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DYNAMICS OF THE TOTAL FACTOR PRODUCTIVITY IN LITHUANIAN FAMILY FARMS: FRONTIER MEASURES

Abstract. *This paper analyses the total factor productivity in the Lithuanian agricultural sector, namely family farms reporting to the Farm Accountancy Data Network. More specifically, the Malmquist productivity index and data envelopment analysis are employed to analyze productivity changes and thus define respective policy implications. The research covers the period of 2003–2009. The four output indicators were employed for DEA, namely land productivity, labour productivity, return on assets, and intermediate consumption productivity. The analysis showed that the total factor productivity in the Lithuanian family farms had been decreasing throughout 2004–2005, and has been recovering by 1.3–8.1 per cent annually. However, technical change contributed to the increase in the total factor productivity rather insignificantly.*

Keywords: total factor productivity, Malmquist productivity index, DEA, Lithuania, agriculture.

JEL Classification: C44, C61, Q10.

1. INTRODUCTION

The measurement and analysis of efficiency and productivity constitutes the fundament of the managerial economics. Indeed, appropriate strategic management decisions should be made with respect to perception of trends in productivity of sector under analysis.

The agricultural sector has always been related to certain governmental regulations and support (OECD and FAO, 2011). It is, therefore, important to design and implement an appropriate agricultural policy. The streamlined agricultural policy, specific with rapid response to changes, should alleviate market distortions and provide with incentives for sustainable initiatives. Thus it is necessary to measure and analyse trends of efficiency and productivity in the agricultural sector.

These issues are of particular importance in Lithuania, which, like other post-communist Central and East European states, is peculiar with relatively high significance of the agricultural sector and to some extent still faces the consequences of collectivization (Gorton, Davidova, 2004). The process of de-collectivization in Lithuania started in 1989 and reached its peak in 1992–1993. Since then the Lithuanian agricultural sector has undergone a serious transformation. Lithuania acceded to the European Union (EU) in 2004 and since the Common Agricultural Policy is implemented there.

One of the most elaborated measures for efficiency is data envelopment analysis (DEA), see, for instance, studies by Murillo-Zamorano (2004) and Knežević et al. (2011). Accordingly, various studies employed DEA for efficiency and productivity analysis in agriculture (Alvares, Arias, 2004; Gorton, Davidova, 2004; Douarin, Latruffe, 2011). However, efficiency's estimates are not enough to identify t he underlying trends of productivity. Therefore, the Malmquist productivity index is employed to measure changes in the total factor productivity (Mahlberg et al., 2011; Sufian, 2010, 2011). Furthermore, the DEA is suitable for providing distance function estimates which are wherewithal components of the Malmquist productivity index.

This paper focuses on the Lithuanian agricultural sector, namely family farms reporting to the Farm Accountancy Data Network (FADN). More specifically, the Malmquist productivity index is employed to analyze productivity changes and thus define respective policy implications. The research covers the period of 2003–2009. The paper is organized in the following way. Sections 2 and 3 are dedicated to theoretical background of productivity measures and thus focus on Malmquist productivity index and DEA, respectively. Results of the research are presented in Section 4.

2. DYNAMIC PRODUCTIVITY AND MALMQUIST INDEX

Measurement of the total factor productivity (TFP) of certain DMU involves measures for both technological and firm-specific developments. As Bogetoft and 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 Malmquist productivity index being the most celebrated TFP measure. Hence this section is describing the preliminaries of Malmquist index.

Färe et al. (2008) firstly describe productivity as the ratio of output *y* over input *x*. Thereafter, the productivity can be measured by employing the output distance function of Shepard (1970):

$$D_o^t(x, y) = \min\{\theta : (x, y/\theta) \in T^t\}, \tag{1}$$

where T^t stands for the technology set (production possibility set) of the period *t*. This function is equal to unity if and only if certain input and output set belongs to production possibility frontier.

The Malmquist productivity index (Malmquist, 1953) can be employed to estimate TFP changes of single firm over two periods (or *vice versa*), across two production modes, strategies, locations etc. In this study we shall focus on output–oriented Malmquist productivity index and apply it to measure period–wise changes in TFP. The output–oriented Malmquist productivity index due to Caves et al. (1982) is defined as

$$M_o = \left(M_o^0 \cdot M_o^1\right)^{1/2} = \left(\frac{D_o^0(x^1, y^1)}{D_o^0(x^0, y^0)} \frac{D_o^1(x^1, y^1)}{D_o^1(x^0, y^0)}\right)^{1/2}, \tag{2}$$

with indexes 0 and 1 representing respective periods. The two terms in brackets follows the structure of Fisher's index. Consequently 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, Färe et al. (1992) decomposed productivity change into efficiency change (EC or catching up) and technical change (TC or shifts in the frontier):

$$M_o = EC \cdot TC, \tag{3}$$

where

$$EC = D_o^1(x^1, y^1) / D_o^0(x^0, y^0), \tag{4}$$

and

$$TC = \left(\frac{D_o^0(x^1, y^1)}{D_o^1(x^1, y^1)} \frac{D_o^0(x^0, y^0)}{D_o^1(x^0, y^0)} \right)^{1/2}. \tag{5}$$

EC measures the relative technical efficiency change. The index becomes greater than unity in case the firm approaches frontier of the current technology.

TC indicates whether the technology has progressed and thus moved further away from the observed point. In case of technological progress, the TC becomes greater than 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 unity.

3. PRELIMINARIES FOR DEA

DEA is a nonparametric method of measuring the efficiency of a decision–making unit (DMU) such as a firm or a public–sector agency (Ray, 2004). The very term of efficiency was initially defined by Debreu (1951) and then by Koopmans (1951). Debreu discussed the question of resource utilization at the aggregate level, whereas Koopmans offered the following definition of an efficient DMU: *A DMU is fully efficient if and only if it is not possible to improve any input or output without worsening some other input or output*. Due to similarity to the definition of Pareto efficiency, the former is called Pareto–Koopmans Efficiency. Finally, Farrell (1957) summarized works of Debreu and Koopmans thus offering frontier analysis of efficiency and describing two types of *economic efficiency*, namely *technical efficiency* and *allocative efficiency* (indeed, a different terminology was used at that time). The concept of technical efficiency is defined as the capacity and willingness to produce the maximum possible output from a given bundle of inputs and technology, whereas the allocative efficiency reflects the ability of a DMU to use the inputs in optimal proportions, considering respective marginal costs (Kalirajan, Shand, 2002). However, Farrell (1957) did not succeed in handling Pareto–Koopmans Efficiency with proper mathematical framework.

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 $j = 1, 2, ..., t, ..., N$ DMUs, each producing $r = 1, 2, ..., m$ outputs from $i = 1, 2, ..., n$ inputs. Hence, DMU t exhibits input–oriented technical efficiency θ_t, whereas output–oriented technical efficiency is a reciprocal number $\theta_t = 1/\phi_t$. The output–oriented technical efficiency φ_t may be obtained by solving the following multiplier DEA program:

$$
\begin{aligned}
&\max_{\phi_t, \lambda_j} \phi_t \\
&\text{s. t.} \\
&\sum_{j=1}^{N} \lambda_j x_i^j \leq x_i^t, \quad i = 1,2,..., n; \\
&\sum_{j=1}^{N} \lambda_j y_r^j \geq \phi y_r^t, \quad r = 1,2,..., m; \\
&\lambda_j \geq 0, \quad j = 1,2,..., N; \\
&\phi_t \text{ unrestricted.}
\end{aligned}
\tag{6}
$$

In Eq. 6, coefficients λ_j are weights of peer DMUs. Noteworthy, this model presumes existing constant returns to scale (CRS), which is 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 $\sum_{j=1}^{N} \lambda_j = 1$, which enabled to tackle the variable returns to scale (VRS). The BBC model, hence, can be written by supplementing Eq. 6 with a convexity constraint $\sum_{j=1}^{N} \lambda_j = 1$.

The best achievable input can therefore be calculated by multiplying actual input by technical efficiency of certain DMU. On the other hand, the best achievable output is obtained by dividing the actual output by the same technical efficiency $\theta_t = 1/\phi_t$, where ϕ_t is obtained from Eq. 6. The difference between actual output and the potential one is called slack. In addition it is possible to ascertain whether a DMU operates under increasing returns to scale (IRS), CRS, or decreasing returns to scale (DRS). CCR measures gross technical efficiency (TE) and hence resembles both TE and scale efficiency (SE); whereas BCC represents pure TE. As a result, pure SE can be obtained by dividing CCR TE by BCC TE. Noteworthy, technical efficiency describes the efficiency in converting inputs to outputs, while scale efficiency recognizes that economy of scale cannot be attained at all scales of production (Ramanathan, 2003).

4. TFP IN LITHUANIAN FAMILY FARMS: DATA AND RESULTS

The research relies on aggregate data. As for benchmarking in agriculture, the FADN is the most elaborated data source. The FADN reports (Ūkių ..., 2010) provide with the relevant data describing performance of family farms with respect to farming type, farm size, and geographic location. This paper focuses on the first option. The farming type assigned to certain farm depends on its output structure in terms of production value. In our case, nine alternatives were considered, namely eight different farming types and one average value (Table 1).

Table 1. Farming types and respective notations.

Abbreviation	Farming type
CEREAL	Specialist cereals, oilseeds
CROP	General field cropping
HORT	Horticulture, permanent crops
DAIRY	Specialist dairying
MCROP	Mixed cropping
MLGRZ	Mixed livestock, grazing
MCRGRZ	Field crops – grazing livestock
MCRGRN	Field crops – granivores, pigs
ALL	All farms

Usually, the following main variables presented in FADN reports are considered when analyzing the farming efficiency (Rimkuvienė et al., 2010; Bojnec, Latruffe, 2008): output (Lt), utilized land area (ha), labour (AWU), total assets (Lt), and intermediate consumption (Lt). These four input indicators and one output indicator were thus chosen for further analysis. The data cover the period of 2003–

2009. Firstly, the three indicators expressed in monetary terms were deflated by employing respective agricultural input or output price indexes provided by EUROSTAT. Secondly, output was divided by each of the four input indicators. Therefore, the four output indicators were defined for DEA, namely land productivity (Lt/ha), labour productivity (Lt/AWU), return on assets (per cent), and intermediate consumption productivity (times).

As one can note, the four indicators are measured in different dimensions. The first two indicators were obtained by dividing output by utilized agricultural area and labour input. The third indicator measures return on assets (ROA) and was calculated by dividing output by the total assets. This ratio can be multiplied by 100 per cent and thus expressed as a percentage. The last indicator identifies the efficiency of employment of the working capital, namely seeds, fertilizers, feedstuffs, and farming overheads.

Considering the average values for 2003–2009, the following findings are valid. The highest land productivity was observed for horticulture and permanent crop farming, whereas the highest labour productivity was reached in general field cropping farms. Meanwhile, the mixed field crop – granivore, pig farms were specific with the maximum ROA. Finally, the utmost intermediate consumption productivity was achieved in horticulture and permanent crop farming. Therefore, there is no single type of farming peculiar with the maximal values of the observed indicators. Accordingly, an application of MCDM method will enable to tackle all the objectives simultaneously.

The relative farming efficiency (i. e. technical efficiency) was estimated by DEA method across different faring types during 2003–2009 (Table 2). The *FEAR* package was employed for the analysis (Wilson, 2010).

Table 2. Technical efficiency across farming types, 2003–2009.

Period	CEREAL	CROP	HORT	DAIRY	MCROP	MLGRZ	MCRGRZ	MCRGRN	ALL
2003	1.000	0.926	1.000	0.931	1.000	1.000	1.000	1.000	0.930
2004	0.945	0.912	1.000	0.847	0.932	1.000	0.878	1.000	0.886
2005	1.000	0.972	1.000	0.971	1.000	0.993	0.980	0.991	0.965
2006	0.957	0.978	1.000	0.885	1.000	0.960	0.932	1.000	0.927
2007	0.972	0.916	1.000	0.902	1.000	0.994	0.906	0.882	0.930
2008	0.951	0.989	1.000	0.892	1.000	1.000	0.978	0.897	0.946
2009	0.989	1.000	1.000	0.905	1.000	1.000	0.991	0.917	0.958
Average	0.973	0.955	1.000	0.904	0.990	0.992	0.951	0.954	0.934

As Table 2 suggests, horticultural farms were operating relatively efficiently throughout the whole research period. However, this finding does not imply that these farms were operating truly efficiently; indeed, there was just no any linear combination of other farming types indicating possible output improvement. As of 2008–2009 TFP growth in specialist dairying, mixed cropping, mixed livestock (mainly grazing), and mixed field crops – grazing livestock farms was lower if compared to the average. Generally speaking, crop farming was peculiar with higher TE if compared to livestock farming. Dairying farms exhibited the lowest TE.

The last columns of Tables 2–5 exhibit TE estimate of an average Lithuanian family farm. This value, hence, can be considered as a yardstick for distinguishing between better performing and underperforming farming types.

The technical efficiency, however, is a static measure and does not provide one with information about productivity changes, Therefore, the DEA-based Malmquist index was employed. Table 3 describes period–wise analysis of TFP changes across different farming types in Lithuania.

Table 3. TFP changes (Malmquist productivity index) for different farming types, 2003–2009.

Period	CEREAL	CROP	HORT	DAIRY	MCROP	MLGRZ	MCRGRZ	MCRGRN	ALL
2004	1.061	1.105	1.096	0.962	0.948	0.973	0.933	1.083	1.007
2005	0.837	0.842	0.810	0.928	0.962	0.874	0.922	0.790	0.884
2006	1.072	1.129	1.341	1.027	1.185	1.104	1.071	1.214	1.081
2007	1.028	0.947	0.966	1.031	0.984	1.051	0.985	0.862	1.016
2008	0.978	1.080	0.899	0.990	1.085	1.023	1.079	0.973	1.016
2009	1.052	1.021	0.875	1.002	0.861	0.927	1.006	1.043	1.013
Average	1.001	1.016	0.983	0.989	0.999	0.989	0.997	0.984	1.001

TFP had been increasing for the average Lithuanian farm during 2003–2004 and since 2005. However, the observed growth rate fluctuated around 1 per cent since 2006. Such a trend clearly exhibits a need for technological and institutional innovations in the Lithuanian agricultural sector. Indeed, the changes in TFP varied across farming types. For instance, horticulture—the most technically efficient farming type—exhibited significant TFP growth, namely 34 per cent in 2005–2006 and subsequent decreases of 3.4 to 12.5 per cent. This case exactly illustrated the possibilities of Malmquist index to identify shrinking TFP in spite of stable TE. The highest TFP growth rate was observed for general field cropping. The following Tables 4 and 5 decompose TFP into EC and TC, respectively.

Table 4. Efficiency changes (catch-up) across different farming types, 2003–2009.

Period	CEREAL	CROP	HORT	DAIRY	MCROP	MLGRZ	MCRGRZ	MCRGRN	ALL
2004	0.945	0.985	1.000	0.910	0.932	1.000	0.878	1.000	0.953
2005	1.058	1.066	1.000	1.147	1.074	0.993	1.116	0.991	1.090
2006	0.957	1.006	1.000	0.912	1.000	0.967	0.952	1.009	0.961
2007	1.016	0.937	1.000	1.018	1.000	1.035	0.972	0.882	1.003
2008	0.978	1.080	1.000	0.990	1.000	1.006	1.079	1.017	1.016
2009	1.040	1.012	1.000	1.014	1.000	1.000	1.014	1.022	1.013
Average	0.998	1.013	1.000	0.995	1.000	1.000	0.999	0.986	1.005

Table 5. Technical changes across different farming types, 2003–2009.

Period	CEREAL	CROP	HORT	DAIRY	MCROP	MLGRZ	MCRGRZ	MCRGRN	ALL
2004	1.122	1.122	1.096	1.058	1.017	0.973	1.063	1.083	1.057
2005	0.791	0.790	0.810	0.810	0.896	0.880	0.826	0.796	0.811
2006	1.120	1.122	1.341	1.126	1.185	1.141	1.125	1.203	1.125
2007	1.012	1.012	0.966	1.013	0.984	1.015	1.013	0.978	1.012
2008	1.000	1.000	0.899	1.000	1.085	1.017	1.000	0.957	1.000
2009	1.011	1.010	0.875	0.988	0.861	0.927	0.992	1.020	1.001
Average	1.003	1.003	0.983	0.994	0.999	0.989	0.999	0.998	0.996

Given the data in Tables 4 and 5, the decreasing TFP in horticulture was mainly linked to technical changes: the frontier moved inwards and hence more inputs are needed to sustain the same level of outputs. Meanwhile, TFP shifts in general field cropping were driven by efficiency changes (catching–up). Furthermore, specialist dairying, mixed cropping, mixed livestock (mainly grazing), mixed field crops – grazing livestock, and mixed field crops – granivores, pigs farming also faced technical changes that reduced their TFP at a higher rate if compared to the average farm.

5. CONCLUSION

The analysis showed that the total factor productivity in the Lithuanian family farms had been decreasing throughout 2004–2005, and has been recovering by 1.3–8.1 per cent annually. However, technical change contributed to the increase in the total factor productivity rather insignificantly.

Therefore, it might be concluded that the Lithuanian agricultural sector still requires investments which, in turn, could lead to modernization of the production processes. Indeed, the relatively efficient sectors—for instance, horticulture, mixed farming—were specific with diminishing total factor productivity. Therefore, there should be a substantial incentives developed for productivity improvements in these sectors.

Further studies should address each particular sectors and determinants of efficiency therein. Furthermore, such measures as super-efficiency should also be employed for more robust analysis.

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