DE GRUYTER OPEN

*Folia Oeconomica Stetinensia*
DOI: 10.1515/foli-2016-0005

WYDZIAŁ NAUK EKONOMICZNYCH I ZARZĄDZANIA
UNIWERSYTET SZCZECIŃSKI

# MODELLING OF EFFICIENCY CHANGE AS A SOURCE OF ECONOMIC GROWTH IN AGRICULTURE

Agnieszka Bezat-Jarzębowska, Ph.D., Eng.[1]

Prof. Włodzimierz Rembisz[2]

*Institute of Agricultural and Food Economics – National Research Institute*
*20, Swietokrzyska street, 00-002 Warsaw, Poland*
[1] *e-mail: bezat@ierigz.waw.pl*
[2] *e-mail: rembisz@ierigz.waw.pl*

**Received 9 November 2015, Accepted 11 June 2016**

## Abstract

In the paper, the subject of economic growth in agriculture was raised. One of the determinants of this process, namely an efficiency change was under the assessment. The aim of the paper was to evaluate the changes of efficiency in the Polish agriculture. In the study, a stochastic parametric production function was used.

**Keywords:** economic growth, efficiency, agricultural holdings, the SFA method, panel data

**JEL classification:** O12

## Introduction

Economic growth is a subject of a permanent interest on the part of not only economists, but, in fact, of the whole societies, due to its key significance to the economic prosperity. Traditionally, in the mainstream economics, the key factors to stimulate the economic growth in the short term are the consumer and investment demand, both domestic and foreign, and, on the other hand, in the long term – the sufficient supply and efficiency of productive factors. The agricultural sector is also subject to these universal principles of the market mechanism.

The factors determining the development of agriculture may be divided into internal (endogenous) and external (exogenous) ones. The external conditions include a large number of factors more or less directly affecting the transformations taking place in agriculture (mainly changes in the regulations and agricultural policy, manifesting themselves, *inter alia*, in the scope and level of the support for agricultural producers). What depends mainly on the producer (an endogenous condition), is the improvement in the efficiency of production (improvement in the technical, economic, allocation, and structural efficiency). It is also the condition defining this concept. The speed of the improvement in the efficiency of production is determined by the speed of changes in the productivity of the capital factor, and by the labour productivity growth rate. In fact, this results from the producer's striving for achieving the balance, which is based on the profit maximisation. In particular, this is the maximisation of production from the given resources of productive factors, with the specific production function, and available technologies. The theoretical basis is here the issue of a technical progress, expressed by the improvement of efficiency.

Efficiency of economic entities is not an unambiguous term. There are several different concepts of efficiency, its measurement, and expressions. Within the framework of efficiency, many terms of a similar meaning may be applied. However, these concepts are not identical, and the actual concept of efficiency is derived from the structure of the production function, therefore, is conditioned by the changes in the productivity of production factors and their remuneration, and refers to the allocation of the production factors in the most technically efficient way. Thus, the concept of the production function as a base for analytical considerations and an application tool was used in the paper.

In the paper, attention was devoted to analysing the endogenous sources of the economic growth in agriculture. The use of the factors of production (land, labour, capital) was analysed, specifying the efficiency of agricultural holdings, and the tendency of efficiency changes in the period 2004–2013.

## 1. Production function

The analysis of the economic growth may be carried out based on the main assumptions on the production function, i.e. a relationship between the factors of production and net production (value added, GDP) *Y* (Gomułka, 2008):

$$Y = f(\mathrm{T}, K, L, H, IN, P) \tag{1}$$

where *f* is the production function, *K*-capital, *L*-labour, *T* is the level of technology in the economy, *H* is human capital per employee, *IN* are institutions, and *P* is the economic policy. In relationship (1), there are two sources of economic growth, namely, the sources dependent on a given entity (capital, labour, technology, human capital) – endogenous, and those on which the producer has no influence (institutions, policy) – exogenous.

In the context of the analyses of the endogenous sources of economic growth, the production function is used. In the literature, it is assumed that the production function illustrates the available and effectively used production techniques, as it specifies the maximum value (Y) of the product (production) possible to obtain with the given level of involving the production factor(s) (X). In this sense, the production function reflects the given state of technology, including the used technology, organisation, knowledge, experience (Rembisz, 2005). The basic relationship in the economic sense is formed between the involved factors of production (productive factors) and the obtained product(s). We define it as the factor-product relationship. It defines the efficiency of production, determined by the given technology (technological and engineering dependencies). The factor-product relationship is one of the main theoretical characteristics of the production process, as it is directly related to the implementation of the function of the producer's objective. Improving the factor-product relationship, i.e. improving the efficiency of production, is an endogenous source of economic growth.

The structure of the production function is here indispensable research and an analytical tool. It presents the relationship between the endogenous factors of economic growth. In a general form, we have:

$$Y = f(\mathrm{T}, \mathrm{K}, \mathrm{L}, \mathrm{R}) \tag{2}$$

where:

*K* – capital inputs,

*L* – labour inputs,

*R* – natural resources inputs.

An important element distinguishing between the production processes in agriculture and the production processes in other sections and branches of the economy, and generally expressed in economics, is the use of a land factor in the agricultural sector. Due to this, the Cobb-Douglas function must be supplemented by the land factor, which determines the essence of the management process in agriculture. In the analyses on agriculture, the Cobb-Douglas function is often used.[1] We formulate it as:[2]

$$Y = AL^{a_1}K^{a_2}Z^{a_3} \tag{3}$$

where:

- $Y$ – (final) production,
- $L$ – labour factor (may be expressed as labour inputs in days),
- $K$ – capital factor(capital may be expressed as fixed asset inputs (measured by depreciation) and material inputs,
- $Z$ – land factor (may be expressed as the area of agricultural land in ha).

Generalisation of the Cobb-Douglas function is the translogarithmic production function. The three-factor function is formulated as:

$$\begin{aligned} \ln(Y) = {} & \ln(A) + a_1\ln(L) + a_2\ln(K) + a_3\ln(Z) + b_{11}\ln(L)\ln(L) + \\ & + b_{22}\ln(K)\ln(K) + b_{33}\ln(Z)\ln(Z) + b_{12}\ln(L)\ln(K) + b_{13}\ln(L)\ln(Z) + \\ & + b_{23}\ln(K)\ln(Z) = f(L,K,Z) \end{aligned} \tag{4}$$

The analysis of efficiency requires the adoption of a function describing the input-output relationship. In the paper, both algebraic forms, i.e. the Cobb-Douglas production function and the translogarithmic function, were implemented. The objective of the paper was to evaluate the efficiency changes in the Polish agricultural sector. To evaluate the efficiency, we applied the Stochastic Frontier Analysis (SFA).

In the further part of the paper, the methodological assumptions are clarified. The research chapter includes the presentation of the results and their interpretation. The final part includes

---

[1] The functions most often used in empirical studies are the Cobb-Douglas function and translogarithmic function (cf. Fried, Lovell, Schmidt 2008: 16–20). The Cobb-Douglas function was applied by, *inter alia*: Z. Yuan (2011), pp. 5916–5922; P.D. Constantin, L.M. Martin, E.B. Rivera (2009), pp. 20–34; C. Echevarria (1998, pp. 63–75; W. Meeusen, J. van den Broeck (1977), pp. 435–444.

[2] In the study by W. Rembisz, *Micro- and macroeconomic bases for the growth in the agri-food sector,* the three-factor function was usedin the analysis, characterising the production in agriculture with Tinbergen's modification: $Y = AK^{\alpha}L^{\beta}Z^{\delta}e^{ut}$ and in the intense form for agriculture (per land factor unit) as: $Q = A(\frac{L}{Z})^{\varphi}(\frac{K}{Z})^{\phi}e^{ut}$ and in the logarithmic form (growth rates): $q = \varphi k + \phi l + ut$, which implicitly assumed the homogeneity of degree 1 (Rembisz 2008, pp. 248–253).

the conclusions drawn from the study, and the reference to the efficiency changes in the context of the economic growth in agriculture.

## 2. Methodology

The efficiency evaluation method is the SFA, which bases on the production function. It is a widely used stochastic procedure of the parametric creation of the efficiency frontier. With the SFA as a parametric approach, it is required to identify *a priori* the functional form defining the input(s)/output relationship. The frontier model, being a base for the evaluation of the efficiency, apart from the production function, includes two random components, one of which reflects the random noise (measurement errors or random effects caused by e.g. the impact of weather conditions), and other models of the potential inefficiency (Mortimer, Peacock, 2002). The efficiency frontier is determined econometrically using the method of least squares and its derivatives, or the method of maximum likelihood (Coelli, Rao, O'Donnell, Battese, 2005). In order to select the functional form that best describes the relationship between the analysed variables, the likelihood ratio is applied. The $\gamma$ indicator showing the proportion of inefficiency in the total variance of variables is also assessed.

In the paper, a model for panel data proposed by Aigner, Lovell and Schmidt (Aigner, Lovell, Schmidt, 1977, pp. 21–37), and developed by Coelli, Prasada and Rao (Coelli, Prasada, Rao, 1998) was used:

$$\ln y_{it} = f(x_{j,it}, t, \beta) + \varepsilon_{it} \tag{5}$$

where:

$$\varepsilon_{it} = v_{it} - u_{it} \tag{6}$$

with

$$v_{it} \sim N(0, \sigma_v^2)\ ^{3} \tag{7}$$

and

$$u_{it} \sim N(\mu, \sigma_u^2)\ ^{4} \tag{8}$$

The equation (5) assumes the following form:

$$y_{it} = \exp f(x_{j,it}, t, \beta) \times \exp(v_{it}) \times \exp(-u_{it}) \tag{9}$$

---

[3] Variance of the random component.

[4] Variance of the component specifying inefficiency.

where:

$f(\cdot)$ – means the appropriate functional form (e.g. Cobb-Douglas function, trans-logarithmic function),

$y_{it}$ – specifies the effect of the $i$-th agricultural holding over time $t$,

$x_{j,\,it}$ – specifies the $j$-th input of the $i$-th agricultural holding over time $t$,

$\beta$ – vector of parameters for estimation,

$v_{it}$ – a component specifying measurement errors or random effects caused by e.g. the influence of weather conditions,

$u_{it}$ – a component specifying the technical efficiency (TE).

## 3. Evaluation of efficiency using the SFA method

The study group were 4,233 agricultural holdings keeping accounting records within the framework of the FADN system,[5] continuously in the years 2004–2013 (the selection of the temporal range was determined by the data availability). The efficiency of the analysed companies has been determined with respect to three inputs: total labour (identified within the framework of the FADN system as SE010), area of land(in ha SE025), and ʻcapital inputs' defined by total costs (identified within the framework of the FADN system as SE270). The resulting value, i.e. the product, has been defined by the value of the final production (the sum of total crop production – SE135, SE206; total livestock production – SE206; and total other production – SE256). The estimation of the parameters has been carried out for two functional forms, i.e. Cobb-Douglas function and translogarithmic function.

$$\ln y_{it} = \beta_0 + \sum_{j=1}^{k} \beta_j \ln x_{j,it} + v_{it} - u_{it} \tag{10}$$

$$\ln y_{it} = \beta_0 + \sum_{j=1}^{k} \beta_j \ln x_{j,it} \sum_{j=1}^{k} \sum_{h=1}^{k} \beta_{jh} \ln x_{j,it} \ln x_{h,it} + v_{it} - u_{it} \tag{11}$$

The parameters of the models (10) and (11) have been estimated using the method of maximum likelihood in the R programme. The comparison of the two selected functional forms (Cobb-Douglas model and translogarithmic model) has been made on a basis of the statistics of a likelihood ratio test.[6] A basis for the study was the hypothesis $\mu_n, \upsilon_m \geq 0$, that means the

[5] Farm Accountancy Data Network.

[6] The LR statistics assumes the form of: $LR^* = -2[\ln L(\hat{\theta}_R) - \ln L(\hat{\theta}_N)]$, where: $\ln L(\hat{\theta}_R)$ – logarithm of the value of the greatest likelihood of the model with restrictions (Cobb-Douglas model), $\ln L(\hat{\theta}_N)$ – logarithm of the value of the maximum likelihood of the model without restrictions (translogarithmic model). The test statistics (LR*) assumes the

adoption of restrictions for the vector of parameters $\boldsymbol{\Theta}$ (equivalent to the adoption of the Cobb-Douglas model). The likelihood ratio values and the verification of the hypothesis regarding the selection of the functional form are presented in Table 1.

Table 1. Likelihood ratio values and verification of the selection of the functional form

| $\ln L(\hat{\theta}_R)$ | $\ln L(\hat{\theta}_N)$ | LR* | Verification of hypothesis[a] |
|---|---|---|---|
| 2,814.529 | 2,918.847 | 8.636 | No reason to reject $H_0$ |

[a] The value of the $\chi^2$distribution for 6 degrees of freedom and with the statistical significance of 0.05 amounted to 12.59 in all the analysed years.

Source: own calculation.

It was stated that there was no reason to reject $H_0$, which means that the functional form which to a better extent describes the input/output relationships is the Cobb-Douglas model. Hence, the results of the analyses based on this function are presented in the further part. The results of the estimation of the Cobb-Douglas function parameters are presented in Table 2.

Table 2. Results of estimation of the Cobb-Douglas function parameters using the method of maximum likelihood

| Specification | Parameter estimate | Standard error | Value *z* | Pr(>\|z\|) | Significance |
|---|---|---|---|---|---|
| Constant | 1.569 | 0.033 | 47.282 | 2.2e-16 | *** |
| log(SE010) | 0.078 | 0.004 | 19.114 | 2.2e-16 | *** |
| log(SE025) | 0.070 | 0.004 | 19.306 | 2.2e-16 | *** |
| log(SE270) | 0.893 | 0.003 | 19.497 | 2.2e-16 | *** |
| γ | 0.453 | 0.009 | 47.012 | 2.2e-16 | *** |
| t (time) | –0.0038 | 0.001 | –3.852 | 0.00011 | *** |

Signif. codes: 0.01 – ***.

Source: own calculations.

The values of the Cobb-Douglas function parameters represent the elasticity of the changes in the dependent variable, in relation to the changes in the independent variable. In these studies, the elasticity values have not been imposed, nevertheless, in accordance with the microeconomic theory of production, it was expected that they would assume the values from the range (0.1).[7] The results show that this requirement has been met in the case of all

chi-square distribution ($\chi^2$) with the degrees of freedom equal to the difference in the number of parameters in the null hypothesis and in the alternative hypothesis.

[7] Cf. the study by J. Marzec, A. Pisulewski (2013), pp. 255–271.

parameters. The results obtained are consistent with those presented by, *inter alia*: Brümmer, Glauben, Thijssen (2002), and Marzec, Pisulewski (2013).

Based on the obtained parameters, it may be concluded that the output (production value = product) shows the highest elasticity in relation to the capital factor inputs. The production elasticity in relation to the capital factor amounts to 0.893. The capital factor (operating costs) is characterised by the price given exogenously. The reverse situation takes place in the case of the labour factor, whose remuneration is shaped endogenously. As it results from the conducted study, the production elasticity in relation to the labour factor – log(*SE010*), Table 2 – is very low, and points to its small importance in shaping the result value, as with the increase in the labour factor by 1%, the value of production increases by 0.078%. A similar situation is in the case of the land factor – the production elasticity in relation to this factor amounts to 0.07. A decrease in the importance of the labour and land factors for the benefit of the capital factor, demonstrated in the study, is in line with current trends in agriculture consisting in shifting from labour- and land-intensive techniques to capital-intensive, and labour- and land-saving techniques. In the process of growth, there are the above-mentioned changes in the production techniques. The paths of the agricultural development in general terms are like that.[8]

The sum of exponents in the Cobb-Douglas function informs about the proportion taking place between the increase in the production value and in the factors of production. The sum of the Cobb-Douglas function's parameters exceeding one[9]shows that the output increases faster than the inputs (in the analysed group, there are increasing returns to scale). In these studies, the sum of the estimated parameters is 1.04, which shows that in the analysed period, i.e. 2004–2013, the production value increased faster in relation to the increase in the involved factors of production. This means that in the analysed period in the analysed group of agricultural holdings, we could observe the increasing returns to scale.

In the context of the research objectives adopted in the paper, the major emphasis has been put on the interpretation of the results regarding the efficiency of the analysed holdings. The evaluation of the impact of the technical inefficiency on the deviations of objects from the production function has been carried out using the $\gamma$ parameter:

$$\gamma = \frac{\sigma_u^2}{\sigma_u^2 + \sigma_v^2} \tag{11}$$

[8] Cf. model by Herlemannand Stamer specified by W. Rembiszand, Z. Floriańczyk (2014).

[9] In classical terms, the Cobb-Douglas function is homogeneous, which means that the production grows in proportion to the growth in inputs, i,e. this function illustrates such a technique, which is characterised by fixed returns to the scale. In the case of introducing into the Cobb-Douglas function the third or subsequent variable on the part of inputs, the assumptions on the homogeneity of the function are cancelled (the function remains homogeneous but not homogeneous in degree 1), which means that the sum of exponents may be different from one (cf. Rembisz 2011).

The parameter $\gamma$ assumes the values of $0 \leq \gamma \leq 1$ and shows what proportion of the total variance of the variables is inefficiency.[10] With the significance level of 0.01, it may be assumed that in the analysed sample more than 45% of the variance results from the inefficiency of agricultural holdings, therefore, more than 50% of the variance results from the presence of the random component. The value of the $\gamma$ index confirms the validity of applying the stochastic method (SFA), which allows to take into account the random noise (component $v_{it}$, equation (9)).[11]

The average efficiency of the analysed group in the individual years of analysis is presented in Table 3.

Table 3. Average, minimum and maximum value of the efficiency index in the analysed group of agricultural holdings in the years 2004–2013

| Specification | Year | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | 2004 | 2005 | 2006 | 2007 | 2008 | 2009 | 2010 | 2011 | 2012 | 2013 |
| min. | 0.275 | 0.273 | 0.272 | 0.271 | 0.269 | 0.268 | 0.267 | 0.265 | 0.264 | 0.263 |
| average | 0.699 | 0.698 | 0.698 | 0.697 | 0.696 | 0.695 | 0.694 | 0.693 | 0.692 | 0.691 |
| max. | 0.989 | 0.989 | 0.989 | 0.989 | 0.989 | 0.989 | 0.989 | 0.989 | 0.989 | 0.989 |

Source: own calculations.

The average efficiency index amounted to about 0.7 which means that the efficiency of individual agricultural holdings could have been increased by, on average, 30% in relation to the best agricultural holdings in the analysed group. It was observed that the efficiency index value decreased in the analysed years. This trend is also confirmed by the time component value (*t*, time, Table 2). This index assumes the negative value of -0.0038, at the significance level of less than 1% . The conducted studies indicate the decreasing efficiency of agricultural holdings keeping accounting records under the FADN system in the years 2004–2013. On the other hand, within the framework of the agricultural policy, the increasing share of support in the production value is observed (cf. Bezat-Jarzębowska, Rembisz, 2013). It should be noted that (as stated in the initial part of the paper), the source of economic growth in agriculture are both internal (efficiency changes), and external factors (political conditions, including the scope and level of support).Naturally, an agricultural producer reaches to both these sources of the income evolution and growth, i.e. to the improvement in the efficiency, and to external funding

[10] The $\gamma = 0$ value means that the deviations of objects from the efficiency frontier result from errors in the model specification and the occurrence of the random component while they do not result from the inefficiency (cf. Sellers--Rubio, Más-Ruiz 2009, pp. 652–669).

[11] This aspect is very important in the case of agriculture which is characterized by the random effects caused by e.g. the influence of weather conditions.

sources (*inter alia*, support in the form of payments). However, the producers, in their rational behaviour, reach, to a greater extent, to this source which is more useful, i.e. gives better results in relation to costs (efforts) associated with it (adapting flexibly to the exogenous conditions, *inter alia*, changes in the agricultural policy) (Bezat-Jarzębowska, Rembisz, 2013). So, we may ask a question whether the changes in the regulations and economic policy (in particular, in the agricultural policy) do not affect the efficiency changes taking place among agricultural holdings. The aspect of the evaluation of substitutional dependencies between these two sources of economic growths will be a subject of further studies. Based on the considerations and analyses made in this paper, it may be concluded that the endogenous factor, being a component of the economic growth (i.e. efficiency changes) in agriculture, showed a downward trend in the years 2004–2013.

## Conclusions

The paper raised the issue of the economic growth in agriculture. It has been indicated that the factors determining the development of agriculture may be divided into external (mainly changes in the regulations and agricultural policy, manifesting themselves, *inter alia*, in the scope and level of support for agricultural producers), and internal (efficiency changes) ones. As a part of the study, particular attention was devoted to the evaluation of this second determinant of the economic growth in agriculture. The objective adopted in the paper was to evaluate the efficiency changes among agricultural holdings keeping accounting records within the framework of the FADN system. The studies covered the years 2004–2013. The study applied the parametric stochastic production function (SFA).

It has been shown that in the years 2004–2013 in agricultural holdings keeping accounting records within the framework of the FADN system, the efficiency index showed a downward trend. The average efficiency index amounted to 0.7. The downward trend in the efficiency changes is also indicated by the time component value (–0.0038, with the significance level of less than 1%) included in the model (equation (10), Table 2). Based on the obtained results, it was stated that the main element affecting the resultant value (production value) was the capital factor. The production elasticity with respect to that factor amounted to 0.893. The growing importance of the capital factor in shaping the resultant value (production value), demonstrated in the study, is in line with the current trends in agriculture consisting in shifting from labour- and land-intensive techniques to capital-intensive, and labour- and land-saving techniques.

As it results from the review of the literature and the studies conducted by the authors of the paper, the downward trend with regard to the efficiency among agricultural holdings (endogenous changes in the economic growth) may be due to – on a basis of substitutability – the growing importance of the external sources of support for the agricultural production (exogenous changes in the economic growth).

## References

Aigner, D.J., Lovell, C.A.K., Schmidt, P. (1977). Formulation and estimation of stochastic frontier production functions. *Journal of Econometrics*, *6*, 21–37.

Bezat-Jarzębowska, A., Rembisz, W. (2013). Political and economic rent as a source of income of the agricultural producer. In: A. Kowalski, P. Chmieliński, M. Wigier (eds.), *Economic, social and institutional growth factors in the agri-food sector in Europe* (pp. 28–41). Warsaw: IAFE-NRI.

Brümmer, B., Glauben, T., Thijssen, G. (2002). Decomposition of Productivity Growth Using Distance Functions: The Case of Dairy Agricultural holdings in Three European Countries. *American Journal of Agricultural Economics*, *84*, 628–644.

Coelli, T., Prasada, R.D.S., Battese, G.E. (1998). *An introduction to efficiency and productivity analysis.* Boston: Kluwer Academic.

Coelli, T.J., Rao, D.S.P., O'Donnell, Ch.J., Battese, G.E. (2005). *An introduction to efficiency and productivity analysis.* 2. Edition. New York: Springer.

Constantin, P.D., Martin, L.M., Rivera, E.B. (2009). Cobb-Douglas, Translog Stochastic Production Function and Data Envelopment. *Journal of Operations and Supply Chain Management. International Conference of the Production and Operations Management Society*, *2* (2), 20–34.

Echevarria, C. (1998). A three-factor agricultural production function: the case of Canada. *International Economic Journal*, *12* (3), 63–75. DOI:10.1080/10168739800000029.

Fried, H.O., Lovell, C.A.K., Schmidt, S.S. (2008). *The Measurement of Productive Efficiency and Productivity Growth.* New York: Oxford University Press.

Gomułka, S. (2008). Mechanism and sources of the economic growth in the world. In: R. Rapacki (ed.), *Economic growth in the post-Communist countries: convergence or divergence*. Warsaw: PWE (based on the lecture given at the conference at SGH, 16 November 2006). Available at: www.pte.pl/pliki/2/12/mechanizm_03_10.doc.

Marzec, J., Pisulewski, A. (2013). Econometric analysis of the technical analysis of the technical efficiency of dairy farms in Poland based on the data from 2004–2011. *Annals of the Collegium of Economic Analysis*, *30*, 255–271.

Meeusen, W., van den Broeck, J. (1977). Efficiency Estimation from Cobb-Douglas Production Functions with Composed Error. *International Economic Review*, *18*, 35–444.

Mortimer, D., Peacock, S. (2002). Hospital Efficiency Measurement: Simple Ratios vs Frontier Methods. *Working Paper*, *135*. Australia: Centre of Health Program Evaluation.

Rembisz, W. (2005). Remunerations of productive factors at agricultural holdings. *Issues of Agricultural Economics*, 4, Warsaw: IAFE-NRI.

Rembisz, W. (2008). *Micro- and macroeconomic bases for the growth in the agri-food sector*. Warsaw: VizjaPress&IT.

Rembisz, W. (2011). *Analytical properties of the agricultural production function*. *Communications, Reports, Expert Opinions*, 544, Warsaw: IAFE-NRI.

Rembisz, W., Floriańczyk, Z. (2014). *Models of the economic growth in agriculture.* Warsaw: IAFE-NRI.

Sellers-Rubio, R., Más-Ruiz, F.J. (2009). Technical efficiency in the retail food industry: the influence of inventory investment, wage levels and age of the firm. *European Journal of Marketing*, *43* (5/6), 652–669.

Yuan, Z. (2011). Analysis of agricultural input-output based on Cobb–Douglas production function in Hebei Province, North China. *African Journal of Microbiology Research*, *5* (32), 5916–5922. DOI: 10.5897/AJMR11.961.