Impact of farmers' differentiation on farmland-use efficiency: Evidence from household survey data in rural China

Xu HENGZHOU, Chen TONG

School of Management and Economics, Tianjin University, Tianjin, P.R. China

Abstract: Farmer differentiation has important implications for the efficiency of farmland use. Applying the model of DEA and Tobit, using the household survey data, this paper investigates the effects of the farmer stratum differentiation on the efficiency of farmland use. The empirical results showed that the type of farmer differentiation was positive and statistically significant at 5% level. The regression coefficient is 0.295; this result implies that if this variable improves one percentage, the efficiency of farmland use will increase by 29.5%. The farmer horizontal differentiation and farmer vertical differentiation pass the significance test at the 1% and 5% level, respectively. This indicates that they all have a significant positive impact on the farmland use efficiency. We conclude that corresponding measures should be implemented to further facilitate the farmer differentiation. Another implication of our results is that the policies matched with the farmer differentiation and transfer should be gradually perfected, and then they will provide a better environment of the society and economy for free migration of farmers.

Key words: farmer differentiation, farmland use efficiency, rural households

Farmland is not only the basic element for agricultural production, but also it is the essential resource and condition for the human being survival. Almost 90 percent of human food comes from the production of farmland, at the same time; the farmland has the function of food security, ecological security and social stability (Costanza et al. 1997; Yang and Li 2000; Lichtenberg and Ding 2008). Moreover, dynamic changes of farmland and its quality degree of effective utilization undoubtedly are the key issues which affect the regional sustainable development and food security, especially for China with its large population. At the end of 2010, China had about 0.10 ha of farmland per capita compared to 0.47 ha of cropland per capita in the United States and 0.69 ha per capita in the European Union. The government of China responded to these food security concerns by introducing a number of strict measures aimed at protecting farmland, especially farmland with the greatest production potential. Nevertheless, the tendency of farmland loss has not been improved, so obviously, in the years to come, the amount of farmland will continue to decrease. Meanwhile, with the rapid development of industrialization and urbanization, more and more farmland will be occupied, and thus it will further intensify the human-land conflict. Although the economic growth needs more farmland to be converted, only an efficient use can meet the harmony between the natural resource protection and economic growth. On this background, the most effective way for ensuring food security is to enhance the utilization efficiency of farmland on the basis of reinforcing the amount preservation of farmland (Deng et al. 2005). Whereas, farmland abandoned and extensive farming have caused a serious resources waste and it is an extremely unfavourable thing to ensure food security. Consequently, it has become a very exigent problem how to effectively make use of farmland; this also became the concerned focus of researchers and the government.

While the existing literature has reported many methods for studying the utilization efficiency of farmland, this includes the Stochastic Frontier Production Model (Sanzidur and Mizanur 2008), the Cobb-Douglas Productive Function (Deininger et al. 2008), the Data Envelopment Analysis approach (Yang et al. 2010) and the DEA-Tobit Two Step Method (Yang and Li 2011), etc. The above-mentioned works generally use the panel data to analyze, and from the perspective of the macroscopic level. However, from the micro-aspect of the farmland use, as the micro-

subject of agricultural production, economic behaviour of household always has had a direct impact on the farmland utilization efficiency. However, farmers in rural areas have been stratified during the China's socioeconomic transition, which phenomenon will cause some influences on the farmland use behaviour of household, and it will further affect the technical efficiency and the factor allocation efficiency in the process of farmland use. Therefore, under the background of the farmers' differentiation and the rapid development of rural economy, it is of a great significance to analyze farmland use efficiency of farmers of different strata. The present literature about the farmer differentiation mainly focused on the impact of the household differentiation (differentiation of farmland scale and concurrent business of farmers) on the agricultural production efficiency (Jiang 1995; Kong and Sun 1998; Fan and Chan 2005).

As the special case of social stratification, farmer differentiation also has two important characteristics: the specificity of function and the diversity of position. It also has two basic forms: one is the heterogeneity of farmers increasing; another is the changes of the farmers' social inequality (Liu 2009). The differentiation of vocation and income between farmers has lead to the difference of farmers in the resources endowment, the skill structure and the level of economic income. According to the theory of labour division and specialization, households will make the decision for resources allocation based on the resources endowment and the target of family production. This not only will realize the maximization of the production efficiency by reasonable utilization of resources, but also realize the specialization of production by a rational division among the family members, which will further improve the efficiency of production. While the social stratum enhanced the farmers' advantages of specialization and the competition to some extent, this favourably improves the efficiency of the farmland utilization for the farmers who are skilled in agriculture.

A little literature has analyzed the impact of the household differentiation (the type and degree of differentiation) on the agricultural production efficiency based on the perspective of sociology. Therefore, the objective of this paper is to examine the impact of the farmer stratum differentiation on the efficiency of the farmland use. To reach this objective, with the data of the farm household and village survey in the microscopic level, firstly, we employ the DEA model to calculate the efficiency of the farmland use; secondly, we use the Tobit model to discuss mainly the impact of the farmer stratum differentiation on the efficiency of farmland use.

METHODS AND DATA

There are two primary components to our empirical analysis. In the first, we estimate the efficiency of farmland utilization using the nonparametric DEA. In the second, we specify a Tobit model to examine the extent to which the farmer differentiation may be associated with the decision of the farmers to the efficient farmland utilization. In the following, we introduce the details of the analysis.

Methodology of DEA

The estimates of the efficiencies for rural households are based on the extensions of the Farrell's (1957) piece-wise linear convex hull approach to frontier estimation. In 1978, Charnes et al. (1978) extended the Farrell's measures of technical efficiency from a single-input, single-output process to a multiple-input, multiple-output process. Since then, this method has been referred to as the Data Envelopment Analysis (DEA), and it is a nonparametric method for measuring the efficiency of a decision-making unit (DMU). Any group of entities that receives the same set of inputs and produces the same set of outputs could be designated as a DMU; it could be a group of people, companies, hospitals, schools, industries, or countries (Morais and Camanho 2011). In this paper, we will consider the household as a decision-making unit (DMU), and construct a piece-wise surface (a frontier) over the production data for all households by the method of Fare (Fare et al. 1994). Measures of farmland use efficiency for each household are then calculated relative to that surface (Coelli et al. 2005). This is accomplished by calculating the best performance measure for each household, and comparing this measure with similarly calculated measures for all households. This comparison results in a ranking of the DMUs in terms of their relative efficiency, where the highest-ranking DMUs are considered relatively efficient and assigned a perfect score of 1, while the rest of the DMUs in the sample are considered to be relatively inefficient.

The DEA is a flexible method (Cook et al. 2010) that can be applied under different underlying economic assumptions about the returns to scale which yield different DEA models. An assumption of the constant return-to-scale (CRS) model reflects the situation where the changes in output are in the same proportion as the changes in inputs (e.g., changes of 50% in inputs correspond to the changes of 50% in outputs), while the assumptions of the variable returns-to-scale (VRS) model reflect increasing (e.g.,

changes of 25% in inputs correspond to the changes of 50% in outputs), and the non-increasing returns-to-scale (NIRS) model reflects decreasing (e.g., changes of 50% in inputs correspond to the changes of 25% in outputs) returns to scale. Under the imperfect market competition, the decision-making unit cannot operate in the optimal scale, therefore, the VRS model accords with the actual situation.

Tobit model

Since the dependent variable of the farmland use efficiency parameters varied between 0 and 1, the ordinary least square would produce biased and inconsistent estimates (Greene 2003). Therefore, in this paper, the dependent variables were censored and the Tobit regression was used to analyze the data. The Tobit models refer to regression models in which the range of the dependent variable is constrained or limited in some way (Amemiya 1984; Greene 1997). So, we can use the model like this:

$$Y_i^* = \boldsymbol{\beta}' \boldsymbol{X}_i + \varepsilon_i \qquad i = 1, 2, 3, \ldots, n$$

$$Y_i = Y_i^* \quad \text{if} \quad Y_i^* > 0$$

$$Y_i = 0 \quad \text{if} \quad Y_i^* \leq 0$$

where Y_i^* is a vector of the latent variable, X_i represents vector of the independent variables, Y_i is the observed variable, β is the vector of parameters to be estimated, ε_i is the vector of the error terms that are distributed normally with the mean 0 and variance σ^2, $i = 1, 2, 3, \ldots, n$ represents the number of observations.

Data and variable definitions

The data used in this paper were collected in a farm household survey in the Xiqing District, the Jinghai County, the Linqing City and the Guanxian County. The two former are located in the Tianjin City, bordering the Beijing City, the two final areas are located in the West of the Shandong Province. Selecting the study areas, the following two aspects were considered: firstly, there are more opportunities for the off-farm employment and diversification of farmer occupation; secondly, there is a certain disparity in economic development in two case areas. Based on this, with the method of simple random sampling, we selected three towns from every county, and three administrative villages from every town. In this survey, we got 485 questionnaires, then the questionnaires with omitted and false information were eliminated, and 439 ones were in effect, so that the effective rate was 90.52%.

The data were collected with the method of questionnaire survey and the participatory rural appraisal (PRA). The reason why choose the PRA method is that the farmers have differentiated into different strata, because of the difference of stratum and social position, the farmers have different cognition on the function of farmland, however, it was neglected usually by the method of traditional investigation.

The questionnaire was organized as follows: the first part is the basic information on the household, including family size, income, years of education, age and farmland endowment; section 2 includes the variables of tillage conditions and the cognition of the relevant policy; the third part is the condition of the farmer differentiation, mainly the differentiation of income and occupation.

The variables of the DEA method

In our analysis, land, capital and labour were the input variables. According to the practical investigation, they were represented by area of farmland measured in hectare, the expenditures of pesticide and fertilizer measured in RMB Yuan, the total power of agricultural machinery measured in kilowatt, labour in agricultural production measured by the number of workers. The output variable was the agricultural income of household, also measured in RMB Yuan.

The variables of the Tobit model

According to the existing literature and the actual investigation, we think that the influential factors of the farmland use efficiency mainly include six categories, namely the individual characteristics, the family characteristics, the variable of tillage condition, policy factors, the regional economy and the farmer differentiation.

Farmer characteristics were represented by gender, age and education. Age of the household head was used as a proxy for the family's farming experience. The effect of age on efficiency is ambiguous, depending on whether older farmers are more experienced or more likely to stick to farming traditions and less likely to adopt new technologies. Education of the household head was used as a proxy for the management skills of the family. The farmland use efficiency is expected to increase with education as education increases the household's ability to utilize the existing technologies and to make the farm management decisions (Battese and Coelli 1995).

Household characteristics were represented by the average income of the family, the proportion

of agricultural income, the farmland scale and the farmland fragmentation. Households with a higher average income of family are expected to face fewer obstacles in agricultural production, as they have more resources available for paying fixed costs and for obtaining the information needed to adopt new technologies. So the average income of family is expected to improve the farmland use efficiency. The household farmland scale is expected to have a positive impact on efficiency, because a larger land endowment implies the economy of scale. The square of this variable was added to the equation to capture the possible non-linearities in its impact. The number of plots in the household is an indicator of land fragmentation, which can have either negative or positive effects on efficiency (Tan 2005). On one hand, a larger number of plots needs more labour (Nguyen et al. 1996) and it may be more difficult to manage. On the other hand, it enables households to optimize their labour allocation over different crop species and seasons, especially if there is no market for agricultural labour (Fenoaltea 1976).

Tillage variables were represented by the total power of agricultural machinery, the multiple cropping index and the rate of efficient irrigation. Households with a better tillage are expected to be more efficient since they have more advantages available to implement the farm management practices in time.

The influence of policies on farmland use efficiency cannot be neglected, either. In our analysis, the policy variables were represented by agricultural subsidies and the guidance of agricultural technical staff. Agricultural subsidies consist of the direct allowance for grain, the high-class seeds subsidy and the agricultural machinery subsidy. Theoretically, agricultural subsidies improved the enthusiasm of farmers for planting crops, so they have a positive effect on the improvement of the farmland use efficiency.

Table 1. Descriptive statistics of regression variables

Variable	Description	Mean	Standard error
Individual characters			
Gender	male = 1; female = 0	0.715	0.426
Age	actual age	36.175	7.943
Education training	education years	6.824	1.253
Family characters			
Average family income	the ratio of the total population-income (USD)	504.021	317.226
Proportion of agricultural income	proportion of agricultural income (%)	0.483	0.561
Farmland scale per capita	farmland per capita (mu)	1.273	0.622
Farmland fragmentation	the number of plots in a household	2.172	0.935
Variable of tillage condition			
Total power of agricultural machinery	input of machinery power per unit area (kilowatt/mu)	1.246	0.472
Multiple cropping index	(%)	1.647	0.625
The rate of efficient irrigation	(%)	0.832	0.549
Variable of policy factors			
Agricultural subsidy	subsidy per unit area (USD/mu)	12.631	1.817
Guidance of agriculture technical staff	yes = 1; no = 0	0.436	0.538
Characteristics of regional economy			
Regional dummy variable	Tianjin = 1; Liaocheng City = 0	0.497	0.341
Characteristics of farmer differentiation			
Type of differentiation	agricultural labors = 1; peasant workers = 2; employees = 3; peasant intellectual = 4; individual workers and individual business = 5; private entrepreneurs = 6; township enterprisers = 7; executives of rural affairs = 8	5.572	0.603
Horizontal differentiation	the rate of non-farmer employment in a household (%)	0.387	0.472
Vertical differentiation	Engel coefficient in a household (%)	0.421	0.297

The characteristics of regional economy were represented by dummy variables. It was divided into two parts: the developed area and the undeveloped area.

The impact of farmer differentiation on the efficiency of farmland use is the core content of my thesis. According to the theory of social stratification, farmer differentiation was presented by two variables: the type of farmer differentiation and the degree of farmer differentiation. In our analysis, farmers were divided into eight strata; the degree of farmer differentiation includes the horizontal differentiation and vertical differentiation. These were denoted by the rate of the non-farmer employment and the Engel coefficient, respectively. Table 1 contains the descriptive statistics for all the independent variables.

EMPIRICAL ANALYSIS AND RESULTS

Calculation of the farmland use efficiency

The results indicated that the average value of comprehensive efficiency of the farmland use for all investigated households is 0.758, that is, the practical output occupied 75.8% of the ideal output, in other words, the space of efficiency improvement is 0.242. Therefore, the comprehensive efficiency is generally not too high (Table 2).

The investigated households are classified by the value of the comprehensive efficiency of the farmland use presented in Table 3.

From the distribution of the farmland use efficiency estimates, it was observed that 10.92% of the farmers in the sample achieved the comprehensive efficiency greater than 0.8, the number of households is 48; more specifically, in the sample, about 44.87% of farmers achieved the farmland use efficiency scores under 0.8 and above 0.6; 28.25% of farmers achieved the efficiency scores between 0.4 and 0.6; 9.56% of farmers achieved the efficiency scores less than 0.4 and higher than 0.2; and only about 4% of those surveyed achieved the farmland use efficiency scored less than 0.2. It has come to be a middle distribution which is "big in the middle and pointed in both ends". Therefore, it is necessary to analyze which factors affect the farmland use efficiency and the influence degree of farmer differentiation on the farmland use efficiency.

Impact of farmer differentiation on farmland use efficiency

In order to further understand the influence of farmer differentiation on the farmland use efficiency, the Tobit model based on the method of the maximum likelihood estimation was employed to empirically analyze the influential factors which affect the farmland use efficiency of households, especially the variable of farmer differentiation. Table 4 reports the estimated coefficients for influential factors of the farmland use efficiency.

The estimated coefficient of the type of farmer differentiation was positive and statistically significant at 5% level. This suggests that keeping other parameters constant, the type of farmer differentiation had a significant positive impact on the efficiency of the farmland use, the regression coefficient is 0.295. This result implies that if this variable improves by one percentage, the efficiency of farmland use will increase by 29.5%.

Among the two variables of the differentiation degree, the variable of horizontal differentiation is found to have a significant positive impact on the farmland use efficiency; it also passes the significance test at the 1% level. This suggests that keeping other parameters constant, the higher is the degree of the farmer horizontal differentiation, the higher is the farmland use efficiency of the household. A possible explanation is that the farmer horizontal differentiation virtually is the differentiation of occupation, according to the theory of labour division and specialization, the farmers with farming experi-

Table 2. The average of farmland use efficiency for all investigated households

Efficiency index	Comprehensive efficiency	Pure technical efficiency	Scale efficiency
Average efficiency of household	0.758	0.894	0.848

Table 3. Distribution of the farmland use efficiency

Comprehensive efficiency (CE)	$0 \leqslant CE \leqslant 0.2$	$0.2 < CE \leqslant 0.4$	$0.4 < CE \leqslant 0$	$0.6 < CE \leqslant 0$	$0.8 < CE \leqslant 1$
Amount of household	18	42	124	197	48
Percentage	4.10	9.56	28.25	44.87	10.92

ences will more intently on farm cropping, and the dependence of the likelihood on farmland will be aggregated. Therefore, the farmers will strive to improve the efficiency of the farmland use.

The variable of vertical differentiation is also found to have a significant positive impact on the farmland use efficiency; it also passes the significance test at the 5% level. The regression coefficient is 0.238 and this result implies that if this variable improves by one percentage, the efficiency of farmland use will increase by 23.8%. A possible explanation is that the degree of the farmer vertical differentiation was mainly measured by economic income of farmers, the advance of economic income made the farmer able to invest into farmland, so this will improve the efficiency of the farmland use.

The regression results of other significant control variables were also represented in Table 4. Among the variables of the individual characteristics, only educational training positively affected the farmland use efficiency. An explanation for this may be that farmers with a high educational background have a stronger capability to digest and absorb the agricultural technology, and they also have a strongly self-adapted ability for the changes of agricultural technology and environment. With respect to the effect of family characteristics, from the estimation results, the variable of the average family income is found to have a significant positive impact on the efficiency of the farmland use. The number of plots in a household negatively affected the farmland use efficiency, which indicates that the land fragmentation reduces the efficiency. A possible explanation is that the land fragmentation was unfavourable for the use of the large-scale agricultural machinery, and it increased the costs of the household cultivation and irrigation. To a certain extent, this reflects the necessity of a moderate scale management for farmland in the rural China.

The total power of agricultural machinery and the rate of efficient irrigation all positively affected the farmland use efficiency. This indicates that in order to improve the efficiency, it is necessary to pay more attention to the technology and capital during the process of the farmland use. As expected, agricultural subsidies have a positive effect on the farmland use efficiency. The impact of the dummy variable on efficiency was in the same way, which indicates

Table 4. Regression results of influential factors for the farmland use efficiency

Independent variables	Coefficient	Standard deviation	*t*-value	Significance
Gender	1.326	0.825	0.813	0.376
Age	0.843	0.672	1.756	0.182
Education	1.270**	0.438	4.975	0.039
Average family income	0.273**	1.216	4.532	0.042
proportion of agricultural income	0.518	0.727	1.528	0.193
Farmland scale per capita	–0.726	0.583	1.439	0.207
Farmland fragmentation	–1.372*	0.829	–3.706	0.052
Total power of agricultural machinery	0.428***	0.470	6.142	0.007
Multiple cropping index	0.573	0.254	2.072	0.139
the rate of efficient irrigation	0.184*	0.372	3.326	0.064
Agricultural subsidy	0.928**	1.523	6.285	0.027
Guidance of agriculture technical staff	0.219	0.834	1.724	0.194
Regional dummy variable	1.176*	0.768	3.583	0.056
Type of differentiation	0.295**	0.425	4.637	0.043
Horizontal differentiation	0.372***	0.684	6.351	0.006
Vertical differentiation	0.238**	0.476	3.916	0.043
Constant	0.837*	0.416	2.735	0.078
Adjusted R^2		0.795		
Log likelihood		83.562		

*significant at 10% level ($p < 0.10$), ** significant at 5% level ($p < 0.05$), *** significant at 1% level ($p < 0.01$)

that the economic development level was beneficial to the improvement of the farmland use efficiency.

CONCLUSIONS

Farmer differentiation has important implications for the efficiency of the farmland use. Applying the model of the DEA and Tobit, using the household survey data, this paper investigates the effects of the farmer stratum differentiation on the efficiency of the farmland use. The empirical results showed that the type of farmer differentiation was positive and statistically significant at 5% level. The regression coefficient is 0.295 and this result implies that if this variable improves one percentage, the efficiency of the farmland use will increase by 29.5%. The farmer horizontal differentiation and the farmer vertical differentiation pass the significance test at the 1% and 5% level, respectively. This indicates that they all have a significant positive impact on the farmland use efficiency.

In addition, among other control variables, the educational training, the average family income, the total power of agricultural machinery, the rate of efficient irrigation, agricultural subsidy and the regional dummy variable were all found to have a significant positive impact on the farmland use efficiency, however, the farmland fragmentation had a significant negative effect on the farmland use efficiency.

Based on the above conclusions, the corresponding policy implications are as follows: firstly, it is vital to enhance the cultural and professional quality of rural labour, to breed the advantage of the resource endowment for different farmer strata, thus it can provide a technical guarantee for farmers to choose different employment, and it will further facilitate the farmer differentiation; secondly, the integration of the urban and rural social security system must be implemented by phase and by step, in order to reduce the farmer' s anxiety about lacking the old-security, the policies matched with the farmer differentiation and transfer should be gradually perfected, such as how to solve the issues of the household registration system and the old-age security under the dual rural-urban system, and then it is necessary to provide a better environment of the society and economy for a free migration of farmers.

Acknowledgements

The authors are grateful to the National Natural Science Foundation of China (71203157 and 41101537) and the Research Center of Public Resources Management of Tianjin University for providing financial support to the research. We also like to thank Shi Shuqin and Wu Gancen for their valuable comments on earlier drafts versions of this paper. Of course the remaining mistakes belong to the authors.

REFERENCES

Amemiya T. (1984): Tobit models: A survey. Journal of Econometrics, *24*, 3–61.

Battese G.E., Coelli T. (1995): A model for technical inefficiency effects in a stochastic frontier production function for panel data. Empirical Economics, *20*: 325–332.

Charnes A., Cooper W., Rhodes E. (1978): Measuring the efficiency of decision making units. European Journal of Operation Research, *2*: 429–444.

Coelli T.J., Rao D.S., O'Donnel C.J., Battee G.E. (2005): An Introduction to Efficiency and Productivity Analysis. 2nd ed. Springer Science, Inc., New York.

Cook W., Liang L., Zhu J. (2010): Measuring performance of two-stage network structures by DEA: a review and future perspective. Omega, *38*: 423–430.

Costanza R., d'Arge R., Groot R. et al. (1997): The value of the world' s ecosystem services and natural capital. Nature, *387*: 253–260.

Deininger K., Jin S., Hari K. (2008): Efficiency and equity impacts of rural land rental restrictions: Evidence from India. European Economic Review, 52: 892–918.

Deng X., Huang J., Rozelle S. (2005): Change of farmland and its impacts on agricultural bioproductivity in China. China Soft Science, 5: 65–70.

Fan S., Chan-Kang C. (2005): Is small beautiful? Farm size, productivity, and poverty in Asian agriculture. Agricultural Economics, *32*: 135–146.

Fare R., Grosskopf S., Lovell C. (1994): Production Frontiers. Cambridge University Press, New York.

Farrell M.J. (1957): The measurement of productive efficiency. Journal of the Rural Statistical Society, Series A, *120*: 253–290.

Fenoaltea S. (1976): Risk, transaction costs, and the origin of medieval agriculture. Exploration in Economic History, *13*: 129–151.

Greene W.H. (1997): Econometric Analysis. Limited dependent variable models (Ch. 22). Prentice-Hall, Inc., New Jersey.

Greene W.H. (2003): Simulated likelihood estimation of the Normal-Gamma stochastic frontier function. Journal of Productivity Analysis, *19*: 179–190.

Jiang C.Y. (1995): Dynamic analysis on farmer differentiation during the course of urbanization. Chinese Rural Economy, *9*: 50–56.

Kong X.Z., Sun T.S. (1998): Comparative analysis of investment behavior of different types of farmers. Economic Survey (China), *3*: 76–80.

Lichtenberg E., Ding C. (2008): Assessing farmland protection policy in China. Land Use Policy, *25*: 59–68.

Liu H.R. (2009): Pragmatic series research on farmer s class diversification in the beginning of the century. Issues in Agricultural Economy (China), *5*: 55–62.

Morais P., Camanho A. (2011): Evaluation of performance of European cities with the aim to promote quality of life improvements. Omega, *39*: 398–409.

Nguyen T., Chen E., Findlay C. (1996): Land fragmentation and farm productivity in China in the I990s. China Economic Review, *7*: 169–180.

Sanzidur R., Mizanur R. (2008): Impact of land fragmentation and resource ownership on productivity and efficiency: The case of rice producers in Bangladesh. Land Use Policy, *25*: 95–103.

Tan S. (2005): Land fragmentation and rice production: a case study of small farms in Jiangxi Province, P.R. China. [PhD Thesis.] Wageningen University, Wageningen.

Yang C.H., Wu L., Lin H.L. (2010): Analysis of total-factor cultivated land efficiency in China's agriculture. Agricultural Economics – Czech, *5*: 231–242.

Yang H., Li X. (2000): Cultivated land and food supply in China. Land Use Policy, *17*: 73–88.

Yang S., Li S. (2011): Study on the farmland use efficiency and its influencing factors in Shanxi province. China Land Science, *25*: 47–54.

Received: 5th November 2012
Accepted: 3rd January 2013

Contact address:

Xu Hengzhou, School of Management, Tianjin University, No.92 Weijin Road, Nankai District, Tainjin, China, 300072
e-mail: xuhengzhou@163.com