Fuzzy Time Series Forecasting Model Based on DRDDR and Application

Ming Liu[1,a], Hongxu Wang[2,b], Youming Li[3,c], Xuebing Huang[4,d]

[1] College of Computer Engineer, Hainan Tropical Ocean University, Sanya, 572022, China

[2] Hainan Tropical Ocean University, Sanya, 572022, China

[3] College of Tropical Biology and Agronomy, Hainan Tropical Ocean University, Sanya, 572022, China

[4] School of China and Austria, Hainan Tropical Ocean University, Sanya, 572022, China

[a]email:liumm2001@163.com, [b]email:whx16233@126.com, [c]email:youmingli@outlook.com, [d]email: pub.huang@qq.com

Keywords: Fuzzy Time Series Forecasting Model; DRDDR, Difference; Difference in Difference; Tertiary Industry

Abstract. A fuzzy time series forecasting model-DRDDR was proposed based on difference and deifference in difference in paper. Prportion of tourism revenue in tertiary industry during 2015-2018 in Hainan province. Results of DRDDR would provide useful help for the development and planning of tourism in some departments in Hainan province. In addition, a new model proposed was a beneficial supplement for the solving of time series forecasting.

Introduction

The problem of time series forecasting was a ancient topic and new ideals about it emerge in endlessly. Dates of time series was a prediction problem represented by fuzzy sets. Song, etc. proposed firstly fuzzy time series forecasting model in 1993 and analyzed the prediction problem of enrollment in University of Alabama during the 1971-1992 period[1][2]. Saxena, etc. developed a improved fuzzy time series forecasting model, and analyzed same problem as Song, and obtained the best accuracy since 2012 year [3]. Wang and Guo simplified prediction model and proposed some new fuzzy time series forecasting models which improved prediction accuracy in some classic cased [4][5][6][7][8]. The fuzzy time series prediction methods based on difference rate and difference of difference rate (DRDDR) was proposed in this paper, which would further simplify prediction models proposed in references 3-8. The percentage of tourism income divided by GDP was defined as proportion of possession of tourism income in GDP. Higher proportion of possession represents higher status of tourism income in national economy. Proportion of possession was important parameter for the status of tourism income in GDP. Proportion of possession can provide some important information, such as status of tourism in national economy, improvement of living standards, expansion of domestic demand, rapid transformation of national economy, for development and planning of tourism in some departments in China. In this paper, we analyzed the proportion of possession of tourism income in GDP in Hainan province using DRDDR and found that DRDDR is indeed a new method for time series forecasting analysis.

Predicting models of DRDDR

Predicting formulas of DRDDR.

$$P_k = Z_{k-1} \times \left(1 + I_{k-1} + \frac{0.003+1}{\frac{0.003}{I_{k-1}} + \frac{1}{J_k}} \right), \tag{1}$$

P_k reprsents forecasting value of proportion of possession in k year, Z_{k-1} represents the proportion of possession in k-1 year, I_{k-1} represents difference rate in k-1 year, J_k represents

difference of difference rate in k year, 0.003 represents membership degree of I_{k-1}.

Application steps of DRDDR.

First step: inputting of historical datas; second step: establishing universe of discourse of propprtion; third step: establishing predictiong formulas-(1) of DRDDR; forth step: prediting the proportion of possession of historical datas using DRDDR; fifth step: prediting the proportion of possession of unknown datas using DRDDR.

Prediction of known proportion of possession of Hainan province during the 2005-2015 period using DRDDR model

Proportion of tourism income in GDP in corresponding period of Hainan province was analyzed using DRDDR during the 2005-2015, which was called prediction of known proportion of possession of Hainan province. Dates of both tourism income and GDP in corresponding period were shown in Table-1.

Table 1 Proportion of possession of tourism income in GDP of Hainan province during the 2005-2015 period.

Year	Tourism income (Billion RMB)/ L_k	GDP of Hainan province (Billion RMB)/ G_k	Proportion of possession (%)/ Z_k
2005	125.05	918.75	13.6109
2006	141.43	1065.67	13.2715
2007	171.37	1254.17	13.6640
2008	192.33	1503.06	12.7959
2009	211.72	1654.21	12.7989
2010	257.63	2064.50	12.4791
2011	324.04	2522.66	12.8452
2012	379.12	2855.54	13.2766
2013	428.56	3177.56	13.4871
2014	484.98	3500.72	13.8537
2015	572.49	3702.80	15.4610

Establishing universe of discoursed of historical datas.

Universe of discoursed of tourism income and GDP of Hianan province were established respectively based on the datas of Table-1.

Universe of discoursed of tourism income:

$L=\{ L_{2005}= 125.05，L_{2006}= 141.43，…，L_{2014}=484.98，L_{2015}= 572.49\}$,

Universe of discoursed of GDP:

$G=\{ G_{2005}= 918.75，G_{2006}= 1065.67，…，G_{2014}=3500.72，G_{2015}= 3702.80\}$.

Universe of discoursed of proportion of possession for tourism income/GDP in Hainan province was established using the formula of $Z_k=(L_k \div G_k)\times 100\%$：

$Z = \{ Z_{2005}= 13.6109，Z_{2006}= 13.2715，…，Z_{2014}=13.8537，Z_{2015}= 15.4610\}$,

Above results of different discoursed universe were shown in Table-1 and Table-2 respectively.

Difference rate-discoursed universe of of proportion of possession was established using the formula of $I_k=(Z_k -Z_{k-1})/Z_{k-1}$:

$I = \{ I_{2006}= -0.0249，I_{2007}= 0.0296，…，I_{2014}=0.0272，I_{2015}= 0.1160\}$.

Difference-discoursed universe of difference rate of proportion possession was established using the formula of $J_k=I_k -I_{k-1}$:

$J = \{ J_{2007}= 0.0545，J_{2008}= -0.0931，…，J_{2014}=0.01113，J_{2015}= 0.0888\}$.

Above discoursed universe results about proportion of possession, about difference rate of proportion of possession, about difference of difference rate of proportion of possession were shown in Table-2.

Table 2 Prediction of proportion of possesion of tourist income in GDP in Hainan province based on DRDDR.

Year	Proportion of possession (%)/ Z_k	Differen-ce rate/I_k	Difference of difference rate/J_k	Forecasting value/P_k	$(P_k - Z_k)^2$	$\lvert P_k - Z_k \rvert / Z_k$
2005	13.6109	-	-	-	-	-
2006	13.2715	-0.0249	-	-	-	-
2007	13.6640	0.0296	0.0545	13.6710	0.000049	0.000512
2008	12.7959	-0.0635	-0.0931	12.7799	0.000256	0.001250
2009	12.7989	0.0002	0.0637	12.8036	0.000022	0.000367
2010	12.4791	-0.0250	-0.0252	12.2818	0.038927	0.015810
2011	12.8452	0.0293	0.0543	12.8510	0.000034	0.000452
2012	13.2766	0.0336	0.0043	13.2768	0.000000	0.000015
2013	13.4871	0.0159	-0.0177	13.4864	0.000000	0.000052
2014	13.8537	0.0272	0.0113	13.8539	0.000000	0.000014
2015	15.4610	0.1160	0.0888	15.4524	0.000074	0.000556
AFER						0.2114%
MSE					0.004374	

Forecasting formula for estalishing DRDDR was same as formula-(1).

Forecasting of historica proportion of possession in Hainan province during the 2005-2015 perion.

Proportion of possession of 2005-2015periond in Hainan province was predicted using formula-(1) and results were shown in Table-2. We found that average forecasting error rate (AFER) and mean square error (MSE) was 0.2114% and 0.004374 respectively. These results suggested that prediction accuracy was very high.

Forecasting of unknown proportion of possession in the 2016-2018 period of Hainan province using DRDDR

Forecasting of unknown proportion of possession of tourism income in GDP in the 2016-2018 period in Hainan province using DRDDR.

when we analyse the unknown proportion of possession of tourism income in GDP in 2016, we found that difference (J_{2016}) of difference rate was unknown in 2016 and can not get directly forecasting value of number of tourist in 2016 using the formula-(1). It is necessary to set up the forecasting rules of unknown proportion of possession based on DRDDR.

Employment of forecasting rule-(5-3-5-1) about unknown proportion of prossession based on DRDDR.

We took several measures for the forecasting objective is the accurate number of tourists in 2016. we aassumed that proportion of possession of tourism income in GDP was unknown. Difference of difference rate of proportion of possession in each year before 2015 was J_{2010}= -0.0252, J_{2011}=0.0543, J_{2012}=0.0043, J_{2013}= -0.0177, J_{2014}=0.0113. Results of calculation was as following:

$V = (J_{2010}+J_{2011}+J_{2012}+J_{2013}+J_{2014})/2 = (-0.0252+0.0543+0.0043-0.0177+0.0113)/2$
$= 0.027/2 = 0.0135$

$I_{2014} = 0.0272$,

$K_{2015} = (J_{2015} - J_{2014})/v = (0.0888-0.0113)/0.0135 = 0.0775/0.0135=5.74\approx6$

We took following parameters (the objective was that the minimum value of error rate between forecasting value and actual data in 2015 was not greater than 1%):

I_{2014}= 0.0272 and J_6= min{J_{2012}, J_{2013},J_{2014}} +6v= -0.0177 +0.0810= 0.0633;

I_{2014}= 0.0272 and J_7= min{J_{2012}, J_{2013},J_{2014}} +7v= -0.0177+0.0945=0.0768;

I_{2014}= 0.0272 and J_8= min{J_{2012}, J_{2013},J_{2014}} +8v= -0.0177+0.1080=0.0903；

I_{2014}= 0.0272 and J_9= min{J_{2012}, J_{2013},J_{2014}} +9v= -0.0177+0.1215=0.1038；

I_{2014}= 0.0272 and J_{10}= min{J_{2012}, J_{2013},J_{2014}} +10v= -0.0177+0.135=0.1173；

We also calculated the value of Z_{2014} with formula-(1) of DRDDR and the data results(predicted value) in the order of smallest to largest in size was smaller, small moderate, large, larger of unknown proportion of possession respectively in 2015. These predicted values - forecasting error rate between actual data- were arranged in the order from small to large, namely, the smallest predicted value was in the first place. We assumed the smaller as the predicted vale of proportion of possession in 2015, therefore, the corresponding parameter of the smaller predicted value' parameter was used as the parameter of each year after that and was shown in Table-3.

Table 3 Forecasting of proportion of possession of Hainan province in 2015 based on forecasting rules of DRDDR (5-3-5-1)

Prediction type of prediction value	Prediction parameter	Actual value/ Z_{2015}	Prediction value/ J_{2015}	$\lvert P_{2015}-Z_{2015}\rvert/G_{2015}$	Order[1]
smaller	I_{2014} and J_6	15.4610	15.1449	2.0445%	4
small	I_{2014} and J_7	15.4610	15.2889	1.1131%	2
moderate	I_{2014} and J_8	15.4610	15.4732	0.0789%	1
large	I_{2014} and J_9	15.4610	15.6561	1.2619%	3
larger	I_{2014} and J_{10}	15.4610	15.8389	2.4442%	5

Note: [1] represents the order between prediction value and prediction error rate of actual data.

Moderate prediction value was 15.4732, in the first, and the forecasting error rate between it and actual data was 0.0789%.

Small prediction value was 15.2889, in the second, and the forecasting error rate between it and actual date was 1.1131%.

Large prediction value was 15.6561, in the third, and the forecasting error rate between it and actual date was 1.2619%.

We took moderate prediction value as prediction value of proportion of possession in 2015.

Prediction value of proportion of possession in 2016: When we chanaged Z_{2014} to Z_{2015} using the parameter which made prediction value of proporion of possession in 2015 in the first, we calulated the prediction values of 2016 based on formula-(1) of DRDDR, which were shown in Table-4. Prediction value of proportion of possession in 2017: When we chanaged Z_{2014} to Z_{2016} using the parameter which made prediction value of proporion of possession in 2015 in the first, we calulated the prediction values of 2017 based on formula-(1) of DRDDR, which were shown in Table-4. Prediction value of proportion of possession in 2018: When we chanaged Z_{2014} to Z_{2017} using the parameter which made prediction value of proporion of possession in 2015 in the first, we calulated the prediction values of 2018 based on formula-(1) of DRDDR, which were shown in Table-4.

Table 4 Forecasting of proportion of possession of Hainan province in the 2016-2018 period based on forecasting rules of DRDDR (5-3-5-1).

Year	Actual value of proportion of possession Z_j	Prediction Value of proportion of possession P_j	Increased percentages than previous year
2015	15.4610	15.4732	0.0798%
2016		17.2684	11.6901%
2017		19.2871	11.6901%
2018		21.5418	11.6902%

We called the prediction rules of unknown proportion of possession as the (5-3-5-1)-prediction rules of DRDDR.

Conclusion

Proportion of possession was important parameter which can predict the status of tourism income in GDP. Tourism industry of Hainan Province has been growing rapidly since 2013 and would be growing rapidly in future years, which would provide relentless power for the economic transformation and sustainable development of Haiman province. DRDDR has several advantages, such as simple step, easy learning, hige prediction accuracy. DRDDR can also predict the proportion of possession of toruism income in GDP and the unknown proportion of possession, which offers a new prediction tool for the forecasting of tourism economy.

Acknowledgments

This research was funded by the Natural Science Foundation of Hainan Province (Project No. 714283, 114011) and Coorperative Project between Sanya City and University (Project No. 2015YD34) and Youth Fund Project of Qiongzhou University(Project No. QYQN201434).

Reference

[1] Q Song, B S Chissom. Forecasting enrollments with fuzzy time series—Part II.Fuzzy Sets and Systems,1994,62:1-8.

[2] Q Song, B S Chissom. Forecasting enrollments with fuzzy time series—Part I.Fuzzy Sets and Systems,1993,54: 1-9.

[3] Preetika Saxena, Kalyani Sharma, Santhosh Easo. Forecasting enrollments based on fuzzy time series with higher forecast accuracy rate. Int. J. Computer Technology& Applications,2012,3(3): 957-961.

[4] Hongxu Wang, Jianchun Guo, Hao Feng, and Hailong Jin. An improved forecasting model of fuzzy time series. Applied Mechanice and Materials,2014, 678: 64-69.

[5] HongXu Wang, JianChun Guo, Hao Feng, HaiLong Jin. A fuzzy time series forecasting model based on percentages. 2nd International Conference on Frontiers in Computer Education (ICFCE2014), December 24-25, 2014, Wuhan, China. 1 ICT IN EDUCATION. Frontiers in Computer Education.2014.11-14.

[6] Hongxu Wang, Jianchun Guo, Hao Feng, and Hailong Jin. A new forecasting model of fuzzy time series. Applied Mechanice and Materials,2014,678: 59-63.

[7] H X Wang, J C Guo, H Feng, F J Zhang. A new model of forecast enrollment using fuzzy time series. Education Management and Management Science, 2014 .International Conference on Education Management and Management Science (ICEMMS 2014), 7-8 August,2014,Tianjin, China,2014. 95-98.

[8] HongXu Wang, JianChun Guo, Hao Feng, HaiLong Jin. A fuzzy time series forecasting model based on data differences. 2nd International Conference on Frontiers in Computer Education (ICFCE2014), December 24-25, 2014, Wuhan, China. 1 ICT IN EDUCATION. Frontiers in Computer Education.2014. 15-18.