Development of productivity and its components in Slovak agriculture before and after EU accession: analysis of the impact of CAP introduction on the performance indicators of Slovak crop and livestock farms

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Summary

The common agricultural policy affects a broad range of issues on farms. Their productivity is no exception and CAP can affect it with different intensities and in different directions. CAP was introduced in the Slovak Republic after its accession to the EU in 2004. From that moment there was a significant increase in number of farms receiving subsidies. The aim of this paper was therefore to analyze the impact of these changes on the development of productivity and its components on the Slovak farms. The research consisted of two stages. The first stage we got a detailed picture of the evolving nature of the performance of Slovak crop and livestock farms in the period 2000-2012 by applying two approaches to evaluation of change in total factor productivity and its components, namely Malmquist Productivity Indices and Luenberger Productivity Indicators. We found that on average both types of farms increased their total factor productivity during the specified period. The driving force behind this development was the technological progress, the slowing factor was deterioration of technical efficiency of farms. By way of further decomposition of Malmquist indices we have also revealed Hicks-non-neutral technical change in the character of Slovak agriculture since the industry increasingly opted for automation and mechanization of production and mitigated use of *the workforce. In the second stage we applied Random Effect Models for analyzing panel data to examine the effects of accession to the EU on the development of performance indicators of Slovak farms and input bias of technical change. We found that dependence on farm subsidy policy was significantly higher after joining the Union, while total factor productivity after 2004 developed worse for both types of farms. The effect of changes in the share of total subsidies received on total farm income was the net effect of investment induced productivity growth and the negative effect of efficiency loss. The first prevailed in the case of crop and the second one in the case of livestock farms.*

Keywords: Malmquist Productivity Indices, Luenberger Productivity Indicators, EU accession, Common Agricultural Policy, input bias of technical change

JEL Classification codes: C23, C25, C44, Q18

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1. INTRODUCTION

Subsidy policy influences optimal farmers' decisions through different mechanisms, thus directly affecting the performance of their farms. The form of this relationship is not clear. If subsidies provide incentive for innovation and the transition to new, more productive technologies, their impact on the productivity of farms should be positive in the long term. If, however, they lead to worsening of the technical and allocative efficiency, their effect is negative. As the authors Rizov et al. (2012) state, the overall response of farm performance to allocated subsidies is the net effect of such investment induced increase of productivity and efficiency losses.

The results of the empirical literature are largely consistent. The negative impact of CAP subsidies on farm performance was found by several authors, for example Latruffe et al. (2012), who found that greater dependence on subsidies was in significantly negative relation with the performance of dairy farms in eleven EU countries, and Zhu et al. (2012), who concluded that the incentives of farmers on dairy farms in the Netherlands, Germany and Sweden to work efficiently was lower when these farms were more dependent on subsidies. Latruffe and Fogarasi (2009) investigated the performance differences between Hungarian and French farms specialized in milk and crop production in 2001-2004 and found that in both countries and both sectors received subsidies reduced farms’ technical efficiency. Authors Bojnec and Latruffe (2013), based on the analysis of the performance of Slovenian farms in 2004-2006, concluded that more subsidized farms were less technically efficient. Manevska-Tasevska et al. (2013) measured the performance of Swedish farms with different production specializations in 1998-2008 and found that the dependence on subsidies had a negative impact on the performance of all types of farms. Significant adverse impact of subsidies on the performance of farms was also revealed by the authors Iraizoz et al. (2005) in the case of Spanish cattle farms in the 90s, by Trnková et al. (2012) on Czech farms with major livestock production in 2004-2009 and by Bakucs et al. (2010) when examining the performance of the Hungarian farms in 2001-2005.

After accession to the EU, new Member States adopted the Common Agricultural Policy, which, among other things, meant a significant increase in the volume of subsidies provided for local farms. The Slovak Republic was not an exception. According to the study by Bielik and Sojková (2006) in 2004 (the year of accession to the EU) there was a statistically significant increase in the amount of subsidies per hectare compared with previous year, both in farms operating in productive areas, and in LFA areas. The volume of payments also grew in following years due to the gradual convergence towards the EU average. How was such an increase of subsidies reflected in the performance of the Slovak farms? Was it a driving force or, conversely, the brake in the development of their performance?

The aim of this paper was to investigate the impact of accession of the Slovak Republic to the EU and the associated increased dependence of the local farms on subsidy policy on the indicators of the total factor productivity change, technical efficiency change and technical change, as well as input bias of technical changes. The analysis consisted of two stages. In the first stage we analyzed the evolution of productivity and its components at Slovak crop and livestock farms in the period 2000-2012 by using two approaches, namely Malmquist Productivity Indices and Luenberger Productivity Indicators, to measure the performance development of decision-making units. In the second phase of the research we investigated the effects of the introduction of the common agricultural policy and dependence of farms on subsidies on the calculated indicators using Random Effects Models for the panel data analysis.

The article proceeds as follows: In Chapter 2 we describe the used approaches focusing on the evaluation of the performance development of decision-making units. In Chapter 3 we describe the data we used in our calculations. In Chapter 4 we present the results of our research and the final fifth Chapter lists the conclusions of this study.

2. METHODOLOGY

2.1. Malmquist Productivity Indices

Malmquist Productivity Index (MPI) allows us to measure changes in the total factor productivity between two arbitrary periods. By decomposing it, it is also possible to detect sources of such change. The basis for calculations are the output Shephard distance functions (Shephard, 1970) indicating the maximum proportional radial increase of outputs' vectors at a given level of inputs' vectors.

Caves et al. (1982) proposed a calculation of Malmquist index as the ratio of two output distance functions for the time t and t + 1 relative to the technology at the time t, which was later modified by Färe et al. (1989, 1994a) as a geometric mean of two Malmquist indices for two adjacent periods t and t + 1 relative to the technology at time t and t + 1, as follows:

$$M_o^t(x^t, y^t, x^{t+1}, y^{t+1}) = \sqrt{\frac{D_o^t(x^{t+1}, y^{t+1})}{D_o^t(x^t, y^t)} \times \frac{D_o^{t+1}(x^{t+1}, y^{t+1})}{D_o^{t+1}(x^t, y^t)}} \qquad (1)$$

The calculated value of Malmquist index can be compared with a value of 1. If the MPI for the given farm is greater than 1, its total factor productivity between the periods t and t + 1 increased. MPI less than 1 indicates the decrease of the given farms' total factor productivity between the two periods. MPI equal to 1 is associated with no change of the total factor productivity of the farm.

Malmquist index (1) can be further decomposed into the technical efficiency change index (TECH) and technical change index (TCH). The starting point for this division is the following writing of MPI:

$$M_o^t(x^t, y^t, x^{t+1}, y^{t+1}) = \frac{D_o^{t+1}(x^{t+1}, y^{t+1})}{D_o^t(x^t, y^t)} \times \sqrt{\frac{D_o^t(x^{t+1}, y^{t+1})}{D_o^{t+1}(x^{t+1}, y^{t+1})} \times \frac{D_o^t(x^t, y^t)}{D_o^{t+1}(x^t, y^t)}} \tag{2}$$

where the mathematical expression before the square root is the technical efficiency change between the periods t and t + 1 and the expression under the square root represents a technical change between these two periods. The pattern is that the index of change in total factor productivity is the product of technical efficiency change and technical change.

If the index of the technical efficiency change is greater than 1, the evaluated enterprise has improved its technical efficiency compared to previous period and caught up to others. If the value of this index is less than 1, the technical efficiency of the enterprise has deteriorated over time and efficient enterprises are leaving it behind. In the case that the technical efficiency change is equal to 1, there has been no change in the relative performance of the given enterprise. If the value of technical change is greater than 1, there has been a technological progress between the period t and t + 1. If this value is less than 1, there has been a regress in the use of technology in the monitored enterprise. If the value of this variable is equal to 1, there has been no technical change.

Indices of technical efficiency change and technical change are based on the assumption of constant returns to scale. If we extend this assumption to allow variable returns to scale, the authors Färe et al. (1994b) claim that it is possible to decompose the technical efficiency change component to the scale efficiency change (SECH) and pure technical efficiency change (PTECH):

$$TECH(x^t, y^t, x^{t+1}, y^{t+1}) = \left[\frac{\dfrac{D_o^{t+1}(x^{t+1}, y^{t+1}|KVR)}{D_o^{t+1}(x^{t+1}, y^{t+1}|VVR)}}{\dfrac{D_o^t(x^t, y^t|KVR)}{D_o^t(x^t, y^t|VVR)}}\right] \times \left[\frac{D_o^{t+1}(x^{t+1}, y^{t+1}|VVR)}{D_o^t(x^t, y^t|VVR)}\right] \tag{3}$$

where the mathematical expression in the first brackets represents the scale efficiency change and the expression in the second brackets shows the change in pure technical efficiency. The pattern is that the technical efficiency change index is the product of scale efficiency change index and pure technical efficiency change index.

Interpretation of indicators is similar to that in previous cases. If the change of scale efficiency is greater than 1, the enterprise has improved its efficiency of scale in the period t and t + 1. In the case that this value is less than 1, the scale efficiency has deteriorated in the monitored period. If the change of scale efficiency is equal to 1, the scale efficiency of the monitored enterprise has not changed. If the value of the pure technical efficiency change is greater than 1, the enterprise has improved the pure technical efficiency during the period t and t + 1. If this value is less than 1, pure technical efficiency of the monitored enterprise has deteriorated over time. In the case that the pure technical efficiency change is equal to 1, this indicator has not changed over time.

Changes in the structure of inputs in favor of more efficient and technologically advanced production factors, as well as changes in the structure of output produced lead to distortions that may result in a disproportionate shift of isoquants. Färe et al. (1997) proposed a method for the assessment of these changes through decomposing the technical change into the component of output bias of technical change (OBTCH), input bias of technical change (IBTCH) and magnitude of technical change (MTCH).

$$TCH = \sqrt{\frac{\frac{D_o^{t+1}(x^{t+1}, y^t)}{D_o^t(x^{t+1}, y^t)}}{\frac{D_o^{t+1}(x^{t+1}, y^{t+1})}{D_o^t(x^{t+1}, y^{t+1})}}} \cdot \sqrt{\frac{\frac{D_o^{t+1}(x^t, y^t)}{D_o^t(x^t, y^t)}}{\frac{D_o^{t+1}(x^{t+1}, y^t)}{D_o^t(x^{t+1}, y^t)}}} \times \left[\frac{D_o^t(x^t, y^t)}{D_o^{t+1}(x^t, y^t)}\right] \tag{4}$$

where the mathematical expression under the first square root is a measure of output bias of technical change, the expression under the second square root expresses input bias of technical change and the expression in brackets represents the magnitude of the technical change. The technical change index is thus the product of multiplication of OBTCH, IBTCH and MTCH indices.

Output bias indicates whether the input isoquant shifts proportionally for different combinations of outputs and the input bias indicates whether the output isoquant shifts proportionally for the various input mixes. Technical change contains no deformation and thus is Hicks-neutral for inputs and outputs, provided the OBTCH and IBTCH are equal to 1. In this case, the component MTCH is equal to TCH, thus the total technical change is contained in the magnitude of technical change. However, if only the component of output bias is equal to 1, the technical change is the result of the input bias and technical change magnitude.

In Table 1 we show how can be input bias values and the ratio of capital and labor used in the identification of capital or labor-using nature of the technical change. This procedure can also be applied in the case of other input pairs.

Table 1. The direction of input bias of technical change.>

	IBTCH > 1	**IBTCH = 1**	**IBTCH < 1**
$(C/L)^{t+1} > (C/L)^t$	capital using, labour saving	Hicks-neutral	labour using, capital saving
$(C/L)^{t+1} < (C/L)^t$	labour using, capital saving	Hicks-neutral	capital using, labour saving

Source: Kumar (2006)

Calculations of MPI and its components are based on the fact that the distance function is reciprocal to the Farrell technical efficiency score (Farrell, 1957). To estimate distance functions, authors Färe et al. (1994a) proposed to use linear programming method of Data Envelopment Analysis (DEA), introduced by Charnes et al. (1978).

Objective function: $$\varphi_o^* = \max\varphi_o \tag{5}$$

Subject to: $$\sum_{j=1}^{n} x_{ij}\lambda_j \leq x_{io} \; i = 1, 2, \dots, m$$

$$-\varphi y_{ro} + \sum_{j=1}^{n} y_{rj}\lambda_j \geq 0 \;\; r = 1, 2, \dots, s$$

$$\lambda_j \geq 0 \;\; j = 1, 2, \dots, n$$

where x_{ij} is i input of j DMU, y_{rj} is r output of j DMU, x_{io} is i input of evaluated DMU, y_{ro} is r output of evaluated DMU, λ_j is intensity variable of j DMU, φ_o is the technical efficiency score of the evaluated DMU.

For the calculation of distance functions, which form the basis for MPI and all its components, we need to resolve eight DEA models for each enterprise. Six assume constant returns to scale (CRS) and two are under conditions of variable returns to scale (VRS). These are the following models:

- CRS model with inputs and outputs of the evaluated farm at the time t with respect to the technology at the time t
- CRS model with inputs and outputs of the evaluated farm at the time t with respect to the technology at the time t+1
- CRS model with inputs and outputs of the evaluated farm at the time t+1 with respect to the technology at the time t
- CRS model with inputs and outputs of the evaluated farm at the time t+1 with respect to the technology at the time t+1
- CRS model with inputs of the evaluated farm at the time t+1 and outputs of the evaluated farm at the time t with respect to the technology at the time t
- CRS model with inputs of the evaluated farm at the time t+1 and outputs of the evaluated farm at the time t with respect to the technology at the time t+1
- VRS model with inputs and outputs of the evaluated farm at the time t with respect to the technology at the time t
- VRS model with inputs and outputs of the evaluated farm at the time t+1 with respect to the technology at the time t+1.

2.2. Luenberger Productivity Indicators

Besides several advantages of Malmquist indices, such as no need of information on prices of inputs and outputs and no need to meet the assumptions about the structure and behavior of production technology, their disadvantage is that when calculating the average indicators for more businesses or periods, these are overestimated due to the nature of the index (Boussemart et al., 2003; Barros et al., 2008). Also subsequent analysis in the second phase of the research would be biased as well.

To cope with this situation, we also calculated the so called Luenberger Productivity Indicator (LPI) and its components. It is an innovative approach based on the values of directional distance functions expressing the maximum simultaneous input reduction and output expansion in the given direction specified by directional vector g at which the evaluated DMU reaches the production frontier. The important question is therefore selecting the appropriate directional vector that must be chosen by the author himself (Färe and Grosskopf, 2000). Since we use output-oriented Malmquist indices, for the sake of comparison we chose calculation of output-oriented Luenberger indicators with the directional vector $g = (0, y)$.

Chambers et al. (1996) defined Luenberger Productivity Indicator (LPI), based on the values of the directional distance functions in the time t/t+1 as follows:

$$L\,(x^t, y^t, x^{t+1}, y^{t+1}) = \frac{1}{2}\,(D_{T^{t+1}}(x^t, y^t; g) - D_{T^{t+1}}(x^{t+1}, y^{t+1}; g) + D_{T^t}(x^t, y^t; g) - D_{T^t}\,(x^{t+1}, y^{t+1}; g)) \tag{6}$$

Improved productivity is indicated by positive values, deterioration is, on the contrary, indicated by negative values. If the value is 0, the productivity has not changed.

In our analysis we use the link between the calculation of Malmquist indices and Luenberger indicators that were described by Balk et al. (2008). If we denote Shephard distance functions with capital *A*, *B*, *C* and *D* and the corresponding directional distance functions with letters *a*, *b*, *c* and *d*, then:

$$MPI = \sqrt{\frac{A}{B} x \frac{C}{D}} \text{ then } LPI = \frac{1}{2}[(b-a)+(c-d)]$$

This relationship is true not only for indicator of total factor productivity change, but also for all its components, i.e. the technical efficiency change, scale efficiency change, pure technical efficiency change, technical change, output bias of technical change, input bias of technical change and magnitude of technical change. Same as for the indicator of total factor productivity change, when comparing their values with zero, it is possible to determine whether there is evidence of progress, regress or stagnation in other indicator.

Let us have N decision-making units producing S outputs and M inputs. The linear programming model, with the constant returns to scale, for the calculation of the value of the directional distance function β with the directional vector $g = (-g_x, g_y)$ is as follows:

Objective function $$D_T(x_o, y_o, g) = \max \beta \tag{8}$$

Subject to: $$\sum_{j=1}^{n} \lambda_j x_{ij} \leq x_{io} - \beta\, g_{x_i}, i = 1, \ldots, M$$

$$\sum_{j=1}^{n} \lambda_j y_{rj} \geq y_{ro} + \beta\, g_{y_r}, r = 1,2, \ldots, S$$

$$\lambda_j \geq 0, j = 1,2, \ldots, N$$

where x_{ij} is i input of j DMU, x_{io} is i input of evaluated DMU, y_{rj} is r output of j DMU, y_{ro} is r output of evaluated DMU, λ_j is intensity variable of j DMU, g_{xi} is the value of directional vector for i input, g_{yr} is the value of directional vector for r output and β is the value of directional distance function.

To estimate values of directional distance functions needed for calculations of LPI and all its components for each farm and each period, we have to solve eight DEA models again. The choice of time t, or t + 1 for inputs and outputs of evaluated farm, as well as the choice of technology is the same as in the previous subchapter.

3. DATA AND VARIABLES

The source of the data utilized in our research was the Database of Information Sheets of the Ministry of Agriculture and Rural Development of the SR. Given that the production technology of various types of enterprises is different, the performance was evaluated separately for farms specialized in crop and livestock production. Their input and output variables were as follows:

Crop farms:

- Input 1: Labour (annual personnel costs in €)
- Input 2: Capital (annual depreciation + amortization of tangible assets in €)
- Input 3: Land (cultivated agricultural land in hectares)
- Input 4: Seeds (annual expenditures on seeds in €)
- Input 5: Fertilizers (annual expenditures on fertilizers in €)
- Input 6: Other (annual expenditures on other materials and energy in €)
- Output 1: Crop production (annual revenues from the sale of crop production in €)
- Output 2: Other production (annual revenues from the sale of other production in €)

Livestock farms:

- Input 1: Labour (annual personnel costs in €)
- Input 2: Capital (annual depreciation + amortization of tangible assets in €)
- Input 3: Land (cultivated agricultural land in hectares)
- Input 4: Feeds (annual expenditures on feeds in €)
- Input 5: Other (annual expenditures on other materials and energy in €)
- Output 1: Livestock production (annual revenues from the sale of livestock production in €)
- Output 2: Other production (annual revenues from the sale of other production in €)

Individual monetary variables were deflated according to the corresponding price indices relative to year 2005. Indices were obtained from the database SLOVSTAT from the Statistical Office of the SR.

In the second phase of our research we evaluated the impact of accession to the EU and changes in dependence on farm subsidies on the development of the performance of farms. The effect of Slovakia's accession to the Union was modeled using the dummy variable having 0 value in the period before 2004 and one after 2004, when Slovakia was introduced CAP. Dependence on subsidies was measured by the proportion of total farm subsidies received on its total revenues. As the performance indicators of farms were expressed through the annual change, dependence indicator was adjusted to the same form.

The impact of mentioned variables on total factor productivity change, technical efficiency change and technical change was investigated using the model of panel data analysis. When examining the effect of external variables on the incidence of input bias of technical change we applied logit models of panel data analysis. The first step was the application of Hausman test, based on which we decided between the choice of the model with fixed or random effects. As we rejected the null hypothesis in all cases, we considered random effects model to be a better option.

4. RESULTS AND DISCUSSION

We identified a total of 73 farms specialized in crop production and 97 farms with prevailing livestock production throughout the whole period 2000-2012 in the Database of Information Sheets of the Ministry of Agriculture and Rural Development of the SR. The descriptive characteristics of input and output variables for the entire period are presented in Table 2 for crop and Table 3 for livestock farms.

Table 2. The descriptive characteristics of input and output variables of crop farms throughout the whole period 2000-2012.>

Variable	Mean	St. dev.	Minimum	Maximum	Mode	Median
Labour (€)	230006	209784	230	1604149	150448	172357
Capital (€)	121118	122931	35	995090	1290	79264
Land (ha)	1154	837	20	4169	205	969
Seeds (€)	76718	65671	227	390167	17532	58885
Fertilizers (€)	92760	112507	108	1339860	14062	59468
Other costs (€)	231895	196342	5900	1024978	-	173649
Crop production (€)	628675	532149	12671	3334059	-	487086
Other production (€)	159540	209105	0	1780995	0	71039

Source: own calculations

Table 3. The descriptive characteristics of input and output variables of livestock farms throughout the whole period 2000-2012.>

Variable	Mean	St. dev.	Minimum	Maximum	Mode	Median
Labour (€)	355561	342251	360	2479564	468277	246830
Capital (€)	198357	195753	700	1299119	136158	138805
Land (ha)	1398	1059	13	6530	374	1038
Feeds (€)	201286	590138	220	9473049	827	79090
Other costs (€)	190659	208270	190	1311565	168560	109277
Livestock production (€)	608180	1129611	1176	12263317	32387	361972
Other production (€)	213936	393226	0	3262053	0	68038

Source: own calculations

In the first stage of our research we focused on the assessment of productivity developments in Slovak crop and livestock farms and its components using two approaches – Malmquist indices and Luenberger indicators. Median value of the Malmquist Productivity Index of crop farms, 0.981 throughout the whole period, shows that there has been deterioration in productivity of at least 1.9% in half of the observations throughout the period. Overall, there was a regress of productivity in a large majority of cases (52.5%), while in only 47.5% of cases the productivity rose. The slowing element in the performance improvement of crop farms seems to be worsening technical efficiency, which has not improved in up to 60.7% of cases, while progress was detected in only 39.3% of observations. This fact was caused by scale efficiency change, as well as pure technical efficiency change. In contrast, the growth of crop farms performance was partially caused by the technical progress that has been made in 53.3% of cases, while the deterioration of the technology was marked in only 46.6% of observations. The fact that the indicators of technical change bias acquired a value of 1 only minimally, it indicates the predominant Hicks-non-neutral character of technical change in Slovak crop farms.

Regarding farms specializing in livestock production, the median value of Malmquist Productivity Index , 1.014 throughout the whole period, indicates the overall increase in productivity by at least 1,4% in half cases in the observed period 2000-2012. Overall, in 52.6% of the cases we observed the productivity increased in livestock farms and only in 47.4% of observations the performance worsened. Also in this case the main driver of productivity growth was technological progress, the effect of which was dampened by technical efficiency regress. Technical change, however, was reflected in livestock farms more significantly as technology improvements occurred in 64.9% of cases, while technical regress occurred in only 35.1% of cases. Also in this case there was predominant Hicks-non-neutral technical change on Slovak livestock farms. Regarding the technical efficiency, the deterioration occurred in 51.2%, stagnation occurred in 9.1%, and the improvement in 39.7% of cases. This condition corresponds to prevailing deterioration of efficiency of scale, as well as the prevailing regress of pure technical efficiency.

The quartile values Q1 - Q3, as well as percentage frequencies of regress, stagnation and progress of each index in crop and livestock farm throughout the period are shown in Table 4 and Table 5.

Table 4. Quartiles Q1-Q3 and the percentage frequency of regress, stagnation and progress of the total factor productivity and its components in crop farms in the period 2000-2012.>

Variable	Quartile Q1	Quartile Q2	Quartile Q3	Regress	Stagnácia	Progress
MPI	0.817	0.981	1.203	52.51%	0.00%	47.49%
TECH	0.865	1.000	1.125	42.92%	17.81%	39.27%
SECH	0.962	1.000	1.031	43.95%	17.81%	38.24%
PTECH	0.906	1.000	1.089	35.27%	31.28%	33.45%
TCH	0.892	1.013	1.141	46.69%	0.00%	53.31%
OBTCH	0.997	1.000	1.015	33.68%	14.27%	52.05%
IBTCH	0.999	1.024	1.093	26.48%	0.11%	73.40%
MTCH	0.811	0.966	1.087	58.22%	0.00%	41.78%

Source: own calculations

Table 5. Quartiles Q1-Q3 and the percentage frequency of regress, stagnation and progress of the total factor productivity and its components in livestock farms in the period 2000-2012.>

Variable	Quartile Q1	Quartile Q2	Quartile Q3	Regress	Stagnation	Progress
MPI	0.879	1.014	1.150	47.42%	0.00%	52.58%
TECH	0.851	0.993	1.098	51.20%	9.11%	39.69%
SECH	0.989	1.000	1.013	46.31%	9.11%	44.59%
PTECH	0.852	1.000	1.083	49.91%	12.54%	37.54%
TCH	0.963	1.042	1.136	35.14%	0.00%	64.86%
OBTCH	0.998	1.000	1.012	32.73%	13.83%	53.44%
IBTCH	0.992	1.004	1.028	39.26%	0.43%	60.31%
MTCH	0.934	1.025	1.119	42.35%	0.00%	57.65%

Source: own calculations

The results of the analysis of development of Slovak farms productivity using Luenberger indicators basically confirms these findings. The average value of Luenberger Productivity Indicator of crop farms accounting to 0.003 indicates that, on average, these types of farms increased their total factor productivity over the whole period from 2000 to 2012 only very slightly. Higher growth of performance was once again prevented by the deterioration of technical efficiency (an average of -0.006), caused by the regress of the efficiency of scale (-0.004) as well as the deterioration of pure technical efficiency (-0.002). Progress in performance of farms was only achieved thanks to improved technical changes, when the average value of this indicator stood at 0.009, while it was a Hicks-non-neutral technical change.

In the case of livestock farms we have also come to similar results as in applications of Malmquist indices. The average value of Luenberger Productivity Indicator for the whole period was 0.025, indicating a relatively strong average increase in productivity compared to crop farms. Other results are also broadly consistent with the already known facts. The main driver of productivity growth was relatively strong Hicks-non-neutral technical progress (0.099) and also an insignificant improvement in efficiency of scale (0.002). Because of relatively strong deterioration in pure technical efficiency (-0.077), the progress of performance of livestock farms was not so significant. The average values of Luenberger indicators for crop and livestock farms in individual years, as well as for the entire period are shown in Table 6 and Table 7.

Table 6. The average values of Luenberger indicators of the total factor productivity change and their components in crop farms for each year and for the whole period 2000-2012.>

Years	LPI	TECH	SECH	PTECH	TCH	OBTCH	IBTCH	MTCH
2000/2001	0.194	0.020	0.025	-0.005	0.174	-0.015	0.089	0.100
2001/2002	-0.067	0.006	-0.007	0.013	-0.073	0.023	0.070	-0.166
2002/2003	-0.085	-0.055	0.038	-0.093	-0.030	0.022	0.065	-0.118
2003/2004	0.057	-0.097	-0.083	-0.014	0.153	-0.005	0.083	0.075
2004/2005	0.039	0.170	0.047	0.124	-0.132	0.006	0.081	-0.218
2005/2006	0.054	-0.069	-0.032	-0.037	0.123	0.000	0.060	0.063
2006/2007	-0.244	-0.012	-0.034	0.021	-0.232	0.000	0.046	-0.278
2007/2008	-0.035	-0.086	0.019	-0.105	0.051	0.006	0.052	-0.006
2008/2009	0.348	0.013	-0.043	0.056	0.335	-0.001	0.042	0.295
2009/2010	-0.294	0.086	0.054	0.032	-0.380	0.007	0.067	-0.454
2010/2011	0.031	-0.133	-0.001	-0.132	0.164	-0.031	0.103	0.092
2011/2012	0.042	0.088	-0.029	0.117	-0.046	0.023	0.041	-0.109
Mean	**0.003**	**-0.006**	**-0.004**	**-0.002**	**0.009**	**0.003**	**0.066**	**-0.060**

Source: own calculations

Table 7. The average values of Luenberger indicators of the total factor productivity change and their components in livestock farms for each year and for the whole period 2000-2012.>

Years	LPI	TECH	SECH	PTECH	TCH	OBTCH	IBTCH	MTCH
2000/2001	0.127	-0.144	-0.016	-0.128	0.270	-0.009	0.006	0.272
2001/2002	0.157	0.076	0.035	0.041	0.081	0.005	0.028	0.047
2002/2003	-0.078	-0.073	0.017	-0.089	-0.005	0.022	0.019	-0.046
2003/2004	0.102	-0.052	-0.018	-0.034	0.154	0.004	0.032	0.117
2004/2005	-0.139	-0.172	-0.010	-0.162	0.032	0.004	0.021	0.007
2005/2006	0.000	-0.307	-0.036	-0.271	0.307	0.019	0.012	0.276
2006/2007	-0.109	-0.240	0.031	-0.272	0.123	0.015	0.025	0.083
2007/2008	0.065	0.034	-0.010	0.044	0.031	-0.008	0.030	0.009
2008/2009	0.162	0.042	-0.020	0.062	0.121	0.032	0.027	0.062
2009/2010	-0.013	0.208	0.004	0.203	-0.221	0.063	0.011	-0.295
2010/2011	-0.203	-0.080	0.000	-0.080	-0.124	0.004	0.010	-0.137
2011/2012	0.230	-0.189	0.046	-0.234	0.417	-0.053	0.031	0.440
Mean	**0.025**	**-0.075**	**0.002**	**-0.077**	**0.099**	**0.008**	**0.021**	**0.070**

Source: own calculations

Based on the comparison of values of input bias of technical change and ratios of all input pairs in all consecutive years we found that with regard to crop farms, the most intense use of capital occurred when capital-using and other inputs-saving TCH prevailed. Development of technical change in crop farms in the same period was also characterized by intensified use of fertilizers when fertilizers-using and other inputs-, except for capital, saving TCH prevailed. This was followed by seeds and other material and energy, whose use mitigated with regard to the first two mentioned, but compared to land and labor inputs, these mostly intensified. Land use was relatively constant, which meant the predominant land-saving and all other inputs-, except labor, using character of TCH. Workforce has a saving tendency, when in the period prevailed labor-saving and all other inputs-using TCH. Livestock farms intensified their use of capital when prevailed capital-using and all other inputs-saving TCH in the period 2000-2012. Also there was a predominant intensification of other materials and energy use relative to all other inputs in addition to capital. The utilized agricultural land was relatively constant, which resulted in an essentially land-saving and capital and other material and energy-using and labor and feed-saving nature of TCH. Use of labor and feed on livestock farms largely mitigated when we found the predominant feed-saving and all the other production factors-using and labor-saving and all other inputs-, except feed, using nature of technical change in livestock farms.

Slovakia's entry into the EU was among other things also associated with the adoption of mechanisms and instruments of the Common Agricultural Policy. This meant a significant increase in the volume of granted subsidies, which was also associated with statistically significant increase of their share on total farm income (in the case of crop farms from an average of 11% before 2004 to around 22% after Slovakia's accession to the EU and for livestock farms from 26% before to over 42% after the introduction of CAP).

Both types of farms experienced deterioration in their productivity in the first four years after accession to the EU. In the case of livestock farms the difference was statistically significant. Causes that were behind this development, however, were different. For crop farms it was statistically significantly worse development in their technology. These farms, when compared to livestock farms, received lower amount of investment subsidies that could lead to innovation and were hit by marked price turbulences more often, causing fluctuations in the indicator of technical changes. On the other hand, in comparison with the period prior to accession to EU, there has been better development in the technical efficiency of crop farms. While it almost did not grow on average, at least its decrease from the period has stopped.

The change in productivity developments of livestock farms was different, since, as compared to numbers prior to 2004, the development of technical efficiency changes indicator has significantly worsened. The share of subsidies received by these farms on their total revenues was significantly higher than that on crop farms plus the increase after EU accession was more pronounced compared to crop farms. Therefore, the pressure to operate on the production frontier was probably relatively low. On the other hand, in livestock farms we found almost no change in their development of technology when they reached relatively significant progress in both periods. The results of panel data analysis for crop and livestock farms are listed in Table 8.

Table 8. The analysis of the difference in the development of total factor productivity, technical efficiency and technology of Slovak farms between periods 2000-2004 and 2004-2008.>

Variable	Crop farms		Livestock farms	
	Coeff.[1]	**P-value**[2]	**Coeff.**[1]	**P-value**[2]
LPI	-0.071	0.060	-0.123	0.025
TECH	0.032	0.381	-0.123	0.032
TCH	-0.103	0.000	-0.002	0.917

Source: own calculations
[1] Coeff. – regression coefficient expressing the difference in the average value of the indicator between the examined periods
[2] P-value – for values less than 0.05 the difference in the given indicator between two periods is statistically significant, otherwise the difference is insignificant

The difference between the periods before and after 2004 was also present in input bias of technical changes. After EU accession, crop farms showed insignificant increase in the likelihood of fertilizers-using and all other inputs –saving TCH. Livestock farms showed insignificant increase in the likelihood of feeds-using and all other inputs-saving TCH and also increase in the likelihood of other material-saving and other input-using TCH.

As it also can be seen in several empirical studies, we did not model the impact of the subsidy policy through the total amount of subsidies received, as it is logical that their higher volumes are accepted by larger farms. To remove this size-effect, the indicator of the share of total subsidies received on the total income of farms is frequently used. Throughout the period, crop farms' subsidies accounted for statistically significantly smaller portion of their income compared to livestock farms. The average value of the indicator throughout the period accounted to 18.54% on crop farms and 37.46% on livestock farms.

While the level of the share of total subsidies received on the total income of farms had no significant effect on the size and direction of change of productivity and its components or on the input bias of technical change, the change of this indicator was more pronounced in the development of several other indicators. Specifically, in the case of crop farms it had statistically insignificant positive impact on the change in their productivity. This fact was caused by its positive effect on technical change, which was statistically significant. On the other hand, we found statistically insignificant negative impact of change in the monitored indicator on the technical efficiency change of crop farms. Again, it is but necessary to mention the price turbulence in some years, causing significant fluctuations in industry's technical change and these were often in line with changes in the share of subsidies on total income of farms. These findings are consistent with the theoretical basis under which the subsidies may encourage farmers to innovate and move to new, more productive technologies, or the access to such technology may be made easier through the reduction of their budget constraints (Key et al. 2010) and improved access to credit (Roe et al., 2002). Similar results came in some empirical studies, for example in the case of research authors Latruffe et al. (2012), who found a positive effect of subsidies on the technical change of Danish and Dutch farms or Sipiläinen & Kumbhakar (2010), who revealed the positive effect of technical change on Danish farms. On the contrary, significant negative impact of subsidies on the technical change was found by Latruffe et al. (2012) in four out of eleven countries surveyed and also by Sipiläinen & Kumbhakar (2010) in case of Finnish and Swedish farms.

As for livestock farms, the analysis revealed a statistically significant negative relationship between the development of the total factor productivity and the change in the share of total subsidies on their income. This was primarily caused by significant negative effect of change in the share of subsidies on the total income on the technical efficiency change of these farms. The effect of this indicator on technical change was positive, however, statistically insignificant. The facts are consistent with the literature, according to which higher profits undermine the incentives of managers, which may manifest itself in their reduced efforts. Farms receiving subsidies are also not forced to reorganize their activities to such an extent as would be the case if they did not receive any subsidies (Bergström, 2000). The results of previous analyzes are also consistent with the conclusions of the vast majority of empirical studies, among which are authors Latruffe et al. (2012), who found a negative effect of subsidies on the technical efficiency of dairy farms in eleven EU countries, Zhu et al. (2012), who came to similar conclusions in the case of dairy farms in Germany, the Netherlands and Sweden, or Manevska-Tasevska et al. (2013, who found the same results in the case of Swedish farms of different specializations.

The results also confirm the theoretical basis provided by authors Rizov et al. (2012), who argue that the impact of subsidies on farm productivity is the net effect of positive, investment induced productivity growth (we found a positive relationship between the change in the share of total subsidies on the total revenues and technical changes in both types of farms) and the negative effect of the loss of efficiency (negative correlation between change in the total subsidies received on the total revenues and change in technical efficiency in both types of farms). In the case of crop farms positive effect prevailed, on livestock farms negative effect prevailed. The results of these analyzes are summarized in Table 9.

Table 9. Analysis of the impact of change in the share of subsidies received by crop and livestock farms on their income on change of productivity, technical efficiency and technology for the period 2000-2012.>

Variable	Crop farms		Livestock farms	
	Coeff.[1]	**P-value[2]**	**Coeff.[1]**	**P-value[2]**
LPI	0.012	0.950	-1.331	0.000
TECH	-0.293	0.114	-1.513	0.000
TCH	0.305	0.002	0.179	0.093

Source: own calculations

[1] Coeff. – regression coefficient reflecting the average increase in the value of the indicator at 100% increase in the share of the total subsidies received on the total farm income

[2] P-value – for values less than 0.05, the impact of change in subsidies-dependence on the given indicator is statistically significant, otherwise the effect is not significant

During periods in which the share of total subsidies received by crop farms on their total revenues declined, the likelihood of fertilization-using and all other inputs -saving TCH increased significantly in almost all cases together with the probability of seeds-using and other inputs-saving TCH. While increasing the proportion of total subsidies received on the total income grew insignificantly in the case of livestock farms, probability of feed-saving and all other inputs-using TCH rose insignificantly. Farmland cultivated by both types of farms was the input for which the likelihood of using rose with the rise of subsidies dependence.

5. Conclusion

The paper aimed to analyze the development of Slovak crop and livestock farms productivity in the period 2000-2012, focusing on the impact of the accession of the Slovak Republic to the EU and the associated increase in subsidy payments. We achieved it in two stages.

In the first stage of our research we discovered a very weak average growth of the productivity of crop farms and a stronger increase of the same indicator in livestock farms. Among other reasons there is the fact that the performance of the crop farms is more dependent on external factors such as climatic conditions. The main driver for enhancing the performance of both types of farms was technological progress, its slowing down was caused by deteriorated technical efficiency.

A closer examination of the technical change on the Slovak farms has revealed its Hicks-non-neutral character. During the period 2000-2012 we saw the gradual substitution of labor by capital on both types of farms, indicating ever greater automation and mechanization of production in the agricultural sector of SR. On both types of farms we found prevailing capital-using and all the other factors-saving form of technical change. In the case of crop farms we found prevailing labor-saving technical change with regard to all the other inputs. In comparison with other inputs, livestock farms made use of feed-saving technical change.

We began the second phase of our research by exploring the impact of EU accession on the development of Slovak farms performance. Introducing CAP significantly increased proportion of the total subsidies received in total revenues of both types of farms. Performance development of both types of farms had been worse in the first four years after joining the EU than in the previous period, when its growth, marked in the period prior to accession, was replaced by its decline after 2004. In the case of crop farms decline was caused by technical regress, when these farms were less likely to accept subsidies that would have led to innovation and both were hit by marked price turbulences in some years, causing fluctuations in the technical change indicator. Livestock farms significantly more dependent on subsidies were not forced to operate on the production frontier as much as crop farms, which could cause a significant deterioration in their technical efficiency. EU accession also caused significant difference in the likelihood of other material and energy-saving and all other inputs-using technical change on livestock farms, which increased in the period after 2004. That could be due to stronger specialization of livestock farms after accession to the EU.

The effect of changes in the share of subsidies on farms' revenues accounted to the net effect of positive, investment induced productivity growth and the negative effect of the loss of efficiency for both types of farms. In the case of crop farms the positive effect of changes in the share of total subsidies on their total revenues on a technical change prevailed. In livestock farms prevailed negative effect of this variable on their technical efficiency, which also led to a significant deterioration in their total factor productivity. During periods in which the share of total subsidies received by crop farms on their total revenues declined, the likelihood of fertilization-using and all other inputs-saving technical change increased significantly in almost all cases together with the probability of seeds-using and the remaining input-saving technical change. This could point to the fact that in the case of a higher proportion of subsidies on farm incomes were lower their total revenues lowered, which could cause financial inaccessibility of expensive inputs.

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