Total Factor Evaluation and Influencing Factor Analysis about Arable Land Productivity In Kaifeng City

Yongying HUANG[1,2*], **Liutao LIANG**[2]

1. Financial Division, Henan University, Kaifeng 475004, China; 2. College of Environment and Planning, Henan University, Kaifeng 475004, China

Abstract This paper uses DEA and Malmquist index to analyze the changes in arable land productivity in Kaifeng City during 2003 -2012. The results show that during 2003 -2011, Kaifeng's arable land productivity was inefficient in DEA-terms, indicating that the production resources were not rationally used; in 2012, Kaifeng's arable land productivity was efficient in DEA-terms, indicating that the ratio of input to output in 2012 was optimal; with the lapse of time, the Malmquist total factor productivity showed a trend of "increase-decrease-increase-decrease-increase", and the average technical efficiency was greater than 1, indicating that the agricultural production technology continues to advance. Using Tobit model, we analyze the factors that affect arable land productivity, and results show that the number of large and medium tractors and policy dummy variable have a significantly positive impact, while grain sown area has a significantly negative impact. Therefore, in order to improve arable land productivity in Kaifeng City, it is necessary to adhere to long-term stable agricultural support policy, improve the technological level of new agricultural modernization, increase investment in agricultural science and technology, and expand the sown area of cash crops.

Key words Arable land productivity, DEA, TFP, Tobit model

1 Introduction

Henan, located in the Central Plains, is one of the six provinces covered by China's strategy of "Rise of Central China". In 2012, National Development and Reform Commission officially issued "Central Plains Economic Zone Plan" (2012 -2020), and proposed that we should continue to explore the road of coordinated development of new urbanization, new industrialization, and new agricultural modernization (not at the expense of agriculture, food and environment). Obviously, the arable land use and economic production will change dramatically in Kaifeng City. DEA (Data Envelopment Analysis) is often used for the evaluation of agricultural or arable land productivity, and it has been widely used for the evaluation of agricultural productivity in different countries, provinces, and counties[1-7]. Fulginiti uses the total factor index in DEA to analyze the agricultural productivity of developing countries[8]. Jin Huaiyu and Jian Lirong use nonparametric Malmquist index to calculate China's agricultural TFP during 1996 -2009, and maintain that climate-induced natural disasters have a major negative impact on China's agricultural productivity[9]. Du Jiang uses global Malmquist production index to analyze the change of farming TFP in 29 provinces during 1978 -2011, and believes that technological progress promotes the growth of farming TFP[10]. Henan is a major agricultural province, and one of China's major grain producing areas, so the agricultural production evaluation in Henan Province has always attracted the researchers' attention. Sun Jiang and Yun Hongwan adopt DEA model to evaluate the agricultural productivity in 18 regions of Henan, and find that there is a significant difference in technical efficiency between different regions, and geographical environment and regional resource allocation can lead to differences in agricultural productivity[11]. Xuelong *et al.* use DEA and Tobit regression analysis to evaluate the grain productivity and its influencing factors in 18 cities of Henan during 2000 -2010, and believe that the yield per unit area and effectively irrigated farmland area can significantly promote grain productivity[12]. Fu Zhengyan *et al.* use DEA to analyze the agricultural productivity in 18 cities of Henan in 2012, and point out that regional and natural resource differences lead to differences in agricultural productivity[13]. Song Lili and Qin Mingzhou analyze farmers' income in various counties (cities) of Henan from 1993 to 2013, and recommend that efforts should be made to improve the level of agricultural modernization, coordinate regional economic development in various counties (cities), increase farmers' income, and improve regional development level[14]. Zhengzhou-Kaifeng integration and construction of Central Plains Economic Zone will have an enormous impact on the agricultural land in Kaifeng City, and the rapid development of industrial economy and rural urbanization will be bound to create a huge demand for agricultural land. In this context, it is necessary to study the arable land productivity in Kaifeng City, analyze the impact of various factors of production on productivity, and find out the key factors that affect arable land productivity, in order to provide a scientific basis for further improving agricultural production in Kaifeng City, and offer a decision-making reference for Zhengzhou-Kaifeng integration and construction of Central Plains Economic Zone.

2 Research methods and data sources

2.1 DEA model Data envelopment analysis (DEA), formally

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* Corresponding author. E-mail: hyy@henu.edu.cn

developed by Charnes, Cooper and Rhodes (1978), is a nonparametric method in operations research and economics for the estimation of production frontiers. It is used to empirically measure productive efficiency of decision making units (or DMUs). In this paper, we use output-oriented model of variable returns to scale to calculate and analyze the technical efficiency, scale efficiency and pure technical efficiency of DMUs, thereby achieving the evaluation of DMUs[15]. Economic productivity of arable land is the use efficiency of various resources used for arable land production. In this paper, technical efficiency reflects the overall efficiency of resources element use, configuration and scale in the process of arable land economic production; scale efficiency represents the efficiency of arable land production scale change; pure technical efficiency is the configuration and use efficiency of various input factors in the production process of arable land

2.2 Malmquist TFP index change Malmquist index is generally used to analyze the change in efficiency of DMUs at different times. Malmquist productivity index, based on DEA, was developed by Fare *et al.* in 1994. Malmquist productivity index is decomposed into resource allocation efficiency change and technical level efficiency change at two stages[16]. In this paper, with arable land area, agricultural fertilizer application rate and quantity of rural labor resources as input vector, total agricultural output value as output vector, we use Malmquist index based on DEA to perform the dynamic analysis of arable land production technical efficiency in Kaifeng City during 2003 – 2012.

2.3 Tobit regression model The Tobit model is a statistical model proposed by James Tobin (1958) to describe the relationship between a non-negative dependent variable and an independent variable (or vector). It is usually used for the further analysis of the factors that affect technical efficiency. According to the technical efficiency DMUs in DEA, we employ Tobit regression analysis suitable for data truncation, and use EViews6 to analyze various factors that influence technical efficiency.

2.4 Selection of indicators and data sources According to the location of Kaifeng City, the arable land produces food crops (summer grain and autumn grain), cash crops (cotton, oil), vegetables, melons and fruits, and the total output value of these crops is regarded as the output indicator. Input indicators of arable land productivity include crop sown area (10^3 ha), reflecting the arable land input to agricultural production; number of labor forces in farming (10^4); total agricultural machinery power (10^4 kW), reflecting the main agricultural technical input in arable land production; agricultural fertilizer application rate (calculated by pure discount, t), reflecting the main material consumption in arable land production. The above input and output indicator data are from *Kaifeng Statistical Yearbook* (2004 – 2013).

3 Calculation results and analysis

3.1 DEA model calculation results and analysis According to the statistics about Kaifeng City during 2003 – 2012, combined with output-oriented CRS model and standard DEA model, with year as DMU, we use DEAP (Version 2.1) to calculate TE (Technical Efficiency), PTE (Pure Technical Efficiency), SE (Scale Efficiency) and RTS (Returns to Scale) of arable land in Kaifeng City during 2003 – 2012 (Table 1). We can see from Table 1 that both TE and SE of arable land production in Kaifeng City during 2003 – 2011 were less than 1, indicating that the effectiveness of technology did not reach the ideal state, and under the existing resource and technical conditions, the production factors were not efficiently used for the arable land production in Kaifeng City. In terms of RTS, arable land productivity RTS in Kaifeng City always showed an increasing trend during 2003 – 2011, suggesting that the RTS was constantly improved during 2003 – 2011. In 2012, Kaifeng's arable land TE, PTE and SE were all 1, indicating that the effectiveness of technology was realized, and Kaifeng reasonably input crop sown area, labor, production technology and material consumption into arable land production. Fig. 1 shows the change in arable land productivity over time in Kaifeng City during 2003 – 2011. It can be seen that TE and SE of arable land production in Kaifeng City tend to increase from a macro point of view, but there are four different stages. Stage I (2003 – 2005): TE and SE rapidly increased. Stage II (2005 – 2008): TE and SE were basically stable. Stage III (2008 – 2010): TE and SE rapidly increased. Stage IV (2010 – 2012): After a slight decline, TE and SE increased. According to the slope of the curve, the growth rate of TE and SE in 2011 – 2012 was lower than in Stage I, III. From the RTS change over time, SE was 0.347 in 2003, at a relatively low level. The agricultural production in 2003 was affected by SARS, abnormal weather and pest disasters. Subsequently, it kept a growth trend. In 2012, RTS of arable land production remained unchanged, and TE and PTE reached 1, because Kaifeng City increased investment in agriculture in 2012.

Table 1 DEA results of arable land productivity in Kaifeng City

DMUs	*TE*	*PTE*	*SE*	*RTS*
2003	0.347	1.000	0.347	Increasing
2004	0.460	1.000	0.460	Increasing
2005	0.588	1.000	0.588	Increasing
2006	0.590	0.991	0.595	Increasing
2007	0.595	0.980	0.607	Increasing
2008	0.584	0.983	0.594	Increasing
2009	0.691	0.985	0.702	Increasing
2010	0.932	1.000	0.932	Increasing
2011	0.924	0.996	0.928	Increasing
2012	1.000	1.000	1.000	Constant
Average	0.671	0.993	0.675	–

3.2 Malmquist index calculation results and analysis Table 2 shows the arable land productivity change index (2003 – 2012) calculated using DEA Malmquist index model. As can be seen from Table 2, the average TFPCH (Total Factor Productivity Change) was 1.137, indicating that the arable land productivity showed a growing trend during 2003 – 2012; the average TECHCH

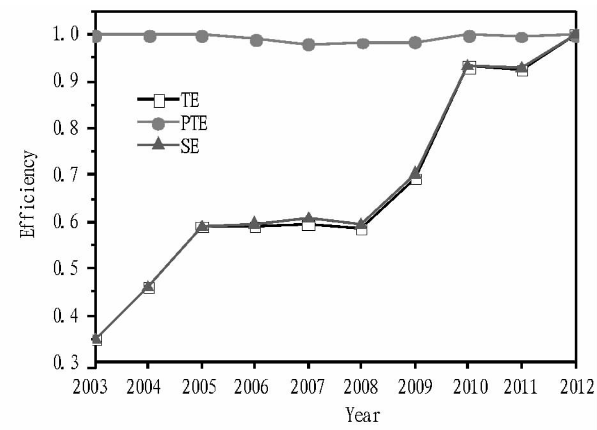

Fig. 1 Change of arable land productivity in Kaifeng City during 2003 – 2012

(Technological Change) was greater than 1, indicating that the production technology continued to progress. Except 2008 and 2011, both TFPCH index and TECHCH index in other years was greater than 1, indicating that arable land technology continued to advance, and productivity continued to increase. In 2008, the arable land productivity was more or less affected by the international financial crisis. Technological advances may be due to the increase in agricultural machinery. Fig. 2 shows the curve of arable land TFPCH in Kaifeng City over time. As can be seen from Fig. 2, during 2003 – 2012, the arable land TFPCH index in Kaifeng City showed an increasing-decreasing-increasing-decreasing-increasing trend. Compared with 2003, the arable land TFPCH index showed an increasing trend during 2004 – 2005, which was mainly due to SARS in 2003 and improvement in social and natural factors for arable land production. During 2005 – 2008, TFPCH showed a declining trend, which was mainly due to the impact of deteriorating international financial order on farm produce from arable land, and TFPCH was smallest amid 2008 international financial crisis. During 2008 – 2010, TFPCH index and TECHCH index showed a growing trend, and after the financial crisis, agricultural market gradually got better, and TFP increased. During 2010 – 2011, TFPCH index showed a decreasing trend, possibly because Kaifeng City achieved a new leap in the industrial economy in 2011, and the rapid development of secondary industry had a negative impact on the development of primary industry. During 2011 – 2012, TFPCH index presented a growth trend again, owing to the implementation of various types of agricultural support funds in 2016.

3.3 Tobit regression and the factors that affect arable land productivity change According to arable land production characteristics of Kaifeng City and TE obtained above, the factors that affect arable land productivity include number of large and medium tractors, number of sprinkler irrigation machinery and number of combine harvester (reflecting the production technique input during arable land production); crop sown area and grain sown area (reflecting the agricultural planting scale input). At the same time, given that the agricultural production is affected by national policy and farmers' enthusiasm, policy dummy variable is added to reflect the agricultural marketing and agricultural support capital size. With 2010 as the node, policy dummy variable is set (value of o during 2003 – 2009; value of 1 during 2010 – 2012). The above influencing factors are from Kaifeng Yearbook (2004 – 2013), to some extent representing the input factors, and they are regarded as the independent variables in Tobit regression model. Using Eviews 6.0, the panel data Tobit regression is performed on TE of arable land production in Kaifeng City during 2003 – 2012, and the regression model is as follows:

$$Y_j = C + \sum_{i=1}^{6} C_i X_{ij} \quad (1)$$

where C is the constant term of the regression equation; C_1, C_2, C_3, C_4, C_5 and C_6 are the parameters to be estimated for the corresponding independent variables, respectively, and it means the number of units increased or decreased by one variable for each additional unit of this variable when other factors are held constant[17]; Y_j is the technological efficiency in year j; X_{1j}, X_{2j}, X_{3j}, X_{4j}, X_{5j} and X_{6j} represent the number of large and medium tractors, number of sprinkler irrigation machinery, number of combine harvester, crop sown area (10^3 ha), grain sown area (10^3 ha), and policy dummy variable in year j, respectively.

Table 2 Productivity and efficiency changes of arable land in Kaifeng City

Year	EFFCH	TECHCH	PECH	SECH	TFPCH
2004	1	1.259	1	1	1.259
2005	1	1.300	1	1	1.300
2006	1	1.067	1	1	1.067
2007	1	1.025	1	1	1.025
2008	1	0.988	1	1	0.988
2009	1	1.197	1	1	1.197
2010	1	1.369	1	1	1.369
2011	1	0.999	1	1	0.999
2012	1	1.094	1	1	1.094
Average	1	1.137	1	1	1.137

Note: EFFCH represents technical efficiency change index; TECHCH represents technological change index; PECH represents pure technical efficiency change index; SECH represents scale efficiency change index; TFPCH represents total factor productivity change index.

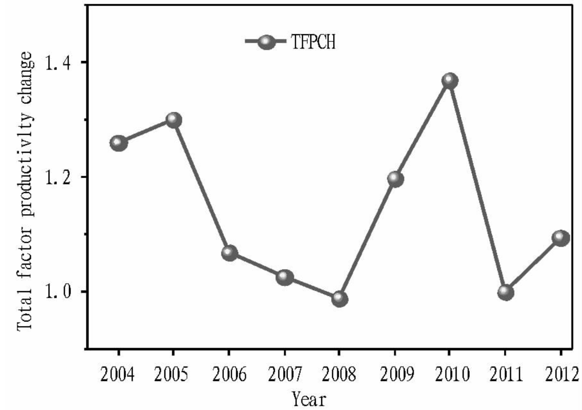

Fig. 2 TFPCH change of Kaifeng's arable land over time

Tobit regression results are shown in Table 3. As can be seen from Table 3, the occurrence probability P value of number of large and medium tractors, grain sown area and policy dummy variable is less than 0.1, passing the 10% significance level test[18], so they are the factors having a significant impact on the arable land productivity in Kaifeng City. (i) The number of large and medium tractors has a significant positive impact on the arable land productivity in Kaifeng City. The Tobit model regression results in Table 3 show that the number of large and medium tractors is positively correlated with the arable land productivity in Kaifeng City, and the larger the number of large and medium tractors, the higher the arable land productivity. This is mainly due to the fact that the number of large and medium tractors represents the level of mechanization or production technology in the process of arable land production. (ii) Major policy changes have a significant positive impact on arable land productivity. By setting the policy dummy variable, it can be found that as the focus of Central Government or Henan Provincial Government's policies changes, it will have a positive correlation with arable land productivity. Therefore, the policies of strengthening agricultural production will greatly affect the arable land productivity in Kaifeng City. (iii) Grain sown area has a significant negative impact on the arable land productivity. This result suggests that the economic efficiency of oil crops, vegetables, fruits and other crops is higher than that of grain, because with the ample grain supply, relatively stable prices and improved people's living standards, there is a significant increase in the price of cash crops such as oil crop, vegetables and melons. In this case, the increase in grain sown area will lead to a reduction in the sown area of other cash crops, thereby reducing the total agricultural output value.

Table 3 Tobit regression analysis results of the factors that affect arable land productivity in Kaifeng City

Variables	Coefficient	Standard deviation	Z-statistic	P value
C (constant)	-0.628364	1.87907	-0.334402	0.7381
X_1 (number of large and medium tractors)	5.61E-05	3.20E-05	1.754006	0.0794 *
X_2 (number of sprinkler irrigation machinery)	-1.19E-05	1.04E-05	-1.148533	0.2507
X_3 (number of combine harvester)	2.36E-05	3.99E-05	0.591648	0.5541
X_4 (crop sown area)	0.003113	0.002935	1.060696	0.2888
X_5 (grain sown area)	-0.003795	0.002228	-1.703177	0.0885 *
X_6 (policy dummy variable)	0.340887	0.163792	2.081218	0.0374 *

Note: * indicates that variables pass significance test at the 10% level.

4 Conclusions and recommendations

4.1 Conclusions In this paper, we use DEA and Malmquist index to analyze the changes in arable land productivity in Kaifeng City during 2003 - 2012. The results show that during 2003 - 2011, Kaifeng's arable land productivity was inefficient in DEA - terms, indicating that the production resources were not rationally used; in 2012, Kaifeng's arable land productivity was efficient in DEA - terms, indicating that the ratio of input to output in 2012 was optimal; with the lapse of time, the Malmquist total factor productivity showed a trend of "increase - decrease - increase - decrease - increase", and the average technical efficiency was greater than 1, indicating that the agricultural production technology continues to advance. Using Tobit model, we analyze the factors that affect arable land productivity, and results show that the number of large and medium tractors and policy dummy variable have a significantly positive impact, while grain sown area has a significantly negative impact. In summary, in order to improve arable land productivity in Kaifeng City, it is necessary to adhere to long - term stable agricultural support policy, improve the technological level of new agricultural modernization, increase investment in agricultural science and technology, and expand the sown area of cash crops.

4.2 Recommendations According to the evaluation and analysis of arable land productivity in Kaifeng City, we bring forward the corresponding recommendations in order to improve arable land productivity in Kaifeng City. Firstly, it is necessary to adhere to long - term, stable preferential agricultural policy, and continue to increase and strengthen it. Secondly, there is a need to put science and technology as the primary productive forces, improve the technological level of new agricultural modernization, and increase investment in agricultural science and technology. Thirdly, we must increase sown area of cash crops and increase farmers' income while maintaining stable grain production.

References

[1] Umetsu C, Lekprichakul T, Chakravorty U. Efficiency and technical change in the Philippine rice sector: A Malmquist total factor productivity analysis [J]. American Journal of Agricultural Economics, 2003, 85(4): 943 - 963.
[2] Alemdar T, Oren MN. Determinants of technical efficiency of wheat farming in southeastern Anatolia[J]. Journal of Applied Sciences, 2006, 6 (4): 827 - 830.
[3] Khai HV, Yabe M. Technical efficiency analysis of rice production in Vietnam[J]. Journal of ISSAAS, 2011,17(1): 135 - 146.
[4] Linh VH. Efficiency of rice farming households in Vietnam[J]. International Journal of Development Issues, 2012, 11(1): 60 - 73.
[5] LIANG LT, MEI Y. Analysis on China cultivated land productivity and its impacts - based on Malmquist Index[J]. Journal of Arid Land Resources and Environment,2011,25(8): 1 - 6. (in Chinese).
[6] HUA J, LI ZL, WU CJ. Research on increase in agricultural total - factor productivity in China based on three - stage DEA - malmquist model[J]. Acta Agriculturae Jiangxi,2015,27(10):134 - 141. (in Chinese).
[7] XUE L, LIU Q. Analysis of food production technical efficiency and total factor productivity of Henan Province[J]. Journal of Henan Agricultural University, 2013, 47(3): 345 - 350. (in Chinese).
[8] Fulginiti LE, Perrin RK. Agricultural productivity in developing countries [J]. Agricultural Economics, 1998, 19 (1 - 2): 45 - 51.
[9] JIN HY, JIAN LR. Calculation and analysis of agricultural TFP in China [J]. Journal of Northwest Sci - Tech University of Agriculture and Forestry (Social Science),2013, 13(2):29 - 35, 42. (in Chinese).

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swine breeding cost is not only influenced from self change, but also influenced from expansion of scale swine slaughter and expansion of scale of swine farms. The profit rate of swine breeding cost was completely influenced from self changes in the first period. However, with lapse of time, the influence dropped to 69% in the 10th period. The influence of changes in scale of swine slaughter increases with the period, and finally rises to 26.4%. Besides, changes in large-scale swine farms start to rise gradually and later decline, finally become stable at 4.19%.

From the above analysis, the profit rate of swine breeding cost is influenced by itself, but also influenced by scale of swine breeding and scale of swine slaughter. On long terms, the contribution rate is 69.4%, 26.4%, and 4.19% respectively. The impact of scale swine breeding is much greater than impact of large-scale swine farms. In sum, swine breeding farms and number of breeding promote changes of swine productivity.

Table 3 Variance decomposition of swine market performance

Period	S. E.	LNY	LNX1	LNX2
1	0.565050	100	0	0
2	0.570555	98.11836	0.023668	1.857970
3	0.604031	88.11236	7.838507	4.049136
4	0.629515	81.67767	13.84522	4.477105
5	0.644003	78.04700	17.43032	4.522687
6	0.660017	74.73534	20.86799	4.396675
7	0.673419	72.23397	23.53963	4.226397
8	0.683331	70.71991	25.15353	4.126563
9	0.691032	69.86231	26.02365	4.114040
10	0.696633	69.42350	26.38767	4.188834

6 Conclusions and policy recommendations

From the above analysis, in recent 10 years, China's swine industry received considerable development, market concentration rate is greatly increased. Data show that swine enterprises with annual slaughter more than 500 heads develop rapidly, while enterprises with annual swine slaughter less than 500 heads are shrinking. With the aid of VAR model, we made analysis of market concentration rate and market performance of China's swine industry, and used impulse response function and variance decomposition. We came up with following conclusions. Firstly, with rise in market concentration of China's swine industry, the corresponding market performance is also rising. Secondly, the influence of scale of swine slaughter on market performance is greater than large-scale swine farms. Major defects of this study: (i) we only considered the influence of profit rate of swine breeding cost on market performance. In fact, market performance is influenced by many external factors. (ii) The data of market concentration rate were replaced with data of breeding scale because it is difficult to collect relevant data. Therefore, for swine breeding, China should issue powerful regulations to encourage large-scale swine breeding, and maximize economic benefits and market welfare considering external problems possibly brought by large-scale breeding.

References

[1] ZHANG CG. The ever – changing domestic animal husbandry agriculture [J]. Guide to Chinese Poultry, 2009(21): 20 – 21. (in Chinese).

[2] QIAO YL, JI XG. An economic analysis on scale pig breeding and household's scatter breeding in China[J]. Chinese Journal of Animal Science, 2012(8): 14 – 19. (in Chinese).

[3] LI X, HAN YY, YAO S, *et al.* An empirical analysis on market concentration and firm performance of Chinese commercial banking industry [J]. Zhejiang Finance, 2011(7): 71 – 76. (in Chinese).

[4] ZHANG YY, SUN SM, PENG YS. Analysis on pig industrial organizations of Shandong Province based on SCP theory[J]. Shandong Agricultural Sciences, 2014(2): 145 – 151. (in Chinese).

[5] LU CH. To reduce the risk of pig industry and increase economic benefits-economic analysis of risk in pig industry[J]. Technoeconomics & Management Research, 2013(4): 17 – 21. (in Chinese).

[6] LONG MF, MA MZ. Introduction to industrial economics[M]. Chengdu: Southwestern University of Finance and Economics Press, 1996: 104. (in Chinese).

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[10] DU J. Agricultural total factor productivity growth and its spatial – temporal differences in China[J]. Science Research Management, 2015, 36 (5): 87 – 98. (in Chinese).

[11] SUN J, YUN HW, WANG RL, *et al.* Data envelopment analysis of the efficiency of agricultural production in Henan Province[J]. Journal of Henan Agricultural University, 2011, 40(6): 5 – 8, 12. (in Chinese).

[12] XUE L, LIU Q. Efficiency analysis of grain production in Henan Province based on DEA – Tobit model[J]. Journal of Henan Agricultural University, 2012, 46 (6): 700 – 704. (in Chinese).

[13] FU ZY, WANG YQ, WANG RB, *et al.* Data envelopment analysis of the efficiency of agricultural production in Henan Province [J]. Journal of Henan Agricultural University, 2014, 48 (6): 790 – 794. (in Chinese).

[14] SONG LL, QIN MZ, ZHANG PY, *et al.* Spatial – temporal difference and coordination degree evaluation between county farmers' income and economic development in Henan Province[J]. Journal of Henan University (Natural Science), 2016, 46 (1): 33 – 39. (in Chinese).

[15] WEI QL. Data envelopment analysis[M]. Beijing: Science Press, 2004. (in Chinese).

[16] Fare R, Grosskopf S, Norris M, *et al.* Productivity growth, technical progress, and efficiency change in industrialized countries[J]. The American Economic Review, 1994, 84 (1): 66 – 83.

[17] ZHANG XM. Basic econometrics[M]. Tianjin: Nankai University Press, 2001. (in Chinese).

[18] Nyagaka DO, Obare GA, Omiti JM, *et al.* Technical efficiency in resource use: Evidence from smallholder Irish potato farmers in Nyandarua North District, Kenya[J]. African Journal of Agricultural Research, 2010, 5 (11): 1179 – 1186.