Prediction of Farmers' Income and Selection of Model ARIMA

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Abstract Based on the research technology of scholars' prediction of farmers' income and the data of per capita annual net income in rural households in *Henan Statistical Yearbook* from 1979 to 2009, it is found that time series of farmers' income is in accordance with I(2) non-stationary process. The order-determination and identification of the model are achieved by adopting the correlogram-based analytical method of Box-Jenkins. On the basis of comparing a group of model properties with different parameters, model ARIMA (4, 2, 2) is built up. The testing result shows that the residual error of the selected model is white noise and accords with the normal distribution, which can be used to predict farmers' income. The model prediction indicates that income in rural households will continue to increase from 2009 to 2012 and will reach the value of 2 282.4, 2 502.9, 2 686.9 and 2 884.5 respectively. The growth speed will go down from fast to slow with weak sustainability.

Key words Farmers' income, Model ARIMA, Prediction, Time series, China

Weak agricultural foundation, underdeveloped rural areas and slow growth of farmers' income have been conspicuous issues in the economic and social development of our country. By the year of 2009, central government has set the stay point of First Document in the field of "agriculture, countryside and farmers" for 6 years successively, which chiefly shows the firm determination of the managing personnel to combine the harmonious development of the rural and urban areas. Promoting rural residents' income to keep a steady growth by all efforts is still the central task of rural work. Studying the fluctuation features of farmers' income after the implement of the reform and opening up policy and predicting its future developmental trend have great significance in precisely evaluating the effect of original implemented policies and making scientific decision.

1 Literature review

In recent years, there are quite a lot of research bibliographies about building non-stationary time series models and prediction by adopting Auto Regression Integration Moving Average. However, public documents applied to the prediction of farmers' income are quite a few. Model ARIMA built by Yang Mao successfully predicted the growing trend of farmers' income in Henan Province[1]. In fact, factors affecting farmers' income often have complex connection with each other. Especially, predicting by using model of causal or structural relationship is relatively difficult since our country is in the period of economic transition. Time series prediction uses random process to analyze and describe the developmental trend without priori hypothesis on the developmental model. Meanwhile, the method itself guarantees a satisfactory model through repetitive revisions to get the optimized prediction with minimum variance[2].

Empirical researches show that income time series is non-stationary. Sample mean and variance can not be used to deduce the distribution characteristics of random variables at different time points. Modeling should be after tranquilization with appropriate methods. And de-trending and difference methods are generally used. The former is applicable to Trend Stationary containing deterministic trend while the latter is applicable to Difference Stationary containing random tend. Practically, the generating process of real data usually can not be understood. Besides, Monte Carlo simulation shows that TS and DS processes can not be distinguished according to statistical information such as periodgram, correlogram or spectral density and so on. Granger and Joyeux even further combine the two into the framework of fraction integration model, which brings difficulties to modeling[3]. Due to the outstanding work of Nelson and Polsser, now a growing number of researchers tend to hold that most of macro-economic time series contain random trend[4]. Therefore, a difference model can be built to simulate the fluctuation of income time series and to predict.

The main contribution of this article is that it breaks the limitation of traditional theory of Box-Jenkins' correlogram-based method identification, comprehensively adopts more formal as well as objective calculating rules like AIC (Akaike information criterion) and SC (Schwarz Criterion) and proposes more operational modeling methods.

2 Data sources and research methods

2.1 Data sources and processing As a traditional major province in agriculture and population, though GDP of Henan has ranked the fifth in China for 5 years successively, per capita indices are still within intermediate and low level. And Henan Province can be a typical example in our country. Time series

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of per capita nominal net income of rural households can be obtained with yuan as the unit according to *Henan Statistical Yearbook* from 1979 to 2009. Consumer price index (CPI) is used to calculate reduction for convenience of directly comparing and analyzing values of different years. Firstly, chain data of rural residents' consumer price index of Henan Province over the years are converted to fixed base data. Then, nominal income is deflated to get actual income over the years with 1992 as the base period. Time period is limited within 1978 to 2008.

Fig. 1 describes the variation of horizontal time series inc, first-order differential time series $\triangle inc$ and second-order differential time series $\triangle^2 inc$ of peasants' income respectively. Time series *inc* bears obvious characteristics of non-linear long-term rising trend; $\triangle inc$ carries high-order autocorrelation and the non-stationarity can be directly observed; only time series $\triangle^2 inc$ presents certain randomness and may be stationary. With the reform and opening up, the average annual increasing rate of peasants' income is 6.3%, which is much lower than that of GDP in the corresponding period, and bears different variation features during different historical periods. It had relatively slow growth and fierce fluctuation before the 1980s and thereafter, experienced a long-time linger and even falling stage until 1995. After that, the growth speed increased greatly and the fluctuation abated gradually. From 2003 till now, peasants' income has stepped into a new rapid growing stage with rare growth rate as well as time of duration in the history.

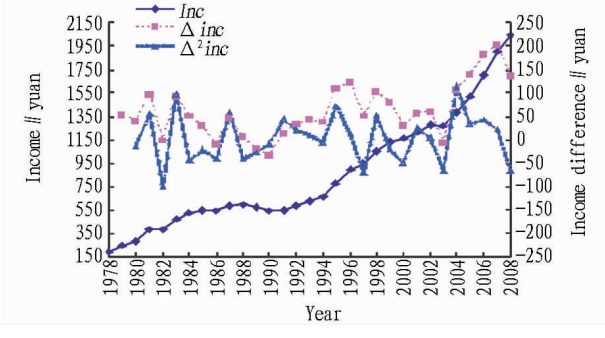

Fig. 1 Per capita income of farmers from 1978 to 2008

2.2 Establishment of model ARIMA Central task of establishing model ARIMA (p, d, q) is to determine the order of the model, recognize, diagnose and inspect the model successively. That is to determine the precise values of parameter p, d and q successively under the guidance of various statistical rules to make sure that the fixed model has optimal statistic property.

2.2.1 Stability of income time series. To establish a proper dynamic model of economic calculation, method of ADF (Augmented Dickey Fuller) is adopted to inspect the stability of time series. The maximal lag order is 7 and the optimal one is determined to be the minimal value according to the Schwarz Criterion (SC). T test adopts the unilateral critical value of MacKinnon to calculate probabilities. The testing result is shown in Table 1 and *inc* can be considered to obey process I (2) under the significance level of 1%. And model ARIMA (p, d, q) can be built for inc with parameter d as 2, which is totally equal to building relative model ARMA (p, q) for $\triangle^2 inc$.

Table 1 ADF test of stability

Variable	Test form	Statistics	Probability	Stable or not
inc	$(c,t,7)$	3.18	1.000 0	No
Δinc	$(c,t,0)$	−2.69	0.248 2	No
$\Delta^2 inc$	$(0,0,0)$	−7.65	0.000 0	Yes

Note: Δ is difference operator; test form (c,t,k) refers to the constant intercept, time trend and lag order in the test equation respectively, 0 means none.

2.2.2 Model recognition and comparison and selection. Let be $dinc = \triangle^2 inc$ to simplify the way of writing, the standardized model ARMA (p, q) can be described as the linear function of time series to its lag value and the present value of random error to the lag value.

$$dinc_t = c + \varphi_1 \cdot dinc_{t-1} + , \cdots , + \varphi_p \cdot dinc_{t-p} + \varepsilon_t - \theta_1 \cdot \varepsilon_{t-1} - \cdots - \theta_q \cdot \varepsilon_{t-q} \quad (1)$$

In the formula, φ_p and θ_q are coefficients of Auto Regression (AR) and Moving Average (MA) respectively; p and q are the maximal lag orders of AR and MA respectively; ε_t is the white noise.

With the introduction of causal operator, the formula can be simplified as:

$$\varphi(B) \cdot dinc_t = \theta(B) \cdot \varepsilon_t \quad (2)$$

In the formula, $\varphi(B)$ and $\theta(B)$ are the lag polynomials of AR and MA respectively.

According to the classical theory of Box Jenkins (BJ), every class of stationary random processes bears a typical pattern of autocorrelation function and partial autocorrelation function. And parameters of model ARMA can be determined according to their trailing or truncation features. Most of the researchers believe that BJ framework is too subjective to be operated since the autocorrelations and partial autocorrelations of AR, MA and ARMA processes are quite similar though from the perspective of rationalism and cannot be distinguished according to limited sample information[5]. To remedy this defect, more formal and objective statistical methods, such as AIC and SC, are to be used. Fan Jianqing and Yao Qiwei synthesized BJ and SC to propose guidelines of model building with more general meanings[6]. The result of Ljung Box Q test observing the lag correlation among various orders of $\triangle^2 inc$ shows that the lag coefficients of AC and PAC in the first and second order do not amount to 0 at the levels of 5% and 10% respectively. Coefficients of AC and PAC are estimated through sample data of time series to be recognized and vary with different samples. The estimated values can only be in accordance with theoretical distribution, thus can only be reference indices for model recognition. A practical and feasible way is to build a set of models to gain statistically reasonable and operable models after overall screening, inspection and revision. Therefore, ARMA (1,1) and ARMA (2,2) are chosen to be benchmark models, parameters are to be adjusted constantly with information provided by AC and PAC coefficients and the lag length is to be prolonged to repeatedly estimate the model so as to select a final model with each statistical index according with the requirement.

The benchmark model and various reference models are

estimated under the combination of different p and q parameters. Thorough diagnose and comparison of each model is shown in Table 2. Models with higher-order lagged variables of MA are not adopted mainly because MA parameter is estimated by method of Iterative Algorithm and easily falls into local minimum value which causes relatively difficult estimation. The third column in Table 2 refers to whether there is constant term c in formula (1); the fourth column gives the values of Ad. R^2 statistic; the fifth column is values of SC; the sixth column gives AR and MA items corresponding to all insignificant regression coefficients at the level of 5% in the model, those in the brackets are the lag orders, c is the constant term; the seventh and eighth column are reciprocals of latent roots of the lag polynomials $\varphi(B)$ and $\theta(B)$ of AR and MA; the ninth column is probabilities corresponding to Breusch Godfrey Largrange Multiplier (LM) test statistic of residual time series; the tenth column is the order of the lagged variable of residual Ljung Box Q test which is significantly different from 0 at the level of 5%, no means the lagged AC and PAC coefficients of residuals at all levels are insignificant.

Firstly, with the combination of data in the third and sixth column in Table 2, we can easily understand that the estimated values in all formulas containing intercept c are insignificant. The standard deviation of time series $\triangle^2 inc$ is 48.5 and the mean value is 5.37 and there is no obvious difference from 0, which is the fundamental reason for insignificant constant term in the model. The comparison between 1 and 2, 8 and 9 shows that c has little influence on properties of the model. So, the final model can be without the constant term.

Secondly, according to values of Ad. R^2 statistic in the fourth column, we can understand that model 7 has the optimal goodness of fit followed by model 8 and 9. It is not difficult to find out that complex models can not surely simulate the real regeneration process of data more effectively. Under the "overfitting" circumstance, there is even deviation between the fitting property of the model and the prediction effect. Apparently, goodness of fit can only be one of the criteria for evaluating whether the model is good or not. And relatively speaking, the value of SC can provide more useful information. It is generally believed that models with low SC values are much better. Thus, model 9 is relatively better than others.

Thirdly, there are terms with insignificant coefficient estimated values in the models except model 2, 6 and 9. Under the requirement of simplicity, redundant variables are better to be ridded from the regression equation, which means imposing extra constraints on the original model. And the effectiveness of constraints can be observed through Wald test. Respective comparison between model 2 and 4, model 7 and 8 indicates that there are irregular changes in the model properties with a general slight falling trend after eliminating regression terms with insignificant coefficients. And this reminds researchers that there should be much carefulness while imposing constraints on parameters.

Fourthly, the precondition of the stability of model ARMA is that the model reciprocal of $\varphi(B)$ is within the unit circle, otherwise the model would diffuse, which usually shows time series has strong memory on impact[7]. Model 7 doesn't meet the requirements of stability. If the model reciprocal of is $\varphi(B)$ out of the unit circle (If next to 1, it would also cause difficulties in estimating and predicting the model.), the model meets the requirements of reversibility. Model 3, 7 and 10 don't meet the requirements of reversibility.

Lastly, residual feature is one of the most crucial criteria for estimating whether the model has excellent properties or not. ADF test shows residuals of all models are stable and meanwhile, all ARCH LM tests negate the original hypothesis, which indicates there is no Auto Regressive Conditional Heteroskedasticity (ARCH) phenomenon. LM test in the ninth column shows that all models reject the original hypothesis that autocorrelation exists in residuals at the significant level of 5% except model 7. LM test observes high-order autocorrelation of residuals. While Ljung Box Q test can observe the lagged autocorrelation of each order more elaborately and one by one. There is autocorrelation at a certain extent in models except model 3, 4, 5, 6, 9, and 10.

According to the above discussed result, various indices uniformly show that model 9 is the optimal.

Table 2 Comparison of ARMA(p,q) model with different parameters

No.	Parameter	c	Ad. R^2	SC	Insignificant coefficient	AR latent root	MA latent root	LM test	Q test
1	$p=1,q=1$	Yes	0.290	10.73	c	−0.80	−0.90	0.298	3
2	$p=1,q=1$	No	0.284	10.61	No	−0.79	−0.92	0.305	3
3	$p=2,q=1$	Yes	0.387	10.71	c	$-0.60 \pm 0.023i$	1.00	0.567	No
4	$p=1,q=2$	Yes	0.374	10.72	c,ma(2)	−0.74	0.38 −0.97	0.973	No
5	$p=2,q=0$	No	0.152	10.79	ar(2)	$-0.21 \pm 0.25i$	–	0.210	No
6	$p=0,q=2$	No	0.227	10.65	No	–	$0.42 \pm 0.84i$	0.155	No
7	$p=2,q=2$	Yes	0.495	10.65	–	0.30 −1.09	0.56; −1.46	0.000	5,6,7
8	$p=4,q=2$	Yes	0.420	10.84	c,ar(3),ar(4)	0.44 −0.82; $-0.51 \pm 0.74i$	$-0.81 \pm 0.50i$;	0.400	7
9	$p=4,q=2$	No	0.401	10.60	No	0.40 −0.80; $-0.50 \pm 0.74i$	$-0.80 \pm 0.50i$	0.995	No
10	$p=3,q=2$	No	0.273	10.89	ar(2),ar(3), ma(1),ma(2)	−0.70 $-0.14 \pm 0.16i$	0.13; −1.00	0.683	No

3 Result and analysis

3.1 Estimation of parameters The estimation of parameters in model ARMA can be divided into two steps. To begin with, parameters of AR are estimated by adopting method of Ordinary Least Square with residual error as the initial estimate of white noise. Then, parameters of MA are estimated by adopting Gauss Newton iterative method. The process is repeated until parameter convergence. The result of estimated model ARMA (4, 2) is shown in formula (3). Since the estimated values of constant term c and ar (3) coefficient are insignificant, both of them are not included in the final model.

$$\triangle^2 inc_t = -1.408\mu_{t-1} - 0.886\mu_{t-2} + 0.259\mu_{t-4} + \varepsilon_t + 1.595\varepsilon_{t-1} + 0.890\varepsilon_{t-2} \quad (3)$$

$$s.e. = (0.156)\quad (0.177)\quad (0.093)\quad (0.070)\quad (0.071)$$

$$t = [-9.02]\quad [-5.01]\quad [2.78]\quad [22.92]\quad [12.47]$$

In the formula, μ_t is the prediction error; ε_t is white noise and all others are lagged values.

3.2 Model diagnosis Residuals of model ARIMA (4, 2, 2) are stationary series after ADF test. Since the purpose of building models is prediction, residuals should be further tested to make sure whether they are white noise. If the residuals are white noise, changes of residuals are random without regularity. Otherwise, this information can be used to improve the precision of model prediction. The result of LM test and Q test shown in the second and third column in Table 2 indicates that there is no autocorrelation. Residual normality will influence the asymptotic effectiveness of the estimating method. Jarque Bera (JB) test in the fourth column shows the original hypothesis of normality can not be rejected. ARCH LM test in the fifth column shows there is no conditional heteroscedasticity. The result of RESET test in the sixth column shows that there is no setting variance in the model. Model ARIMA (4, 2, 2) finally adopted in the research is gained after eliminating the insignificant variables c and ar (3) on the basis of basic models. Effectiveness of model constraints can be tested by Omitted Variables Test. And the seventh column shows it is reasonable to eliminate the above variables.

Table 3 ARIMA(4,2,2) model diagnosis

Test form	LM_2	Q_{12}	JB	ARCH	$RESET_1$	Omitted
Asymptotic distribution	$\chi^2(2)$	$\chi^2(6)$	$\chi^2(2)$	$\chi^2(1)$	F(1,18)	F(2,17)
Statistic value	0.00	7.69	0.77	0.35	0.68	0.28
Probability	1.00	0.36	0.68	0.56	0.42	0.76

The diagnosis result shows that residuals of model ARIMA (4, 2, 2) are white noise, meet the requirements of stability and accord with normal distribution. There is neither autocorrelation and conditional heteroscedasticity nor omitted variables and setting deviation, which can be adopted in the prediction of farmers' income.

3.3 Data fitting and prediction of future income On the whole, from 2005 to 2008, farmers' actual income in Henan had an annual increase rate of 9.4%. Especially, in 2006 and 2007, the increase rates were higher than those of urban residents' income and the year 2006 and 2007 have become the most stable period with the biggest increase rate after the reform and opening up. The grain price increased by 28% in 2004 and half of the increased farmers' income in that year was from the rise of grain price. Henan Province abolished agricultural tax in the beginning of 2005. And in 2006, the fiscal expenditure of Henan Province for improving rural production and living conditions amounted 33 billion yuan; seven kinds of subsidies including direct subsidies for grain production, subsidies for improved varieties and comprehensive subsidies for agricultural means had an total redemption of 3.14 billion yuan; purchased wheat at the protective price amounted 18.13 billion kg which took up 44.3% of that of the whole country; 17.46 million rural labor forces in Henan Province were transferred, which achieved the service income of 95.5 billion yuan[8]. In the former half of 2007, per capita salary cash income of rural residents in Henan was 641.39 yuan with an increase rate of 32.5%. The rise of salary income has become the major force of pulling the growth of farmers' income. In 2008, Henan Province owned raised finance of 41.5 billion yuan most of which were distributed to the rural areas; subsidy favoring agriculture amounted 10.05 billion yuan; over the year, the prices of agricultural products increased by 14.6%, therefore farmers' income increased by 10.5%; throughout the province, 21.55 million people went out to work and the service income was 161.1 billion yuan[9]. At last, transfer income and property income, such as income from household business, salary income, as well as subsidy and relieve, have the contribution rate to income rise of 49.9%, 38.5% and 11.6% respectively.

The new round peasants' income growth mainly depends on three major channels, namely policy favorable subsidy, price rise of agricultural products and salary increase. The difference only lies in the extent of effect exerted by each specific factor during different historical periods. By 2008, the rising speed of peasants' income had slightly declined. Obviously, all the above factors do not possess a long-term stability. And it is a long-term and arduous task of building, perfecting and promoting a long-acting mechanism of increasing peasants' income. The second and third line in Table 4 shows real data of peasants' income and the model fitting values of the past 4 years respectively. The average relative prediction error of all historical data in model ARIMA (4, 2, 2) during the whole sample period from 1978 to 2008 is 3.18%. While, generally speaking, it is considered that a model would have very bad prediction ability if the prediction error is less than 10%[10]. Theil coefficient is 0.017. Further analysis shows a low biased error ratio while a high variance proportion of 95%. And clearly, data fitting has relatively ideal effect. Especially, relative fitting errors of the past two years are 0.09% and 2.93% respectively both of which are lower than historical average error, which also demonstrates that model property is quite reliable and can be used for short-term prediction. The fourth line in Table 4 shows the prediction values of peasants' income in future years. According to the prediction result, peasants' future income will increase at an annual average speed of 8.6% which is not only much lower than that of GDP in the same period, but also lower

than the average increasing rate of peasants' income in the past years. Besides, the increasing rate shows the feature of gradually descending from fast to slow with weak sustainability.

Table 4 Data fitting and future forecasting

Year	2005	2006	2007	2008
Fitting value	1 478.5	1 635.2	1 923.1	2 102.7
Actual value	1 520.9	1 702.3	1 905.8	2 042.6
Year	2009	2010	2011	2012
Predicated value	2 282.4	2 502.9	2 686.9	2 884.5

Note: Unit is yuan, the unchanging price of 1992.

4 Conclusion and discussion

Under the dual influence of internal regulatory demand after the sustainable and high-speed growth of macro-economy and the external shock caused by global financial crisis, there will be more stress on the growth of peasants' income in the future. Not only the promoting effect of the price increase of agricultural products will abate, but room for political increase will be also limited. This suggests that there are still some profound systematic constraints to be broken through urgently, especially the city-biased economic policy implemented for many years by local governments. Otherwise, it would be difficult to substantially transform the social problem of " difficult to increase farmers' income" which has been puzzling Henan Province and even the country[11].

To settle the problem of peasants' income growth, the strategic thought should be proposed from a higher level and with broader horizon. An all-round and fundamental revolution in economic and social system should be conducted thoroughly at the macro level of the country. Moreover, the actual provincial conditions and characteristics of Henan as a major province in population as well as agriculture and the core area of grain of national strategic project should be considered and integrated so as to establish and perfect matching systems and carry out pertinent political measures, such as implementing the strategy of " two regurgitation-feedings" , establishing and perfecting rural social security system, constructing the transfer payment system aiming at the equalization of public service and setting up and perfecting rural organizational system of finance as well as agricultural insurance system and so on.

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interests can be realized. In order to realize the sustainable development of land resources of Pingdingshan City, the government should perfect the land management system; take the overall plan of land use as the basis; strictly manage the use of land; control the total construction land use; promote the intensive land supply of different land types and different function areas; establish strict land protection mechanism; implement the system of connecting the land protection with the interests and prices; promote the land reclamation and consolidate the industrialization of land; and carry out the land consolidation according to the local conditions and reasonably develop the land resources which have not been exploited yet[5].

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