ISSN 1691-3078
ISBN 978-9934-8304-6-4

ECONOMIC SCIENCE FOR RURAL DEVELOPMENT

Proceedings of the International Scientific Conference

No. 30

Production and Cooperation in Agriculture

Finance and Taxes

Nordic Association of Agricultural Scientists

THE TRENDS OF TECHNICAL AND ALLOCATIVE EFFICIENCY IN LITHUANIAN FAMILY FARMS

Tomas Balezentis[1], **Irena Krisciukaitiene**, Dr
Lithuanian Institute of Agrarian Economics
Alvydas Balezentis, Prof. Dr
Mykolas Romeris University

Abstract. The economic or cost efficiency can be decomposed into technical and allocative efficiencies. The technical efficiency is related to farm ability to transform inputs to outputs, whereas the allocative efficiency is the ratio of the observed and the optimal cost, and measures farm's ability to choose an optimal input-mix. The paper employed the Cost Malmquist Index to measure the changes in economic efficiency as well as the technological change. Therefore, the total factor productivity change was estimated for the sample of 200 Lithuanian family farms covering the period of 2004–2009. The results indicated that the cost productivity decreased by some 8%, whereas the total factor productivity – by 20% during the period. Declines in both pure technical efficiencies were the main drivers of the decrease, and the scale effect had almost no impact.
Key words: efficiency, total factor productivity, Malmquist Index, data envelopment analysis, Lithuania.
JEL code: C43, C44, C61, Q10, Q12.

Introduction

The accession to the European Union in 2004 rendered many significant transformations for the Lithuanian agriculture. Specifically, the production and equipment subsidies gave a momentum for modernization. On the other hand, the fluctuations of the relative prices of the agricultural production resulted in the decreasing prevalence of the livestock farming and, to some extent, in farm expansion. These transformations obviously reshaped the technologies of the agricultural production.

Family farms produce the largest share of the agricultural output in Lithuania. As for 2004–2009, some 75–71% of the gross agricultural output was produced in the family farms, whereas the remaining part came from the agricultural enterprises. Although the agricultural companies mainly specialize in crop farming, the share of livestock production there did not decrease to the same extent as it occurred in the family farms.

One of the key features describing the performance of agricultural sector is its productive efficiency. 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 M., Davidova S., 2004; Alvarez A., Arias C., 2004; Henningsen A., Kumbhakar S., 2009; Henningsen A., 2009). Efficiency measures are the primal tools for the economic science and policy-making. Specifically, one can consider certain types of efficiency, e.g. technical efficiency (TE), allocative efficiency (AE), cost efficiency (CE), and profit efficiency. This paper focuses on the technical efficiency measurement, whereof involves no price information and cost efficiency, which require input price data.

The frontier methods are the primal tools for distance function estimation and measurement of the efficiency (Samarajeewa S. et al., 2012). The productivity indices based on the distance functions can then be employed to measure the total factor productivity (Coelli T.J., Rao D.S.P., 2005; Ippoliti R., Falavigna G., 2012; Tohidi G. et al., 2012; Epure M. et al., 2011). The total factor productivity change can also be decomposed into the different terms identifying the causes thereof (Malmquist S., 1953; Fare R. et al., 1992; Fare R. et al., 1994; Maniadakis N., Thanassoulis E.,, 2004).

Whereas Vinciuniene V. and Rauluskeviciene J. (2009), Rimkuviene D. et al. (2010), and Balezentis T. et al. (2012) attempted to estimate the efficiency of the Lithuanian agricultural sector, however the total factor productivity changes and cost productivity changes are still topical issues for the scientific research. Balezentis T. (2012) employed the cost Malmquist Index to analyse the trends of the cost productivity change in Lithuanian agriculture. This particular paper is based on the methodology developed by Balezentis T. et al. (2012). In the present study, the authors will further analyse the results across different farming types.

This paper therefore seeks to assess the changes in cost (economic) efficiency of the Lithuanian family farms during the period of 2004–2009. The non-parametric frontier technique, viz. data envelopment analysis (DEA), is employed alongside with the Cost Malmquist Index to measure the cost productivity change. The micro data covering some 200 family farms for the period 2004–2009 were obtained from the Farm Accountancy Data Network (FADN).

Preliminaries for the cost Malmquist Productivity Index

Measurement of the total factor productivity (TFP) of certain DMU involves measures for both technological and firm-specific developments. As Bogetoft P. and Otto L. (2011) put it, firm behaviour changes

[1] Corresponding author. *Tel.: + 370 5 261 81 45; fax: +370 5 261 45 24.*
E-mail address: tomas@laei.lt.

over time should be explained in terms of special initiatives as well as technological progress. The benchmarking literature (Bogetoft P. and Otto L., 2011; Coelli T., Rao D.S.P., 2005) suggests the Malmquist Productivity Index as the most celebrated TFP measure. Hence, this section describes the preliminaries of the Malmquist Index.

The technology set and respective frontier are likely to shift from one period to another. Therefore, one needs an appropriate measure to identify these changes. The Malmquist Productivity Index (Malmquist S., 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, the authors will 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 Caves D.W. et al. (1982) is defined as

$$M_I = \left(M_I^t \cdot M_I^{t+1}\right)^{1/2} \equiv \left(\frac{D_{I,CRS}^t\left(x^{t+1}, y^{t+1}\right)}{D_{I,CRS}^t\left(x^t, y^t\right)} \frac{D_{I,CRS}^{t+1}\left(x^{t+1}, y^{t+1}\right)}{D_{I,CRS}^{t+1}\left(x^t, y^t\right)} \right)^{1/2}, \quad (1)$$

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

$$\begin{aligned} M_I &= \Delta E \cdot \Delta T \\ &\equiv \frac{D_{I,CRS}^{t+1}\left(x^{t+1}, y^{t+1}\right)}{D_{I,CRS}^t\left(x^t, y^t\right)} \cdot \left(\frac{D_{I,CRS}^t\left(x^{t+1}, y^{t+1}\right)}{D_{I,CRS}^{t+1}\left(x^{t+1}, y^{t+1}\right)} \frac{D_{I,CRS}^t\left(x^t, y^t\right)}{D_{I,CRS}^{t+1}\left(x^t, y^t\right)} \right)^{1/2}, \end{aligned} \quad (2)$$

The term ΔE measures the relative technical efficiency change. The index becomes greater than unity in case the firm approaches 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 unity, and that virtually means, that it is possible to produce more 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 unity.

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

$$M_I = \Delta E \cdot \Delta T \equiv (\Delta PT \cdot \Delta SE) \cdot \Delta T, \quad (3)$$

where the term ΔT refers to Eq. 2 and

$$\Delta PT = D_{I,VRS}^{t+1}\left(x^{t+1}, y^{t+1}\right) \Big/ D_{I,VRS}^t\left(x^t, y^t\right), \quad (4)$$

$$\Delta SE = \left(\frac{D_{I,CRS}^{t+1}\left(x^{t+1}, y^{t+1}\right) \Big/ D_{I,VRS}^{t+1}\left(x^{t+1}, y^{t+1}\right)}{D_{I,CRS}^t\left(x^t, y^t\right) \Big/ D_{I,VRS}^t\left(x^t, y^t\right)} \right). \quad (5)$$

Therefore, ΔPT and ΔSE measures 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 analyse the dynamics of technical and scale efficiency. In order to measure the changes in economic (cost) efficiency, Maniadakis N. and Thanassoulis E. (2004) offered the Cost Malmquist Index:

$$CM \equiv \left(\frac{w^t x^{t+1} / C^t(y^{t+1}, w^t)}{w^t x^t / C^t(y^t, w^t)} \frac{w^{t+1} x^{t+1} / C^{t+1}(y^{t+1}, w^{t+1})}{w^{t+1} x^t / C^{t+1}(y^t, w^{t+1})} \right)^{1/2} . \qquad (6)$$

The cost ratio $w^t x^t / C^t(y^t, w^t)$ is a reciprocal of the Farrel's measure, and measures the extent to which the aggregate production cost in 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 $C^t(y^t, w^t)$.

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

$$CM = \Delta OE \cdot \Delta CT , \qquad (7)$$

where

$$\Delta OE \equiv \frac{w^{t+1} x^{t+1} / C^{t+1}(y^{t+1}, w^{t+1})}{w^t x^t / C^t(y^t, w^t)} , \qquad (8)$$

and

$$\Delta CT \equiv \left(\frac{w^t x^{t+1} / C^t(y^{t+1}, w^t)}{w^{t+1} x^{t+1} / C^{t+1}(y^{t+1}, w^{t+1})} \frac{w^t x^t / C^t(y^t, w^t)}{w^{t+1} x^t / C^{t+1}(y^t, w^{t+1})} \right)^{1/2} . \qquad (9)$$

Thereby, 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 the CM to those of the M Index, one can further decompose the two terms of the CM. Firstly, ΔOE can be decomposed into efficiency change, ΔE and allocative efficiency change (ΔAE). The former term can be estimated by employing either Eq. 2 or Eqs. 4 and 5, whereas ΔAE is obtained by the virtue of the following computations:

$$\Delta AE \equiv \frac{w^{t+1} x^{t+1} \Big/ \left(C^{t+1}(y^{t+1}, w^{t+1}) D^{t+1}_{I,CRS}(x^{t+1}, y^{t+1}) \right)}{w^t x^t \Big/ \left(C^t(y^t, w^t) D^t_{I,CRS}(x^t, y^t) \right)} . \qquad (10)$$

Secondly, ΔCT can be decomposed into technical change, ΔT and price effect, ΔP. The ΔT term is obtained according with the Eq. 2, while ΔP is defined in the following way:

$$\Delta P \equiv \left(\frac{w^t x^{t+1} \Big/ \left(C^t(y^{t+1}, w^t) D^t_{I,CRS}(x^{t+1}, y^{t+1}) \right)}{w^{t+1} x^{t+1} \Big/ \left(C^{t+1}(y^{t+1}, w^{t+1}) D^{t+1}_{I,CRS}(x^{t+1}, y^{t+1}) \right)} \frac{w^t x^t \Big/ \left(C^t(y^t, w^t) D^t_{I,CRS}(x^t, y^t) \right)}{w^{t+1} x^t \Big/ \left(C^{t+1}(y^t, w^{t+1}) D^{t+1}_{I,CRS}(x^t, y^t) \right)} \right)^{1/2} . \qquad (11)$$

Finally, the Cost Malmquist Productivity Index can be decomposed into these components:

$$CM = \underbrace{\underbrace{\Delta PT \cdot \Delta SE}_{\Delta E} \cdot \Delta AE}_{\Delta OE} \cdot \underbrace{\Delta T \cdot \Delta P}_{\Delta AE} \equiv M \cdot \Delta AE \cdot \Delta P . \qquad (12)$$

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

Preliminaries for DEA

The distance functions for respective components of the Cost Malmquist Index can be obtained by employing DEA. Suppose that there are $k = 1,2,...,K$ DMUs, each producing $j = 1,2,...,n$ outputs from $i = 1,2,...,m$ inputs. Hence, DMU *k* exhibits Farrel input–oriented technical efficiency θ_k, whereas Shepard technical efficiency is a reciprocal number, $1/\theta_k$.

The distance function for the *l*-th firm possessing 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 [2]:

[2] Indeed, Maniadakis N. and Thanassoulis E. (2004) used $\left(D^t_{I,CRS}(x^{l,t}, y^{l,t}) \right)^{-1} = \min_{\theta_l, \lambda_k} \theta_l$, i. e. the Shepard measures. These, however, would invert the interpretation of the Malmquist Index presented in this paper, thus making it less intuitive.

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

s. t.

$$\begin{aligned}
&\sum_{k=1}^{K} \lambda_k x_i^{k,t} \leq \theta_l x_i^{l,t}, \quad i = 1,2,\ldots,m; \\
&\sum_{k=1}^{K} \lambda_k y_j^{k,t} \geq y_j^{l,t}, \quad j = 1,2,\ldots,n; \\
&\lambda_k \geq 0, \quad k = 1,2,\ldots,K; \\
&\theta_l \text{ unrestricted.}
\end{aligned} \tag{13}$$

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.

$$\begin{aligned}
&\sum_{k=1}^{K} \lambda_k x_i^{k,t} \leq \theta_l x_i^{l,t+1}, \quad i = 1,2,\ldots,m; \\
&\sum_{k=1}^{K} \lambda_k y_j^{k,t} \geq y_j^{l,t+1}, \quad j = 1,2,\ldots,n; \\
&\lambda_k \geq 0, \quad k = 1,2,\ldots,K; \\
&\theta_l \text{ unrestricted.}
\end{aligned} \tag{14}$$

In Eqs. 13 and 14, the coefficients λ_k are weights of the peer DMUs. Noteworthy, this model presumes 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. The variable returns to the scale model, hence, can be written by supplementing Eqs. 13 and 14 with a convexity constraint, $\sum_{k=1}^{K} \lambda_k = 1$.

According to Thanassoulis E. et al. (2008), in case of considering the input–output bundle and the input costs of the *t*-th period, 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.

$$\begin{aligned}
&\sum_{k=1}^{K} \lambda_k x_i^{k,t} \leq x_i, \quad i = 1,2,\ldots,m \\
&\sum_{k=1}^{K} \lambda_k y_j^{k,t} \geq y_j^{l,t}, \quad j = 1,2,\ldots,n, \\
&\lambda_k \geq 0
\end{aligned} \tag{15}$$

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, if 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.
$$\sum_{k=1}^{K} \lambda_k x_i^{k,t} \le x_i, \quad i = 1, 2, \ldots, m$$
$$\sum_{k=1}^{K} \lambda_k y_j^{k,t} \ge y_j^{l,t+1}, \quad j = 1, 2, \ldots, n.$$
$$\lambda_k \ge 0 \qquad (16)$$

The discussed linear programming models provide the basis for computations of the components of the Cost Malmquist Index.

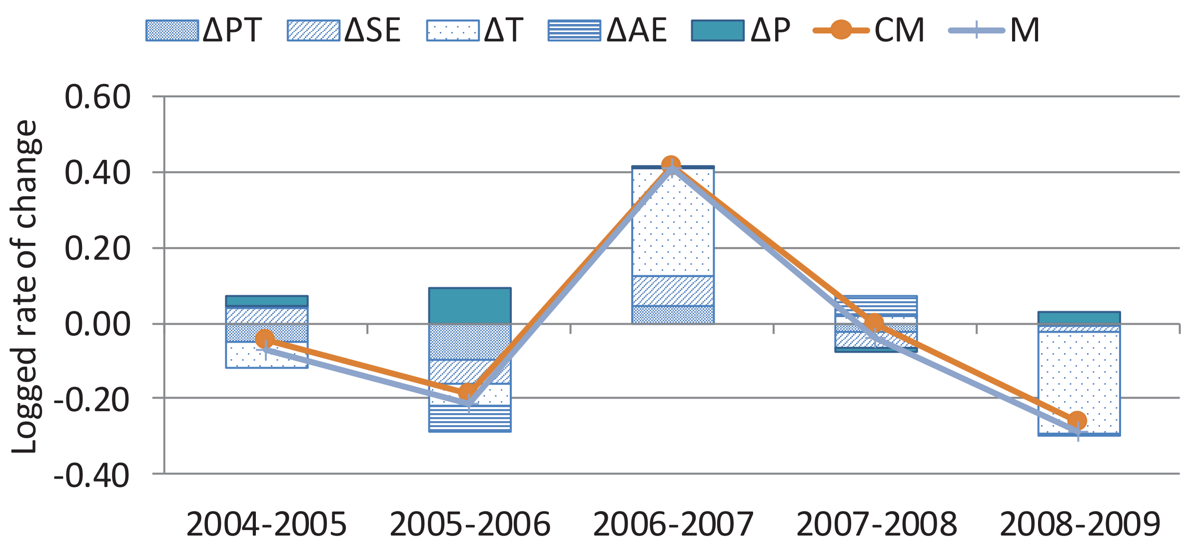
Data Used and Results

The technical and scale efficiency was assessed in terms of the input and output indicators commonly employed for agricultural productivity analyses (Bojnec S., Latruffe L., 2011; Douarin E., Latruffe L., 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 an average salary in the agricultural sector taken from Statistics Lithuania. The price of the capital is depreciation plus interests per one Litas of assets. Meanwhile, the intermediate consumption is directly considered as a part of total costs.

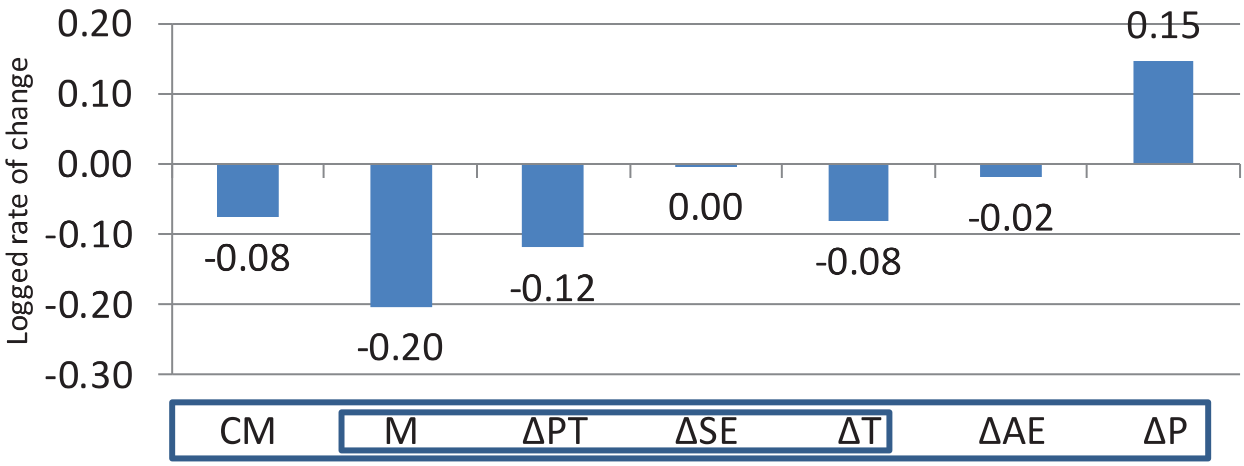
The data for 200 farms selected from the FADN sample cover the period of 2004–2009. Therefore, a balanced panel of 1200 observations is employed for analysis. The analysed sample covers relatively large farms (mean UAA – 244 ha). As for labour force, the average was 3.6 AWU.

The dynamics of the Cost Malmquist Productivity Index and its components is given in Fig. 1. The allocative efficiency and price change either played a rather insignificant role during most of the periods or moved to the opposite directions (e.g. during 2005–2006). Therefore, the difference between the Malmquist Productivity Index, M, and the Cost Malmquist Productivity Index, CM, remained close to nought. Obviously, the TFP was decreasing during most of the periods save those of 2006–2008. As for 2006–2007, the TFP change was mainly driven by the outward movement of the production frontier, which indicated the recovery after unsuccessful year 2006.



Source: designed by the authors.

Fig. 1. **Dynamics of the cost Malmquist Index and its components, 2004–2009**



Source: designed by the authors.

Fig. 2. **The cumulative change in the Cost Malmquist Index and its components, 2004–2009 (rectangles encompass the two productivity indices and their components)**

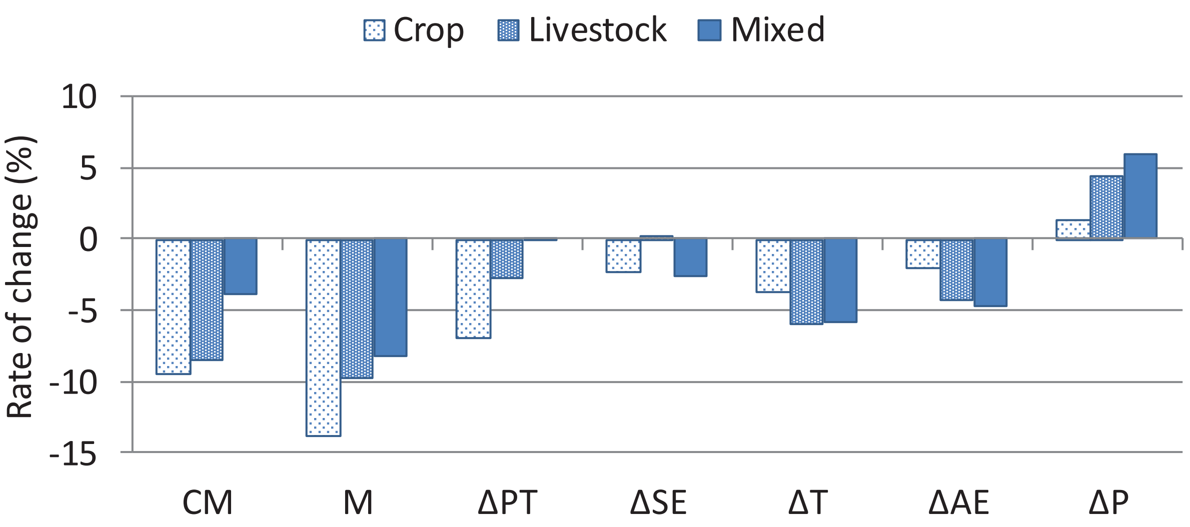


Fig. 3. **The cumulative change in the cost Malmquist Index and its components across farming types, 2004–2009**

Overall, the decrease in the TFP of some 20% was observed for the whole sample taking into account the period of 2004–2009. Thanks to a positive price change effect, ΔP, the cost productivity decreased to a margin of some 8%. The pure technical efficiency decreased by some 12%, and thus constituted the main source of decrease in the TFP. The cumulative scale efficiency change, ΔSE, summed up to zero, thus inducing a presence of the underlying constant returns to scale technology. Meanwhile, the allocative efficiency change, ΔAE, was negative, albeit quite insignificant (2%). Therefore, the input-mix adjustments were not efficiency-increasing either.

In order to assess the farming-type features of the TFP change, the Fig. 3 exhibits the mean values for the Malmquist Productivity Indices across crop (crop output constituted at least 2/3 of the total output), livestock (livestock output constituted at least 2/3 of the total output), and mixed farms. The analysis showed that the crop farms had suffered to the highest extent in terms of the TFP losses. However, the loss in the cost productivity was alleviated by the lowest decrease in productivity caused by change in the allocative efficiency. The latter finding implies that the crop farms were those most efficiently adjusting their input-mixes. The mixed farms experienced both the highest gains from the input price change and the highest losses induced by the decreasing allocative efficiency.

The scale efficiency changed rather insignificantly as regarding the livestock farms, whereas the two remaining farming types experienced a slight decrease therein. The steepest decrease in the pure technical efficiency was observed for the crop farms, whereas the production frontier moved inwards to the highest extent with respect to the livestock and mixed farms.

Conclusions, proposals, recommendations

The paper estimated the total factor productivity change for the sample of 200 Lithuanian family farms covering the period of 2004–2009. The results indicated that the cost productivity decreased by some 8%, whereas the total factor productivity – by 20% during the period. Declines in both pure technical efficiencies were the main drivers of the decrease, and the scale effect had almost no impact.

The crop farming should draw an immediate attention in terms of modernisation of this farming type, experienced the lowest input price effect and the highest decrease in the pure technical efficiency. On the other hand, the very production frontier moved inwards to a lower extent, if compared to the remaining farming types. Although the livestock and mixed farms did not exhibit the same steep decrease in the pure technical efficiency, their production frontiers mowed inwards to a higher extent, and thus resulted in the decreased total factor productivity.

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Acknowledgments

This research was funded by the European Social Fund under the Global Grant measure (VP1-3.1-ŠMM-07-K-03-002).