during 1988-1989.

In just 10 years from 1979 to 1989, China experienced 3 times currency inflation, for six years the inflation is higher than 6. The extreme volatility of inflation cannot be the valid number to predict CPI. Hence, this paper use the CPI from 1898 to 2015 to predict CPI in 2016.

B. Selection of CPI Data

We collected annual consumer price index (%) from 1989 to 2015 from the national data network. As shown in [table 1](#).

IV. CPI FORECAST EMPIRICAL PROCESS

The radical idea of this paper can be divided into the following four steps: First, CPI is related to inflation, it is used to realize the classifications, which divide CPI into five classifications; Second, determine whether the number of CPI has the Markov mathematical nature by chi square test; Third, build up the transition matrix; Forth, calculate One-step, Two-step, Three-step, Four-step and Five-step transition probability matrix by C-K method; Finally, Predicting CPI of 2014 and 2015 to verify the new research method.

Using superimposed Markov chain to carry on the forecast of the CPI, you first need to according to the relationship between CPI and inflation CPI divided into five states; secondly, the data of chi square test that consumer price index series has the Markov property; and then fifth order transfer matrix is constructed to the state after the division of the data, using c-k equation obtained in one step, two steps, three, four, five step probability transfer matrix, finally, the superposition method to forecast to 2014, 2015, confirm the method feasible to 2016 CPI probably range forecasts.

A. State Division

First, according to the relationship between the consumer price index data and the inflation rate, the inflation rate is calculated, and the five sections of the [8] division principle is used for reference, and the interval of the inflation rate is divided.

1) Inflation Rate Calculation

The severity of the inflation rate is reflected by the inflation rate, which shows the range of the price of the goods in a certain period of time. Inflation rates are generally expressed in the consumer price index.

According to the above table 1 in our country in 1989-2015 consumer price index data, the conversion relationship between consumer price index rate of change and the rate of inflation, 1989 to 2015 the 27 years the annual inflation rate, shown in the following [table2](#):

2) State Partitioning Method

Drawing on the division method of the state in the historical evolution and prediction of the Chinese consumer price index by Chen Liang and scholars, according to the principle of [Table 3](#):

3) Results of The State Division

The results of the state division is following [Table 4](#)

B. Markov Test

According to the corresponding state of the consumer price index given by Table 4, we can draw the corresponding transition frequency matrix of the system state:

$$f_{ij} = \begin{pmatrix} 1 & 2 & 1 & 0 & 0 \\ 1 & 2 & 1 & 1 & 0 \\ 1 & 2 & 1 & 2 & 1 \\ 1 & 0 & 2 & 1 & 0 \\ 0 & 0 & 2 & 0 & 4 \end{pmatrix}$$

And then we can get a step state transition probability matrix of the system:

$$p^{(1)} = p^{(1)} = \begin{pmatrix} 1/4 & 1/2 & 1/4 & 0 & 0 \\ 1/5 & 2/5 & 1/5 & 1/5 & 0 \\ 1/7 & 2/7 & 1/7 & 2/7 & 1/7 \\ 1/4 & 0 & 1/2 & 1/4 & 0 \\ 0 & 0 & 1/3 & 0 & 2/3 \end{pmatrix}$$

Using the formula, the calculation statistics, as shown in [table 5](#):

Calculation of $\chi^2 = 49.349$, at the significance level is 0.05, the look-up table derived from 9 in degrees of freedom when the critical value is 16.919. Here $49.349 > 16.919$, so consumer price series with Markov and Markov sequence analysis.

C. C-K Equation to Solve the Probability Transfer Matrix

According to table 5, we can calculate the transition probability matrix of the consumer price index, the following are two steps, three steps, four steps, five step transition probability matrix:

$$p^{(2)} = \begin{pmatrix} 1/5 & 2/5 & 1/5 & 1/6 & 0 \\ 1/5 & 1/3 & 1/4 & 1/5 & 0 \\ 1/5 & 2/9 & 1/3 & 1/6 & 1/9 \\ 1/5 & 1/4 & 1/4 & 1/5 & 0 \\ 0 & 0 & 1/4 & 0 & 1/2 \end{pmatrix}$$

$$p^{(3)} = \begin{pmatrix} 1/5 & 1/3 & 1/4 & 1/6 & 0 \\ 1/5 & 1/3 & 1/4 & 1/5 & 0 \\ 1/6 & 1/4 & 1/4 & 1/6 & 1/8 \\ 1/5 & 2/7 & 1/4 & 1/6 & 0 \\ 0 & 1/7 & 2/7 & 1/8 & 3/8 \end{pmatrix}$$

$$p^{(4)} = \begin{pmatrix} 1/5 & 2/7 & 1/4 & 1/6 & 0 \\ 1/5 & 2/7 & 1/4 & 1/6 & 0 \\ 1/6 & 1/4 & 1/4 & 1/6 & 1/9 \\ 1/5 & 2/7 & 1/4 & 1/6 & 0 \\ 1/7 & 1/5 & 1/4 & 1/7 & 2/9 \end{pmatrix}$$

$$p^{(5)} = \begin{pmatrix} 1/5 & 2/7 & 1/4 & 1/6 & 0 \\ 1/5 & 2/7 & 1/4 & 1/6 & 0 \\ 1/6 & 1/4 & 1/4 & 1/6 & 1/9 \\ 1/5 & 2/7 & 1/4 & 1/6 & 0 \\ 1/7 & 1/5 & 1/4 & 1/7 & 2/9 \end{pmatrix}$$

D. 2014 Year CPI Forecast

By 2013, 2012 and 2011 and 2010 and 2009 CPI (consumer price index), and front solved step, two steps, three steps, four step and five step transition probability matrix and overlay Markov chain prediction method of thinking, to 2014 price refers to the data to predict, as specified in **Table 6 shows**:

According to table 6, (max) =1.59, in state 3 achieved that in 2014 the consumer price index for state 3, namely 2014 consumer price index should be in between 102 - 104 is the normal state from table 1 know, 102 2014 consumer price index, prediction is correct.

E. 2015 Year CPI Forecast

By 2014, 2013, 2012, 2011 and 2010 consumer price index, as well as the first to solve the first step, the two step , **Table 7**

F. 2016 Year CPI Forecast

By 2015, 2014, 2013, 2012 and 2011 CPI (consumer price index), and front solved step, two steps, three steps, four step and five step transition probability matrix and overlay Markov chain prediction method of thinking, to 2016 the price index number according to the prediction, as specified in **Table 8 shows**:

According to table 7. (max) =1.46, in state 2 achieved that in 2016 the consumer price index for phase 2, namely 2016 consumer price index should be in between 100 - 102, is the normal state, but the need to prevent deflation.

V. CONCLUSIONS

Through the forecast of the CPI to for the government to implement policy of expanding domestic demand, stimulate consumption and spur economic growth provides the basis and enable the government to adjust the macro-control policy according to the actual situation, the better to promote the sound and rapid development of the national economy.

By superposition of the Markov chain to carry on the forecast of the CPI, only need to CPI data, the data in the national data network can be directly found, according to the principle of superposition, make full use of the short-term CPI data, according to the characteristics of randomness of CPI, the discretization using Markov chain analysis, the

method is simple, strong operability. It is proved that this method has better prediction effect.

However, overall model still exist some defects, the predicted results from the point of view, it is a range of possible values, and is not specific to the CPI value, how to predict CPI precise numerical is still a topic that needs to continue to explore.

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Table 1 China consumer price index 1989-2015 (%)

year	1989	1990	1991	1992	1993	1994	1995	1996	1997
CPI	118.0	103.1	103.4	106.4	114.7	124.10	117.10	108.30	102.80
year	1998	1999	2000	2001	2002	2003	2004	2005	2006
CPI	99.20	98.60	100.40	100.73	99.20	101.20	103.90	101.80	101.50
year	2007	2008	2009	2010	2011	2012	2013	2014	2015
CPI	104.80	105.90	99.30	103.30	105.40	102.60	102.60	102.0	101.4

data sources : <http://data.stats.gov.cn/>

Table 2 The inflation rate of China during Year 1989-Year 2015 (%)

年份	1989	1990	1991	1992	1993	1994	1995	1996	1997
IR	18	3.1	3.4	6.4	14.7	24.1	17.1	8.3	2.8
年份	1998	1999	2000	2001	2002	2003	2004	2005	2006
IR	-0.8	-1.4	0.4	0.7	-0.8	1.2	3.9	1.8	1.5
年份	2007	2008	2009	2010	2011	2012	2013	2014	2015
IR	4.8	5.9	-0.7	3.3	4.9	2.6	4	2	1.4

Table 3 the division of the CPI

状态	级别	区间
1	通货紧缩	$x < 0$
2	正常 (需预防通货紧缩)	$0 \leq x < 2$
3	正常	$2 \leq x < 4$
4	温和通货膨胀	$4 \leq x < 6$
5	严重通货膨胀	$x \geq 6$

Table 4 The state of CPI

年份	1989	1990	1991	1992	1993	1994	1995	1996	1997
IR 段	5	3	3	5	5	5	5	5	3

Table 5 statistic calculation table of χ^2

State	$f_{i1} \left \ln \frac{p_{i1}}{p_{\cdot 1}} \right $	$f_{i2} \left \ln \frac{p_{i2}}{p_{\cdot 2}} \right $	$f_{i3} \left \ln \frac{p_{i3}}{p_{\cdot 3}} \right $	$f_{i4} \left \ln \frac{p_{i4}}{p_{\cdot 4}} \right $	$f_{i5} \left \ln \frac{p_{i5}}{p_{\cdot 5}} \right $	Total
1	0.1710	0.1703	0.3550	0.3069	0.2113	1.2145
2	1.2153	0.8635	1.7413	0.0000	9.0000	12.8201
3	1.4385	1.0866	1.9644	1.3025	9.0000	14.7921
4	1.7750	1.4231	2.3009	0.9458	1.7346	8.1794
5	1.2153	0.0000	1.0482	1.0794	9.0000	12.3429
Total	5.8151	3.5436	7.4098	3.6347	28.9459	49.3490

Table 6 2014 consumer price index status forecast

Start	original state	Space	State1	State2	State3	State4	State5	Source
2013	4	1	1/4	0	1/2	1/4	0	$p^{(1)}$
2012	3	2	1/5	2/9	1/3	1/6	1/9	$p^{(2)}$
2011	4	3	1/5	2/7	1/4	1/6	0	$p^{(3)}$
2010	3	4	1/6	1/4	1/4	1/6	1/9	$p^{(4)}$
2009	1	5	1/5	2/7	1/4	1/6	0	$p^{(5)}$
	P_i		0.99	1.07	1.59	0.95	0.40	

Table 7 2015 consumer price index status forecast

Start	original state	Space	State1	State2	State3	State4	State5	Source
2014	3	1	1/7	2/7	1/7	2/7	1/7	$p^{(1)}$
2013	4	2	1/5	1/4	1/4	1/5	0	$p^{(2)}$
2012	3	3	1/6	1/4	1/4	1/6	1/8	$p^{(3)}$
2011	4	4	1/5	2/7	1/4	1/6	0	$p^{(4)}$
2010	3	5	1/6	1/4	1/4	1/6	1/9	$p^{(5)}$
	P_i		0.75	1.09	1.04	0.75	0.4	

Table 8 2016 consumer price index status forecast

Start	original state	Space	State1	State2	State3	State4	State5	Source
2015	2	1	1/5	2/5	1/5	1/5	0	$p^{(1)}$
2014	3	2	1/5	2/9	1/3	1/6	1/9	$p^{(2)}$
2013	4	3	1/5	2/7	1/4	1/6	0	$p^{(3)}$
2012	3	4	1/6	1/4	1/4	1/6	1/9	$p^{(4)}$
2011	4	5	1/5	2/7	1/4	1/6	0	$p^{(5)}$
	P_i		0.94	1.46	1.29	0.89	1.29	