ŽEMĖS ŪKIO MOKSLAI. 2012. T. 19. Nr. 3. P. 168–179

The Cost Malmquist Index decomposition for analysis of the total factor productivity change in Lithuanian family farms

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By combining approaches of N. Maniadakis and E. Thanassoulis (2004) and R. Färe et al. (1994), this paper extends the decomposition of the cost Malmquist productivity index to tackle variable returns to scale technology and, hence, scale efficiency. The cost Malmquist index was applied to estimate the dynamics of the total factor productivity in the Lithuanian family farms. The carried out research relies on data from the Farm Accountancy Data Network. Indeed, the balanced panel covering 200 farms throughout the period of 2004–2009 was analyzed. Specifically, the cost Malmquist indices were computed by the means of the data envelopment analysis. What the results of analysis do indicate is that the cost productivity increased by some 7.7% and the technical productivity grew by 22.4% during 2004–2009. The increase in the total factor productivity was mainly driven by increase in technical efficiency. Therefore, one can conclude that the impact of innovations on the overall shifts in the production frontier was a rather meagre one.

Key words: total factor productivity, cost Malmquist index, data envelopment analysis, family farms

INTRODUCTION

Measurement of productivity and efficiency constitutes an important task for the economic science and policy-making. Indeed, these measures are related to profitability and competitiveness of a certain firm, sector, or state. As for agriculture, efficiency is also interlinked with labour intensity, farm structure, technology and investment, and management skills (Henningsen, 2009). Furthermore, public support is expected to ensure the viability of the rural areas and thus needs to be distributed in an appropriate way. As a result, the food consumers may experience certain gains or losses due to changes in product prices (Samarajeewa et al., 2012).

The issues of agricultural efficiency are those of particular importance in the Central and East European (CEE) states thanks to their economic structure influenced by the historical turmoil during the 20th century (Gorton, Davidova, 2004; Alvarez, Arias, 2004; Henningsen, Kumbhakar, 2009; Čechura, 2012). The two seminal methods are usually employed for efficiency analysis, namely the Data Envelopment Analysis (DEA) and the Stochastic Frontier Analysis (SFA). DEA belongs to the class of non-parametric methods, whereas SFA is a parametric method. Accordingly, DEA defines the production possibility frontier in an empirical manner as a piecewise-linear function, and SFA employs an econometric approach. It is due to Henningsen and Kumbhakar (2009) that semi-parametric methods are a subject to application in efficiency research. As for the longitudinal productivity analysis, the Malmquist index remains the primal tool for non-parametric analysis (Coelli, Rao, 2005; Ippoliti, Falavigna, 2012; Tohidi et al., 2012). Indeed, the Luenberger index is also a widely applied method for productivity analysis (Epure et al., 2011).

Therefore, a number of studies attempted to estimate the efficiency, productivity, and dynamics thereof in the agricultural sectors of CEE states. As for the Lithuanian agricultural sector, analysis of efficiency and productivity is of high importance due to (i) public support allocated under the Rural Development Programme, (ii) the ongoing changes in the farm structure, and (iii) the amount of the abandoned land. As G. Kuliešis et al. (2011) approximated, up to 21.7% of the total agricultural area was under the abandoned land. These areas provide certain opportunities for farm expansion. Meanwhile, the Lithuanian agricultural sector remained rather under-analyzed one in terms of efficiency analysis. One can mention studies by V. Vinciūnienė and J. Rauluškevičienė (2009), D. Rimkuvienė et al. (2010), and T. Balezentis et al. (2012) which focused on the productive efficiency of the Lithuanian agriculture. However, these studies employed the Data Envelopment Analysis (DEA) and aggregated data. It should be noted that the Malmquist productivity index was not employed in these studies. Thus, this paper aims at identifying the main productivity drivers in Lithuanian family farms in the terms of Malmquist indices.

The Malmquist productivity index (Malmquist, 1953) is a measure of the total factor productivity (TFP) growth based on the distance functions. R. Färe et al. (1992) decomposed the TFP change into efficiency change (EC or catching up) and technical change (TC or shifts in the frontier). Later on, R. Färe et al. (1994) decomposed the TFP into three parts, namely (i) change in pure efficiency, (ii) change in scale efficiency, and (iii) change in technology (this term is identical to the one proposed by R. Färe et al. (1992). Given the cost efficiency (CE) is determined by both technical efficiency (TE) and scale efficiency (SE), there is a need to define Malmquist indices for each type of efficiency. Therefore, N. Maniadakis and E. Thanassoulis (2004) proposed the cost Malmquist index, albeit they employed the decomposition offered by R. Färe et al. (1992), which does not take into account changes in SE.

This study is to decompose the cost Malmquist index (Maniadakis, Thanassoulis, 2004) by considering the three terms defined by R. Färe et al. (1994) to assess the dynamics of TFP change in the sample of the Lithuanian family farms. The data covering some 200 family farms for the period 2004–2009 was obtained from the Farm Accountancy Data Network (FADN).

The rest of the article is structured in the following manner. Section II presents the definitions and measures of efficiency. Section III is devoted to the cost Malmquist indices, whereas Section IV focuses on the implementation of the discussed measures by the virtue of DEA models. Section V presents the data employed for the research. Finally, Section VI summarizes the results of the research.

DEFINITIONS AND MEASURES OF EFFICIENCY

In order to relate the Debreu-Farrel measures to the Koopmans definition, and to relate both to the structure of production technology, it is useful to introduce some notation and terminology (Fried et al., 2008). Let producers use inputs $x = (x_1, x_2, \ldots, x_m) \in \Re_+^{\,m}$ to produce outputs $y = (y_1, y_2, \ldots, y_n) \in \Re_+^{\,n}$. Production technology can then be defined in terms of the production set:

$$T = \{(x, y) \mid x \text{ can produce } y\}. \tag{1}$$

Thus, the Koopmans efficiency holds for an input-output bundle $(x, y) \in T$ if, and only if, $(x', y') \notin T$ for $(-x', y') \geq (-x, y)$.

Technology set can also be represented by the input requirement set:

$$I(y) = \{x \mid (x, y) \in T\}. \tag{2}$$

The isoquants or efficient boundaries of the sections of T can be defined in radial terms as follows (Farrel, 1957). Every $y \in \Re_+^n$ has an input isoquant:

$$isoI(y) = \{x \mid x \in I(y), \lambda x \notin I(y), \lambda < 1\}. \tag{3}$$

In addition, DMUs might be operating on the efficiency frontier defined by Eq. 4, albeit still use more inputs to produce the same output if compared to another efficient DMU. In this case the former DMU experiences a slack in inputs. The following subset of the boundary $I(y)$ describes Pareto-Koopmans efficient firms:

$$effI(y) = \{x \mid x \in I(y), x' \notin I(y), \forall x' \leq x, x' \neq x\}. \quad (4)$$

Note that $effI(y) \subseteq isoI(y) \subseteq I(y)$.

There are two types of efficiency measures, namely, the R.W. Shepard distance function and the Farrel distance function. These functions yield the distance between an observation and the efficiency frontier. R.W. Shepard (1953) defined the following input distance function:

$$D_I(x, y) = \max\{\lambda | (x/\lambda, y) \in I(y)\}. \quad (5)$$

Here $D_I(x, y) \geq 1$ for all $x \in I(y)$, and $D_I(x, y) = 1$ for $x \in isoI(y)$. The Farrel input-oriented measure of efficiency can be expressed as:

$$TE_I(x, y) = \min\{\theta | (\theta x, y) \in I(y)\}. \quad (6)$$

Comparing Eqs. 5 and 6 we arrive at the following relation:

$$TE_I(x, y) = 1 / D_I(x, y), \quad (7)$$

with $TE_I(x, y) \leq 1$ for $x \in I(y)$, and $TE_I(x, y) = 1$ for $x \in isoI(y)$.

M.J. Farrel (1957) defined the two types of efficiency, which are known as technical and economic efficiency. The economic efficiency and its measures were described above. The economic efficiency is divided into cost, revenue and profit efficiency. For each of the three measures, a respective frontier is established. Here we focus solely on cost efficiency. However, revenue efficiency is a straightforward modification of the cost efficiency.

Assume that producers face input prices $w = (w_1, w_2, \ldots w_m) \in \Re^m_{++}$ and seek to minimize cost. Thus, a minimum cost function – cost frontier – is defined as:

$$c(y, w) = \min_x \{w^T x | D_I(x, y) \geq 1\}. \quad (8)$$

Then the Farrel's measure of cost efficiency (CE) is defined as the ratio of the minimum cost to the actual cost:

$$CE_I(x, y, w) = c(y, w) / w^T x. \quad (9)$$

A measure of input-allocative efficiency AE_I is obtained by employing Eqs. 9 and 7:

$$AE_I(x, y, w) = CE(x, y, w) / TE_I(x, y). \quad (10)$$

Thus, cost efficiency can be expressed as a product of technical efficiency and cost allocative efficiency. Fig. 1 depicts these measures.

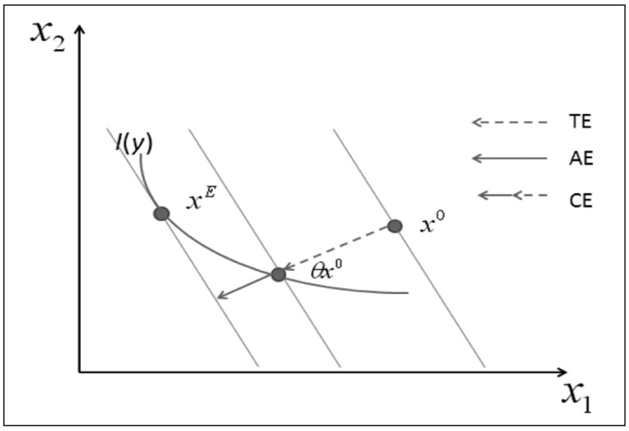

Fig. 1. The cost efficiency (CE) and its decomposition into technical efficiency (TE) and allocative efficiency (AE)

The three lines in Fig. 1 represent respective isocosts, namely, $w^T x^E$, $w^T \theta x^0$ and $w^T x^0$ for points x^E, θx^0, and x^0, in that order. Here the efficient point x^E minimizes cost and thus defines the cost frontier $c(y, w) = w^T x^E$. The cost efficiency of the point x^0 is then given by the ratio $c(y, w) / w^T x^0 = w^T x^E / w^T x^0$ (cf. Eq. 17). The cost efficiency of x^0 can be further decomposed into the technical efficiency $\theta^0 = \theta^0 x^0 / x^0 = w^T(\theta^0 x^0) / w^T x^0$ and the allocative efficiency determined by the ratio $w^T x^E / w^T(\theta^0 x^0)$.

PRELIMINARIES FOR MALMQUIST PRODUCTIVITY INDEX

Measurement of the total factor productivity (TFP) of certain DMU involves measures for both technological and firm-specific developments. As P. Bogetoft and L. Otto (2011) put it, firm behaviour changes over time should be explained in terms of special initiatives as well as technological progress. The benchmarking literature (Coelli et al., 2005; Bogetoft and Otto, 2011; Ramanathan, 2003) suggests the Malmquist productivity index being the most celebrated TFP measure. Hence, this section describes the preliminaries of the Malmquist index.

The technology set and respective frontier (cf. Eqs. 1 and 3) are likely to shift from one period to another. Therefore, one needs an appropriate measure to identify these changes. The S. Malmquist productivity index (Malmquist, 1953) can be employed to estimate TFP changes of a single firm over two periods (or *vice versa*), across two production modes, strategies, locations etc. In this study we shall focus on the input-oriented Malmquist productivity index and apply it to measure period-wise changes in TFP. The input-oriented Malmquist productivity index due to D.W. Caves et al. (1982) is defined as

$$M_I = \left(M_I^t \cdot M_I^{t+1}\right)^{1/2} =$$

$$\left(\frac{D_{I,CRS}^t\left(x^{t+1}, y^{t+1}\right)}{D_{I,CRS}^t\left(x^t, y^t\right)} \frac{D_{I,CRS}^{t+1}\left(x^{t+1}, y^{t+1}\right)}{D_{I,CRS}^{t+1}\left(x^t, y^t\right)} \right)^{1/2}, \qquad (11)$$

with indexes t and $t+1$ representing respective periods and $D^t_{I,CRS}$ being the Shepard distance function (Eq. 5) for the period t assuming constant returns to scale (CRS). The two terms in brackets follow the structure of the Fisher's index. Thereafter, a number of studies (Färe et al., 1992, 1994; Ray and Desli, 1997; Simar and Wilson, 1998; Wheelock and Wilson, 1999) attempted to decompose the latter index into different terms each explaining certain factors of productivity shifts. Specifically, R. Färe et al. (1992) decomposed productivity change into efficiency change (ΔE or catching up) and technical change (ΔT or shifts in the frontier):

$$M_I = \Delta E \cdot \Delta T, \qquad (12)$$

where

$$\Delta E = D_{I,CRS}^{t+1}\left(x^{t+1}, y^{t+1}\right) / D_{I,CRS}^t\left(x^t, y^t\right) \qquad (13)$$

and

$$\Delta T = \left(\frac{D_{I,CRS}^t\left(x^{t+1}, y^{t+1}\right)}{D_{I,CRS}^t\left(x^{t+1}, y^{t+1}\right)} \frac{D_{I,CRS}^t\left(x^t, y^t\right)}{D_{I,CRS}^{t+1}\left(x^t, y^t\right)} \right)^{1/2}. \qquad (14)$$

The term ΔE measures the relative technical efficiency change. The index becomes greater than the unity in case the firm approaches the frontier of the current technology. ΔT indicates whether the technology has progressed and thus moved further away from the observed point. In case of technological progress, the ΔT becomes greater than the unity; and that virtually means that more can be produced using fewer resources. Given the Malmquist productivity index measures TFP growth, improvement in productivity will be indicated by values greater than unity, whereas regress by that below the unity.

As one can note, the decomposition of R. Färe et al. (1992) does not take into account the variable returns to scale (VRS) technology and, consequently, scale efficiency. Färe et al. (1994), therefore, further decomposed the ΔE component into the two factors, namely, pure technical efficiency change (ΔPT) and scale efficiency change (ΔSE). Thus, the Malmquist (M) productivity index was decomposed into three parts:

$$M_I = \Delta E \cdot \Delta T = \Delta PT \cdot \Delta SE \cdot \Delta T, \qquad (15)$$

where the term ΔT refers to Eq. 14 and

$$\Delta PT = D_{I,VRS}^{t+1}\left(x^{t+1}, y^{t+1}\right) / D_{I,VRS}^t\left(x^t, y^t\right), \qquad (16)$$

$$\Delta SE = \left(\frac{D_{I,CRS}^{t+1}\left(x^{t+1}, y^{t+1}\right) / D_{I,VRS}^{t+1}\left(x^{t+1}, y^{t+1}\right)}{D_{I,CRS}^t\left(x^t, y^t\right) / D_{I,VRS}^t\left(x^t, y^t\right)} \right). \qquad (17)$$

Thus, ΔPT and ΔSE measure firm-specific changes in productivity related to shifts in technical and scale efficiency, whereas ΔT identifies shifts in the technology frontier.

The discussed Malmquist productivity index is suitable to analyze the dynamics of technical and scale efficiency. In order to measure the changes in economic (cost) efficiency, N. Maniadakis and E. Thanassoulis (2004) offered the cost Malmquist index:

$$CM = \left(\frac{w^t x^{t+1} / C^t(y^{t+1}, w^t)}{w^t x^t / C^t(y^t, w^t)} \times \right.$$

$$\left. \frac{w^{t+1} x^{t+1} / C^{t+1}(y^{t+1}, w^{t+1})}{w^{t+1} x^t / C^{t+1}(y^t, w^{t+1})} \right)^{1/2}. \qquad (18)$$

The cost ratio $w^t\, x^t \,/\, C^t\,(y^t,\, w^t)$ is a reciprocal of the Farrel's measure (cf. Eq. 9) and measures the extent to which the aggregate production cost in the period t can be reduced while maintaining the output vector y^t given the input price vector w^t. This ratio measures the distance between the observed cost, namely, $w^t x^t$, and the cost frontier defined by $C^t(y^t, w^t)$.

Due to N. Maniadakis and E. Thanassoulis (2004), the cost Malmquist (*CM*) index can be decomposed into the two components, viz. overall efficiency change (ΔOE) and cost-technical change (ΔCT):

$$CM = \Delta OE \cdot \Delta CT, \tag{19}$$

where

$$\Delta OE = \frac{w^{t+1}x^{t+1} / C^{t+1}(y^{t+1}, w^{t+1})}{w^t x^t / C^t(y^t, w^t)} \tag{20}$$

and

$$\Delta CT = \left(\frac{w^t x^{t+1} / C^t(y^{t+1}, w^t)}{w^{t+1}x^{t+1} / C^t(y^{t+1}, w^{t+1})} \times \frac{w^t x^t / C^t(y^t, w^t)}{w^{t+1}x^t / C^{t+1}(y^t, w^{t+1})} \right)^{1/2}. \tag{21}$$

Thus, ΔOE measures firm-specific changes in cost efficiency related to input-mix, and ΔCT catches the combined effect of changes in input prices and technology (both of which are out of firm's control).

By relating components of *CM* to those of the M index, one can further decompose the two terms of *CM*. First, ΔOE can be decomposed into efficiency change, ΔE, and allocative efficiency change (ΔAE). The former term can be estimated by employing either Eq. 13 or Eqs. 16 and 17, whereas ΔAE is obtained by the virtue of the following computations:

$$\Delta AE = \left(\frac{w^{t+1}x^{t+1} / \left(C^{t+1}(y^{t+1}, w^{t+1}) D^{t+1}_{I,CRS}(x^{t+1}, y^{t+1}) \right)}{w^t x^t / \left(C^t(y^t, w^t) D^t_{I,CRS}(x^t, y^t) \right)} \right). \tag{22}$$

Second, ΔCT can be decomposed into technical change, ΔT, and price effect, ΔP. The ΔT term is obtained with respect to Eq. 14, while ΔP is defined in the following way:

$$\Delta P = \left(\frac{w^t x^{t+1} / \left(C^t(y^{t+1}, w^t) D^{t+1}_{I,CRS}(x^{t+1}, y^{t+1}) \right)}{w^{t+1}x^{t+1} / \left(C^{t+1}(y^{t+1}, w^{t+1}) D^{t+1}_{I,CRS}(x^{t+1}, y^{t+1}) \right)} \times \frac{w^t x^t / \left(C^t(y^t, w^t) D^t_{I,CRS}(x^t, y^t) \right)}{w^{t+1}x^t / \left(C^{t+1}(y^t, w^{t+1}) D^{t+1}_{I,CRS}(x^t, y^t) \right)} \right)^{1/2}. \tag{23}$$

Finally, the cost Malmquist productivity index can be decomposed into these components:

$$CM = \underbrace{\underbrace{\Delta PT \cdot \Delta SE}_{\Delta E} \cdot \Delta AE}_{\Delta OE} \cdot \underbrace{\Delta T \cdot \Delta P}_{\Delta AE} = M \cdot \Delta AE \cdot \Delta P. \tag{24}$$

The cost Malmquist index could be further decomposed in the spirit of S. C. Ray and E. Desli (1997), L. Simar and P. W. Wilson (1998), D. C. Wheelock and P. W. Wilson (1999), however, these computations are out of scope of this study.

PRELIMINARIES FOR DEA

The distance functions for respective components of the cost Malmquist index can be obtained by employing DEA. This section, thus, presents the main linear programming problems for estimation of technical and cost efficiency scores which are wherewithal indices for the cost Malmquist index.

The modern version of DEA originated in studies of A. Charnes, W. W. Cooper and E. Rhodes (Charnes et al., 1978; 1981). Hence, these DEA models are called CCR models. Initially, the fractional form of DEA was offered. However, this model was transformed into input- and output-oriented multiplier models, which could be solved by means of the linear programming (LP). In addition, the dual CCR model (i. e. envelopment program) can be described for each of the primal programs (Cooper et al., 2007; Ramanathan, 2003).

Unlike many traditional analysis tools, DEA does not require to gather information about prices of materials or produced goods, thus making it suitable for evaluating both private- and public-sector efficiency. Suppose that there are $k = 1, 2, \ldots, K$ DMUs, each producing $j = 1, 2, \ldots, n$ outputs from $i = 1, 2, \ldots, m$ inputs. Hence, DMU k exhibits the Farrel input-oriented technical efficiency θ_k, whereas the Shepard technical efficiency is a reciprocal number, $1/\theta_k$.

The distance function for the l-th firm possessing the input-output bundle $(x^{l,t}, y^{l,t})$ in terms of the technology set of the period t may be obtained by solving the following multiplier DEA program*:

$$D^t_{I,CRS}(x^{l,t}, y^{l,t}) = \min_{\theta_l, \lambda_k} \theta_l$$

s.t.

$$\sum_{k=1}^{K} \lambda_k x_i^{k,t} \leq \theta_l x_i^{l,t}, \quad i = 1, 2, \ldots, m;$$

$$\sum_{k=1}^{K} \lambda_k y_i^{k,t} \geq y_i^{l,t},\ i = 1, 2, \ldots, n;\ \theta_l \text{ unrestricted.}$$

$$\lambda_k \geq 0, \quad k = 1, 2, \ldots, K. \tag{25}$$

Meanwhile, the distance function when the input-output bundle of one period t is compared to the efficiency frontier of another period may be obtained by solving the following multiplier DEA program:

$$D^t_{I,CRS}(x^{l,t+1}, y^{l,t+1}) = \min_{\theta_l, \lambda_k} \theta_l$$

s.t.

$$\sum_{k=1}^{K} \lambda_k x_i^{k,t} \leq \theta_l x_i^{l,t+1}, \quad i = 1, 2, \ldots, m;$$

$$\sum_{k=1}^{K} \lambda_k y_i^{k,t} \geq y_i^{l,t+1}, i = 1, 2, \ldots, n; \theta_l \text{ unrestricted.}$$

$$\lambda_k \geq 0, \quad k = 1, 2, \ldots, K. \tag{26}$$

In Eqs. 24 and 25, coefficients λ_k are weights of peer DMUs. It is noteworthy that this model presumes the existing constant returns to scale (CRS), which is a rather arbitrary condition. CRS indicates that the manufacturer is able to scale the inputs and outputs linearly without increasing or decreasing efficiency (Ramanathan, 2003).

Whereas the CRS constraint was considered over-restrictive, the BCC (Banker, Charnes, and Cooper) model was introduced (Banker et al., 1984). The CRS presumption was overridden by introducing a convexity constraint $\sum_{k=1}^{K} \lambda_k = 1$, which enabled to tackle the variable returns to scale (VRS). The BBC model, hence, can be written by supplementing Eqs. 25 and 26 with a convexity constraint $\sum_{k=1}^{K} \lambda_k = 1$.

It is due to E. Thanassoulis et al. (2008) that in case the input-output bundle and input costs of the t-th period are considered, the minimum cost can be obtained by the virtue of the following linear cost minimization model:

$$C^t(y^{l,t}, w^{l,t}) = \min_{\lambda_k, x_i} c(y^{l,t}, w^{l,t}) = \sum_{i=1}^{m} w_i^{l,t} x_i$$

s.t.

$$\sum_{k=1}^{K} \lambda_k x_i^{k,t} \leq x_i, \quad i = 1, 2, \ldots, m,$$

$$\sum_{k=1}^{K} \lambda_k y_j^{k,t} \geq y_j^{l,t}, \quad i = 1, 2, \ldots, n,$$

$$\lambda_k \geq 0, \tag{27}$$

where $w_i^{l,t}$ are the input prices for the l-th DMU. This model yields the minimum cost which is compared with the actual costs when computing the cost Malmquist index. In case one wants to obtain the minimum cost with respect to technology of a different period, the following model is implemented:

$$C^t(y^{l,t+1}, w^{l,t}) = \min_{\lambda_k, x_i} c(y^{l,t+1}, w^{l,t}) = \sum_{i=1}^{m} w_i^{l,t} x_i$$

s.t.

$$\sum_{k=1}^{K} \lambda_k x_i^{k,t} \leq x_i, \quad i = 1, 2, \ldots, m,$$

$$\sum_{k=1}^{K} \lambda_k y_j^{k,t} \geq y_j^{l,t+1}, \quad i = 1, 2, \ldots, n,$$

$$\lambda \ \ \geq 0. \tag{28}$$

The discussed linear programming models provide the basis for computations of the components of the cost Malmquist index.

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* Indeed, N. Maniadakis and E. Thanassoulis (2004) used i. e. Shepard measures. These, however, invert the interpretation of the Malmquist index presented in Section III making it less intuitive.

DATA USED

The technical and scale efficiency was assessed in terms of the input and output indicators commonly employed for agricultural productivity analyses (Bojnec, Latruffe, 2008, 2011; Douarin, Latruffe, 2011). More specifically, the utilized agricultural area (UAA) in hectares was chosen as a land input variable, annual work units (AWU) as a labour input variable, intermediate consumption in Litas, and total assets in Litas as a capital factor. On the other hand, the three output indicators represent crop, livestock, and other outputs in Litas, respectively. Indeed, the three output indicators enable to tackle the heterogeneity of production technology across different farms.

The cost efficiency was estimated by defining respective prices for each of the four inputs described earlier. The land price was obtained from the Eurostat and assumed to be uniform for all farms during the same period. The labour price is the average salary in the agricultural sector from the Statistics Lithuania. The price of capital is depreciation plus interests per one Litas of assets. Meanwhile, the intermediate consumption is directly considered as a part of total costs.

The data for 200 farms selected from the FADN sample cover the period of 2004–2009. Thus a balanced panel of 1 200 observations is employed for the analysis. The analyzed sample covers relatively large farms (mean UAA – 244 ha). As for labour force, the average was 3.6 AWU.

RESULTS

The respective DEA models were employed to estimate the Malmquist indices as described in Sections II and III. As already mentioned, there were 200 farms investigated. Therefore, we arrived at the same number of vectors containing cost Malmquist indices for each period. Table 1 presents the correlation estimates for each year between these indices across the investigated farms. As one can note, the cost Malmquist (CM) and ordinary Malmquist (M) indices were highly and significantly correlated throughout the whole period. Generally, both the technological change

Table 1. **Correlation between the cost Malmquist indices during 2004–2009**

	CM	***M***	**ΔAE**	**ΔP**	**ΔPT**	**ΔSE**	***CM***	***M***	**ΔAE**	**ΔP**	**ΔPT**	**ΔSE**
			2004–2005						**2005–2006**			
M	.70***						.90***					
ΔAE	.28***	−.27***					.15**	−.22***				
ΔP	−.19**	−.25***	−.47***				−.19***	−.18**	−.42***			
ΔPT	.53***	.62***	−.22***	.09			.43***	.59***	−.25***	−.12		
ΔSE	.37***	.64***	−.33***	−.16**	−.02		.13*	.31***	−.45***	.18	−.10	
ΔT	.39***	.47***	.29***	−.53***	.09	.03	.77***	.66***	.17	−.24***	−.01	−.07
	2006–2007						2007–2008					
M	.77***						.90***					
ΔAE	.26***	−.28***					.13*	−.23***				
ΔP	−.20***	−.39***	.15**				−.10	−.09	−.51***			
ΔPT	.55***	.75***	−.20***	−.12			.66***	.76***	−.24***	−.07		
ΔSE	.25**	.46***	−.42***	−.05	−.02		.55***	.64***	−.29***	.19**	.07	
ΔT	.48***	.43***	.11	−.65***	.06	−.08	.23***	.17**	.50***	−.80***	−.01	−.07
	2008–2009											
M	.82***											
ΔAE	−.04	−.41***										
ΔP	−.04	−.0573	−.55***									
ΔPT	.73***	.70***	−.32***	.14**								
ΔSE	.42***	.74***	−.52***	.13*	.17**							
ΔT	.22***	.11	.49***	−.75***	−.17**	−.11						

Codes of significance: *** – p < .01, ** – p < .05, * – p < .1

and price change were unrelated to catch-up indices, viz. ΔPT and ΔSE. This indicates that increasing productivity was maintained in spite of the negative trends in the agricultural markets. The results also imply that farms experiencing increase in scale efficiency do not necessarily exhibit increase in technological efficiency, albeit the latter finding does not hold for the period of 2008–2009.

Thereafter, the cost Malmquist indices were aggregated across the farms. In order to maintain the integrity of the Malmquist indices, we employed the geometric average for the latter purpose. The aggregated data are presented in Table 2. As one can note, the cost productivity has always been increasing with exception for the period of 2006–2007. The latter shock might be related to unfavourable climatic conditions of that period. Indeed, no gain in productivity was achieved during the following period. The Malmquist index followed the same pattern of dynamics, albeit it exhibited the increase in the total factor productivity amounting to 3.9% immediately after the critical period of 2006–2007. Considering the three components of the Malmquist productivity index, one can note that the pure technical efficiency change was always positive with exception for the period of 2006–2007, whereas the scale efficiency change and the technology change exhibited some additional features. The scale efficiency change has also caused decrease in productivity during 2004–2005. This might be caused by changes in the farm structure and land ownership following the accession into the European Union. The technology change also indicated that the production frontier moved inwards during the period of 2007–2008. Thus, the earlier crisis persisted during the following period in terms of the overall production technology. Finally, the two cost productivity indices, namely, change in allocative efficiency and prices, indicated decrease in cost productivity throughout most of the research period. These changes were caused by both managerial decisions and rising input prices.

By considering the coefficients of variance for each of the cost Malmquist index components, one can note that it was the technical efficiency changes that caused fluctuations in the cost Malmquist index to the highest extent. Specifically, change in technology, ΔT, was the main determinant of these shifts. Changes in pure technical efficiency and scale efficiency were specific with relatively higher variance and hence had a higher impact on the cost Malmquist index if compared to that caused by cost-related indices. The reciprocal relationship between the cost Malmquist index and price effect suggests that increasing prices of outputs resulted in decreasing cost productivity across the farms.

In order to assess the overall change in productivity throughout 2004–2009, we have calculated the cumulative change of the cost Malmquist indices. As one can note, Fig. 2 exhibits the cumulative changes of both the cost Malmquist index and the ordinary Malmquist index. It is evident that the cost productivity increased by some 7.7%, whereas the technical productivity at a margin of 22.4% during 2004–2009. Indeed, the cumulative change in cost productivity has always been lower than that in technical productivity during the period of 2004–2009. Thus the rising prices and lack of innovations leading to the novel decisions in input-mix management in the Lithuanian family farms caused the decrease in cost efficiency.

The following Fig. 3 provides the juxtaposition of the three components of the cost Malmquist index, viz. the ordinary Malmquist index, change in allocative efficiency, and change in input prices. The cumulative change of the Malmquist index had reached its bottom in 2007 and has been recovering ever since. The cumulative change in allocative efficiency had trended upwards until

Table 2. **The cost Malmquist indices for 2004–2009**

	CM	M	ΔPT	ΔSE	ΔT	ΔAE	ΔP
2004–2005	1.043	1.073	1.051	0.957	1.067	0.995	0.976
2005–2006	1.206	1.241	1.098	1.068	1.058	1.071	0.908
2006–2007	0.660	0.663	0.952	0.927	0.751	0.999	0.996
2007–2008	1.000	1.039	1.020	1.043	0.977	0.952	1.011
2008–2009	1.299	1.335	1.005	1.015	1.309	1.005	0.968
Coefficient of variation	0.236	0.241	0.053	0.059	0.194	0.042	0.041

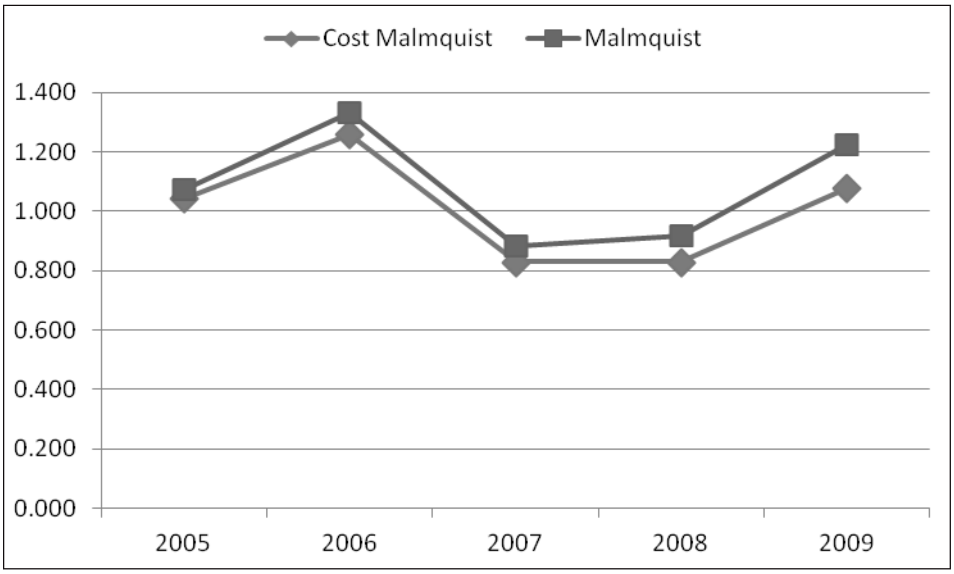

Fig. 2. Dynamics of the cumulative cost Malmquist and Malmquist productivity indices, 2004–2009

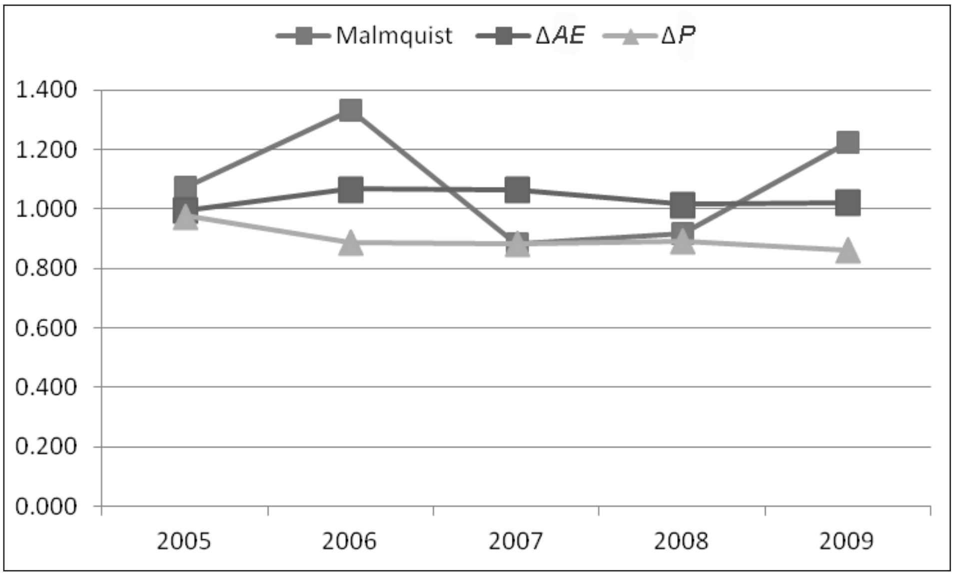

Fig. 3. Cumulative change in the Malmquist index, allocative efficiency (*AE*), and prices (*P*), 2004–2009

2006–2007 and slightly decreased ever since. As for the price effect, its cumulative effect has always been related to decrease in productivity. Thus, the allocative efficiency change accounted for 2% increase in productivity, whereas price effect caused a decrease of 13.7% during 2004–2009. These findings imply that decrease in productivity of the Lithuanian family farms is primarily related to objective causes, namely, input price fluctuations, rather than managerial decisions regarding the input-mix.

Finally, the three components of the ordinary Malmquist productivity index were considered (Fig. 4). The pure technical efficiency change component caused increase in productivity of 12.7%, whereas scale efficiency change resulted in a

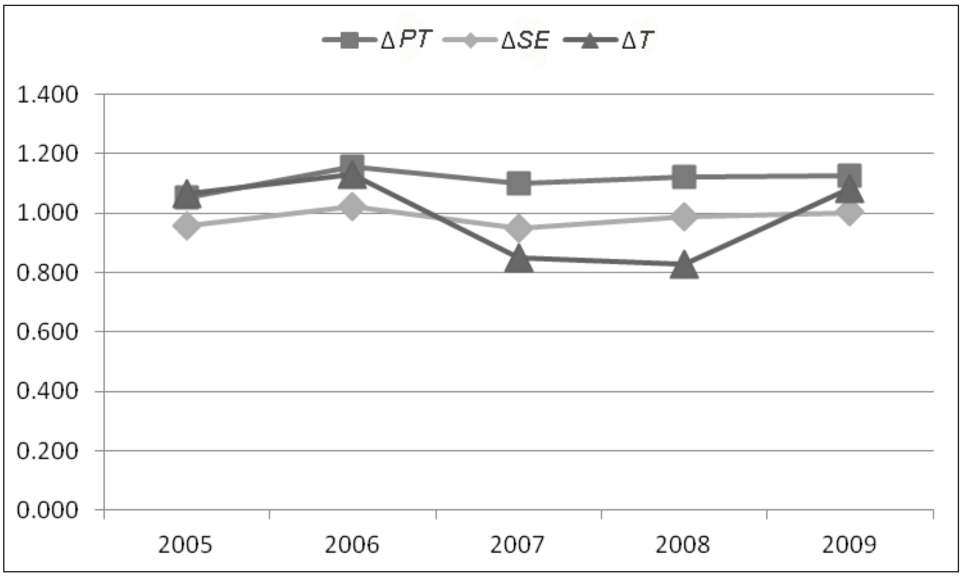

Fig. 4. The cumulative change in pure technical efficiency (PT), scale efficiency (*SE*), and technological frontier shifts (*T*), 2004–2009

meager shift in productivity, i. e. 0.2%. The technology effect exhibited higher volatility and was the underlying factor leading to increase in productivity reaching some 8.4% throughout 2004–2009. Therefore, the Lithuanian family farms managed to sustain the farm-specific growth in level of productivity, which is identified by indices of changes in technical and scale efficiency. However, sector-wide productivity shocks caused the production possibility frontier to move inwards for the certain period.

The observed movements of the production frontier suggest that there is a need for further diversification of the agricultural production. Indeed, meat breeding as well as other livestock productions would provide the farmers with some persistence to the varying climatic conditions. On the other hand, introduction of direct sales would enable to extract an additional value added from crop production; particularly this would be a case for vegetable farming. For prices are rather elastic in retail vegetable markets and unfavourable production states, thus, it results in appropriate price fluctuations which secure a relatively constant level of revenue.

To summarize, the analysis indicated that technical and cost productivity shared the same trend throughout 2004–2009, however, the increase in cost productivity was rather subdued thanks to increasing input prices. The increase in the total factor productivity, therefore, was mainly driven by increase in technical efficiency which, in turn, was a result of firm-specific decisions. These findings imply that the public support under measures of the Rural Development Programme contributed to certain innovations of production process.

CONCLUSIONS

The cost Malmquist index was decomposed into measures of changes in technical, scale, and allocative efficiency and subsequently applied for the analysis of productivity dynamics in the Lithuanian family farms. Indeed, the sample covered rather large farms in the Lithuanian scale.

The carried out correlation analysis suggests that both the technological change and price change were unrelated to catch-up indices, viz. pure technical efficiency change and scale efficiency change. The further analysis also indicated that it was the technical efficiency change that gave a momentum to the growth in cost efficiency. In spite of economic and climatic shocks, the cost productivity increased by some 7.7% and the technical productivity grew by 22.4% during 2004–2009. The increase in the total factor productivity was mainly driven by increase in technical efficiency which, in turn, was a result of firm-specific decisions.

Given the farm structure is likely to change in the direction of the increasing share of the large farms, one can expect for increasing productivity of the whole family farming sector in Lithuania.

Further studies are needed to employ the bootstrapping methods for Malmquist indices and thus obtain confidence intervals thereof. In addition, the second stage analysis of changes in productivity would enable to identify and quantify the main sources of productivity growth.

Received 13 July 2012
Accepted 8 November 2012

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KAŠTŲ MALMKVISTO INDEKSO NAUDOJIMAS VERTINANT BENDROJO PRODUKTYVUMO POKYČIUS LIETUVOS ŪKININKŲ ŪKIUOSE

Santrauka

Straipsnyje apibendrinami metodai, pasiūlyti Maniadakio ir Thanassoulio (2004) bei Färe ir kt. (1994), taip pritaikant Malmkvisto produktyvumo indeksą kintančios masto grąžos gamybos technologijai ir masto efektyvumo vertinimui. Masto efektyvumo įtaka įvertinama apskaičiuojant kintančios ir pastovios masto grąžos techninio efektyvumo rodiklius. Kaštų Malmkvisto indeksas buvo naudojamas vertinant bendrojo produktyvumo pokyčius Lietuvos ūkininkų ūkiuose. Tyrimas remiasi Ūkių apskaitos duomenų tinklo duomenimis. Tyrimo imtį sudaro 200 ūkininkų ūkių, veikusių 2004–2009 m. Nustatant indeksų reikšmes, taikyta duomenų apgaubties analizė. Tyrimo rezultatai parodė, kad kaštų produktyvumas padidėjo apie 7,7 %, o techninis produktyvumas – 22,4 %. Bendrojo produktyvumo augimą daugiausia lėmė techninio efektyvumo pokyčiai, taigi inovacijų įtaka gamybos galimybių kreivės pokyčiams buvo ne itin reikšminga.

Raktažodžiai: bendrasis produktyvumas, kaštų Malmkvisto indeksas, duomenų apgaubties analizė, ūkininkų ūkiai