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ON THE TECHNICAL EFFICIENCY AND PRODUCTIVITY CHANGES DEVELOPMENT IN SLOVAKIAN INSTITUTIONS OF HIGHER EDUCATION 2005-2015: MALMQUIST INDEX APPROACH[1]

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***ABSTRACT**. The aim of this study is to determine efficiency of Slovak faculties in long term time period by whilst distinguish between technological shift and changes in efficiency. We run analysis of efficiency and innovation potential of faculties in Slovak republic using Malmquist index. We distinguish nine groups of faculties: Economics, Philosophy, Agronomy, Technology, Natural, Medicine, Miscellaneous, Education and Law. Input variables in our study are Students and Teachers and Doctoral study. Output variables are Publications and Quotes and Grants. Main finding is that Slovak faculties have rather potential to improve their efficiency rather than innovativeness. We also identify general pattern that dominate among all clusters of faculties and that is that faculties are able to adapt to ranking criteria with aim to score as good as possible in rankings.*

KEYWORDS: Malmquist index, efficiency, innovations, faculties, Slovakia.

JEL classification: C14, C18, D24, I21.

Introduction and the Theoretical Framework

In developing countries' economies, universities play a key role, and their importance has continued to rise in recent years. Universities in developed countries present an important factor in the development of regional as well of national economies, affecting in a variety of ways the competitiveness and performance of the country (Belás *et al*., 2017). As the demand for education is growing in Slovakia, as well as in many other countries, there prevail the public sector of universities and their effectiveness becomes the main topic of academic and political debates (Jeck, Sudzina, 2009; Agasisti *et al*., 2016; Acemoglu *et al*., 2006; Daraio *et al*., 2015). In the literature review, we can find many studies dealing with this issue, especially in the field of assessment of the productivity of research and teaching at given universities or their cost (Guironnet, Peypoch, 2018; Berbegal-Mirabent, 2018; Hayford, 2016; Daraio, Simar, 2007; Flegg *et al*., 2003; Johnes, Johnes, 1993, Edvardsen *et al*., 2017).

In Slovakia, the financial needs of maintaining education at a good quality level exceed the total amount of financial resources provided by the state budget. In order to ensure the quality development of education for the rising generation, at first it is necessary to analyse the current state of the funding system, the criteria for allocations and the amount of government resources into the education sector. Secondly, focusing on management of universities and the ranking of the scientific development of schools and universities at the national level (Korony, Hronec, 2012). Nowadays increased attention is focused on evaluating the overall effectiveness and rankings of universities, which, given the limited capacities of the government budget for effective allocation and use of learning resources, is very important (Mohelska, Sokolova, 2017; Sokolova, Mohelska, 2018).

Universities in the public sector are non-profit organizations, are involved in teaching, research, projects, etc., thus assessment of their results and ranking of their effectiveness is difficult what could lead to a challenging task. By comparing other industries, production in the higher education sector is different from the normal production cycle (Štefko *et al*., 2016a). Despite the complexity and difficulties in measuring of the results of universities, their effective productivity is significant and interesting especially for policy-makers, but also for students, academics and non-academic employers (Wolszczak-Derlacz, 2018; Bonaccorsi *et al*. 2007). This potential efficiency of universities, of course, is also influenced by other social aspects (Gluchmanová, 2011). Guironnet and Peypoch (2018) investigated the diversity of research productivity in higher education and found out that lower university efficiency is reflected in smaller cities and regions outside the capital city, which also have greater difficulties in obtaining investment into the science and research. This assumption is confirmed by studies by Horta and Lacy (2011) and Daraio *et al*. (2015), according to which researchers at larger universities are publishing their research to a greater extent, which consequently has a wider scientific network of contacts. Economical determinants also influence the effectiveness in higher education, according to the study from Italy, the higher is the level of fees per capita the lower is the inefficiency. In this case, the higher is the value added per capita the lower is the technical level of university inefficiency (Agasisti *et al*., 2016).

Universities are being put under pressure to use existing resources in the most effective way. The number of new students as well as graduates is increasing at public higher education institutions each year, but the limited funding from the state remains on an equally stagnant scale. It is not sustainable for universities to work with a higher degree of efficiency under unchanged conditions. In this context, instruments to measure their performance are needed to improve the effectiveness and ranking of universities, taking into account different factors (Kuah, Wong, 2011; Daraio *et al*., 2015; Guironnet, Peypoch, 2018). Many methodologies are considered and applied as tools for measuring the effective functioning of universities. Our study focuses on Technical Analysis by using the Malmquist's index. The Malmquist index is spreading to purely efficient and technological effects such as Catch-up and Frontier-shift, and focusing on changing these efficiency limits (Štefko *et al*., 2016b). Malmquist index also shows the Total Factor Productivity Index measuring a change in overall performance due to the change in the use of all inputs (Wolszczak-Derlacz, 2018; Flegg *et al*., 2003). Malmquist index starts to become popular also in the education sector and was also used by other authors (Table 1).

A study by Wolszczak-Derlacz (2018) compared higher education productivity on 500 universities and found out that in Europe the productivity growth was negatively associated with size of the given university and revenues from government. On the other hand, in USA productivity growth had a negative association with gross domestic product but it was positively affected by the share of government resources out of total revenues. Many of researchers (Flegg *et al*., 2003; Wang *et al*., 2017; Parteka, Wolszczak-Derlacz, 2013; Hu, Liang, 2007) confirm a significant changes of total factor productivity in terms of universities due to long time horizon.

Table 1. Literature review of using Malmquist Index in higher education sector

Authors	Methodology	Sample of study	Time period	Results	
Wolszczak-Derlacz	DEA	Universities (500)	2000 - 2010	EU	USA
2018	Malquist index, TFP	EU, USA		Productivity growth negatively associated with capacity of the university and government revenues.	Productivity growth positively associated with government and negatively with GDP.
Berbegal-Mirabent	Malquist index	Universities (47)	2006–2010	Large universities more likely to display higher efficiency scores.	
2018	DEA	Spain			
Wang *et al*.	Malquist index, TFP	Universities	2000-2015	The efficiencies generally as a increasing trend.	
2017	DEA	China		The efficiency score of universities of humanities and social science is the lowest compared to other three types of universities.	
Torre *et al*.	Malquist index	Universities	2001-2005	Public universities had caught up with private universities last years.	
2017		Spain			
Parteka and Wolszczak-Derlacz	Malquist index	Universities (266)	-	Productivity increased annually in 90 % of examined universities, but statistically significant annual improvements in overall productivity in only 56 % of cases.	
2013		7 EU countries			
Worthington and Lee	Malquist index	Universities (35)	1998–2003	Productivity growth averaged 3.3% across all universities, largely attributable to technological progress.	
2008	DEA	Australia		Gains in scale efficiency played only lower role in productivity growth.	
				The largest productivity growth improvements in smaller, younger universities than in the bigger, older universities.	
Hu and Liang	Malquist index	Universities	-	Technological improvement and innovation - important factors to improve scientific research productivity for Chinese universities and colleges.	
2007		China		Dynamic changes in the research productivity of higher education institutions in China.	

Source: created by the authors.

The aim of this study is to document the longitudinal changes in efficiency/catch up and technological shift/border shift within homogenous groups of faculties in Slovak republic.

2. Methodology

Whereas we can consider DEA models as static as they do not take into account the development or change in efficiency of DMU over time. However, we can remove this shortcoming by using the Malmquist index. The Malmquist index was originally built on the condition of constant returns. Nowadays, it has several variants, it can be oriented to inputs and outputs, with constant, or variable returns to scale.

We have a Decision-making Units in time $t = 1, 2, ..., T$. For each period we know the production technology S^t, which transforms inputs x^t to y^t outputs. $D_q^t(x^t, y^t)$ is a function that characterizes technology at time t and assigns to rated DMU_q the rate of efficiency. In input models, $D_q^t(x^t, y^t)<1$ if the DMU_q is inefficient and $D_q^t(x^t,y^t)=1$, if it is effective. Effective units then define the production possibility frontier. The function $D_q^{t+1}(x^t, y^t)$ uses inputs and outputs from period t with technology in period $t+1$, the function $D_q^t(x^{t+1}, y^{t+1})$ uses contrary the inputs and outputs from $t+1$ with technology from period t. Since there may be a situation that (x^{t+1}, y^{t+1}) does not belong to the S^t technology, the case of $D_q^t(x^t, y^t)>1$ occurs which means that DMU achieved higher efficiency than was allowed in the past. However, the opposite case could occur when $D_q^{t+1}(x^t, y^t)>1$, which essentially reduced the production possibility frontier compared to previous period.

The Malquist index M_q, which measures the change in DMU_q production efficiency between consecutive periods t and t+1 has following formula:

$$M_q(x^{t+1}, y^{t+1}, x^t, y^t)=E_qP_q \qquad \textbf{(1)}$$

where E_q is the change of efficiency (Catch-up) of unit q relative to other units between t and t+1. P_q then describes a change in the production possibility frontier caused by technological developments (Frontier-shift) between periods t and $t+1$. The definition of E_q and P_q is following:

$$E_q = \frac{D_q^{t+1}(x^{t+1}, y^{t+1})}{D_q^t(x^t, y^t)} \qquad \textbf{(2)}$$

$$P_q = \sqrt{\left[\frac{D_q^t(x^{t+1}, y^{t+1}) D_q^t(x^t, y^t)}{D_q^{t+1}(x^{t+1}, y^{t+1}) D_q^{t+1}(x^t, y^t)}\right]} \qquad \textbf{(3)}$$

As mentioned above, Malmquist index is spread over the change in efficiency, also known as Catch-up, and technological shift, or innovation, also referred to as Frontier-shift. Table 2 shows an analysis of Malmquist index decomposition values.

Table 2. Analysis of Malmquist index decomposition values

		E_q - Change in efficiency (Catch-up)	
		≤ 1	$1\leq$
P_q - Technological shift (Border shift)	$1\leq$	Non efficient, but innovative	Efficient and technologically innovative
	≤ 1	Non efficient and technologically lagging	Efficient, but technologically lagging

Source: created by the authors.

We find the best performers according to the values of the indicators in the upper right corner. An efficient and technologically innovative Decision Making Unite (DMU) develops

the edge of technological possibilities and increases its efficiency. If the value of the change in efficiency is greater or equal to one and the value of the technological shift is equally greater or equal to one, we are talking about efficient units with technological innovations. This group is characterized by new technological processes and approaches that can be evaluated and effectively managed by them in the future.

If the change in efficiency is greater than or equal to one, but the value of the technological shift is less than or equal to one, we are talking about an efficient but technologically lagging unit. These units anticipate an effective future development based on proven technology and management decisions that do not want to use new technologies.

Units that have a technological shift greater than or equal to one but the efficiency change is less than or equal to one, are inefficient but innovative. These units are characterized by the use of new technological processes, yet their management cannot effectively evaluate their decisions.

Worst units with the worst values are in the bottom left corner. These are units that are inefficient and technologically obsolete as these units are not using new technologies, and unfortunately their current management cannot ensure their efficiency. Such units have technological shift values and efficiency changes less than or equal to one.

The Malmquist index is calculated as product of catch-up and boarder shift. If the Malmquist index value is greater than 1, we are speaking about improving DMU from the time period t to the time period t+1. This improvement is also called total factor productivity improvement. If the index value is less than 1, there was a deterioration of the total factor productivity of DMU.

2.1 Data

Our dataset comes from The Academic Ranking and Rating Agency (ARRA). All input data used to measure the efficiency of faculties in Slovakia are publicly available on the official website of the Academic Ranking and Credit Rating Agency. ARRA is civil association established in 2004 with the aim of improving the quality of education in Slovakia. Since 2005, ARRA has been issuing evaluations of faculties as well as the overall assessment of universities that were included in the evaluation until 2010. Partial studies on efficiency of universities in Slovakia can be found in Jeck and Sudzina (2009), Korony and Hronec (2012), Kubak *et al*. (2014) and Kanovsky (2018).

The faculty evaluations are performed in specific time periods. From 2005 to 2008, faculties and schools were evaluated globally in six homogeneous groups. In this time period, ARRA used Frascati manual categorization of research areas. This manual categorised research area in countries of Organization for Economic Cooperation and Development since 1963. Specific divisions of the groups looked as follows: Natural sciences, Engineering and technology, Medical and Health sciences, Agricultural sciences, Social sciences, Humanities.

Because of the fact that some faculties were difficult to integrate into a particular science areas proposed above, a new, more detailed breakdown of homogeneous groups has been created since 2009. The initial divisions of the groups were divided, so faculties and schools were rated in eleven homogeneous groups. The new, more consistent, higher-exposure groups look as follows: agricultural sciences, medical science, theological sciences, philosophical sciences, sciences of art, natural sciences, economic sciences, legal science, pedagogical sciences, technical sciences, other sciences

To monitor effectivity in the long run, it was necessary to create homogeneous groups, due to the fact that changes were made in the indicators at certain times. We created three

observed groups which are: 2005-2008, 2009-2011 and 2012-2015. Changes in the monitored indicators that were made in a homogeneous group do not affect the evaluations of effectivity in observed period.

2.2 Assessment Methodology

The methodology used by ARRA when it comes to drawing up its ranks changed every year, but only minimal changes were made. The indicators used in the methodology are chosen in such a way that their higher value corresponds to a higher performance. The faculty, which reaches the highest value in an indicator, has 100 points. Other points are assigned by using a linear interpolation score, with 0 points corresponding to the lowest value.

All of the monitored indicators are grouped into a five compact groups. The group name adequately describes the reasons why individual indicators are included in the group. This breakdown was the very first where small adjustments were made every year. These small changes will be described in every homogenous group. Groups of indicators are following:

1. PUBLICATIONS AND QUOTES (PQ)

- PQ_1: Number of scientific articles in journals registered in the Thomson Web of Knowledge database for a period of 10 years, since the year of the ranking in proportion to the number of teachers and researchers and artistic staff with university education
- PQ_2: Number of citations per researcher. Only quotations for the papers included in PQ_1 were included in the quotation report, thus only quotation which are not older than 10 years are taken into the account. The decisive factor was whether the work appeared in the database before the 31 December of the previous year, such as the year of the ranking.
- PQ_3: The number of publications with more than 5 quotations published 10 years back from the previous year when the ranking is being compiled divided by the number of creative worker at the faculty.

2. DOCTORAL STUDY (DS)

- DS_4: The number of full-time postgraduate students in proportion to the number of professors and associate professors.
- DS_5: The annual average of the number of PhD graduates over a three-year period from the previous year of the creation of the ranking, divided by the number of associate professors and professors in the year preceding the ranking creation.
- DS_6: Share of the number of postgraduate students and the number of full-time students in the previous year.

3. GRANTS (G)

- G_1: Total number of grants issued by The Ministry of Education, Science, Research and Sport of the Slovak Republic within schemes Scientific Grant Agency and Cultural and Educational Grant Agency.
- G_2: Total number of grants issued by The Slovak Research and Development Agency which is in responsibility of by The Ministry of Education, Science, Research and Sport of the Slovak Republic.
- G_3: Total grant resources per creative worker.

4. STUDENTS AND TEACHERS (ST)

- ST_1: Number of students in the daily and in the external form of study divided by the total number of teachers. A smaller number of students per teacher corresponds to a higher number of points.
- ST_2: Number of students in the daily and in the external form of study divided by the number of professors and associate professors. Smaller the ratio is, better for faculty.
- ST_3: The ratio of the number of teachers with the PhD. Degree to the number of all teachers. It is assumed that each professor and associate professor who holds a post is the holder of this title.
- ST_4: The ratio of the number of professors and associate professors to the number of all teachers
- ST_5: Average age of professors. Points are allocated according to the value of 100/(average age of professors).

5. DEMAND FOR STUDY (DS)

- DfS_1: Number of received study applications divided by the number of study places offered by the faculty in the admission procedure.
- DfS_2: Number of enrolled students divided by the number of accepted students.
- DfS_3: Number of students of other citizenship divided by the number of all full-time students.

All data used in our analysis come from above monitored indicators. In the Malmquist index, we used STUDENTS AND TEACHERS and DOCTORAL STUDY as input data and PUBLICATIONS AND QUOTES and GRANTS as output data. Each criterion, whether input or output, was calculated by the arithmetical average of the sub-indicators in the group. Indicator DEMAND FOR STUDY does not enter our analysis, because this is the domain, which is out of our interest and is exogenous. Mainly because faculties can influence this parameter by reduction of requirements for admission etc. STUDENTS AND TEACHERS are understood as input variables, because in Slovakia, majority of financial resources from public budget comes to faculty budget according to number of full-time students. Moreover, this indicator contains also number of teachers at the faculty and their structure. DOCTORAL STUDY is taken as input variable, because of fact, that PhD. students are expected to do research at the faculty. PUBLICATIONS AND QUOTES are output variable in our model, because this indicator indicates the quality of research on the faculty and is worldwide accepted as a criterion of quality. GRANTS are output variable in our model, because of fact, that this variable reflect the competitiveness of the faculty, and assure supplementary founds which are independent to number of students at the faculty.

3. Findings

In following subchapters, the results of analysis for particular groups of faculties and time periods are presented.

3.1 Economics

In the group of Economics, we have been evaluating the data since 2009, because in the years 2005-2008 the economics faculties were evaluated together with the faculties of education, law faculties, faculties of philosophy and faculties from other groups that gradually formed separate groups. Evaluating such a heterogeneous group did not make sense. We visualize the results as follows: Faculties whose Malmquist index was higher than 1 are marked by red colour. Yellow colour is depicting faculties whose catch-up is higher than 1 in

the given period. The green colour highlights faculties whose frontier-shift is in the given period greater than 1.

Table 3. Efficiency assessment of faculties of ECONOMICS, 2005-2015

Faculty	2005 - 2008			2009 - 2011			2012 - 2015		
	Basic MI	Catch -up	Border shift	Basic MI	Catch -up	Border shift	Basic MI	Catch -up	Border shift
1. FoE, TUKE				1.05	1	1.05	1.13	1	1.13
2. FoEaM, SUoAiN				1.19	0.93	1.28	1.05	1	1.05
3. FoNE, UoEiB				0.91	1	0.91	0.78	0.66	1.19
4. FoC, UoEiB				0.6	0.49	1.22	0.85	0.81	1.04
5. FoOaEoTaC, UoZ				1.28	1.44	0.89	0.86	0.73	1.18
6. FoBE, UoEiB				1.09	0.92	1.18	0.99	0.95	1.04
7. FoM, CUiB				1.81	1.5	1.21	0.63	0.59	1.06
8. FoEI, UoEiB				0.67	0.66	1.01	0.93	0.89	1.04
9. FoE, MBU				1.34	1.21	1.11	0.83	0.78	1.60
10. FoBM, UoEiB				1.31	1.42	0.92	1.29	1.24	1.04
11. FoM, UoPiP				0.28	0.43	0.64	0.78	0.78	1.01
12. FoE, JSU							10.9	1	10.9
13. CoIB, ISMSiP							0.57	1	0.57

1. Faculty of Economics, Technical University of Kosice, 2. Faculty of Economics and Management, Slovak University of Agriculture in Nitra, 3. Faculty of National Economy at the University of Economics in Bratislava, 4. Faculty of Commerce, University of Economics in Bratislava, 5. Faculty of Operation and Economics of Transport and Communications, University Zilina, 6. Faculty of Business Economics, University of Economics in Bratislava, 7. Faculty of Management, Comenius University in Bratislava, 8. Faculty of Economic Informatics, University of Economics in Bratislava, 9. Faculty of Economics, Matej Bel University, 10. Faculty of Business Management, University of Economics in Bratislava, 11. Faculty of Management, University of Presov in Presov, 12. Faculty of Economics, J. Selye University, 13. College of International Business ISM Slovakia in Presov

Source: own calculations.

2009-2011

In this period, the majority of faculties within group of Economists improved their productivity. We can see in the Table 3 the most significant improvement in overall productivity compared to other faculties was recorded by the Faculty of Management, Comenius University in Bratislava, which improved the ratio of the number of students to the teacher, also improved the annual average of the number of PhD students and also increase volume of grants and the number of publications. This faculty was able to achieve this improvement through the correct interventions of faculty management and also managed to innovate the teaching strategy. On the other hand, the Faculty of Economics and Management, Slovak University of Agriculture in Nitra and the Faculty of Management at the University of Presov in Presov has improved in the areas of teachers, students and PhD students, but the efficiency of the faculties has decreased, as we can see in a reduced number of citations, publications, as well as in worsening in grants receiving.

2012-2015

Within the period of 2012-2015, only 4 faculties achieved improvement in overall productivity compared to other faculties, while other faculties in total productivity declined

compared to 2012. The most significant improvement in productivity was recorded by the Faculty of Economics, J. Selye University, which has stagnated in efficiency and management during the period under review, but has significantly improved its frontier technology, thus innovation. This faculty has achieved positive improvements in teaching, but the greatest share of this success has been the incremental increase in publications and quotes as well as in the increase in grant efficiency. Expect College of International Business ISM Slovakia in Presov, all other faculties improved in border shift, thus innovations, compared to the first year.

3.2 Philosophy

Again, as in the group of Economics, in the group of Philosophy we have been evaluating the data since 2009, because in the years 2005-2008 the faculties of philosophy were evaluated together with the faculties of education, law faculties and faculties, faculties of economics and faculties from other groups that gradually formed separate groups. Visualisation of the results in the group of Philosophy is following: Faculties whose Malmquist index was higher than 1 are marked by red colour. Yellow colour is depicting faculties whose catch-up is higher than 1 in the given period. The green colour highlights faculties whose frontier-shift is in the given period greater than 1.

Table 4. Efficiency assessment of faculties of PHILOSOPHY, 2005-2015

Faculty	2005 - 2008			2009 - 2011			2012 - 2015		
	Basic MI	Catch-up	Border shift	Basic MI	Catch-up	Border shift	Basic MI	Catch-up	Border shift
1. FoA, CUiB				0.68	0.69	0.98	1.46	1.75	0.84
2. FoHaNS, UoPiP				0.97	1	0.97	0.79	1	0.79
3. FoA, UoPiP				0.84	0.95	0.89	1.22	1.5	0.81
4. FoPaA, UoT				0.75	0.71	1.06	1.22	1.42	0.85
5. FoA, CtPUiN				0.8	0.87	0.92	1.45	1.86	0.78
6. FoA, UoSs.CaMiT				1.02	0.98	1.04	0.77	0.99	0.78
7. FoAaL, CUiR				1.56	1.72	0.91	0.81	1	0.81
8. FoA, PJSUiK				0.32	0.85	0.38	0.77	1	0.77

1. Faculty of Arts, Comenius University in Bratislava, 2. Faculty of Humanities and Natural Sciences, University of Presov in Presov, 3. Faculty of Arts, University of Presov in Presov, 4. Faculty of Philosophy and Arts, University of Trnava, 5. Faculty of Arts, Constantine the Philosopher University in Nitra, 6. Faculty of Arts, University of Ss. Cyril and Methodius in Trnava, 7. Faculty of Arts and Letters, Catholic University in Ruzomberok, 8.Faculty of Arts, Pavol Jozef Safarik University in Kosice

Source: own calculations.

2009-2011

In the period 2009-2011 (Table 4), the overall productivity improvements were achieved only by the Faculty of Arts, University of Ss. Cyril and Methodius in Trnava and the Faculty of Arts and Letters, the Catholic University in Ruzomberok, while other faculties experienced a decrease in overall productivity. Faculties with a decrease in total productivity were affected by bad management interventions that led to a decrease in the effectiveness of the faculties. Only the Faculty of Humanities and Natural Sciences, the University of Presov in Presov did

not changed and the Faculty of Arts and Letters, Catholic University in Ruzomberok improved its position in terms of the faculty's effectiveness. Faculty of Philosophy and Arts, University of Trnava and Faculty of Arts, University of Ss. Cyril and Methodius in Trnava were able to innovate the process of teaching and research. Other faculties have seen a decline in frontier technology between the observed time periods.

2012-2015

In the period 2012-2015, half of the faculties were able to improve overall productivity compared to other faculties, while the other half saw a decline in overall productivity. An interesting indicator is the border shifting criterion in which the frontier technology is monitored at the time, thus a technological change in which all faculties have seen a decline. However, we can say that the Faculty of Arts, Comenius University in Bratislava, has achieved the best improvement either in overall productivity but also in relative efficiency. Only Faculty of Arts, University of Ss. Cyril and Methodius in Trnava recorded a decline in all three criteria, thus failed to increase its productivity and did bad management interventions, what negatively influenced its effectiveness. This faculty also experienced a negative decline in frontier technology over the projection period.

3.3 Agronomy

2005-2008

In the Agronomy group (Table 5) within the period 2005-2008, the Faculty of Biotechnology and Food Sciences at the Slovak University of Agriculture in Nitra achieved the greatest improvement in overall productivity compared to other faculties, where the most important role played proper management interventions and foreign grants obtaining that positively influenced the effectiveness of the faculty. The Faculty of Horticulture and Landscape Engineering, Slovak University of Agriculture in Nitra and the Faculty of Biotechnology and Food Sciences of the Slovak University of Agriculture in Nitra also benefited from the acquisition of larger volumes of grants, thereby improving the overall productivity and efficiency of the faculties. All faculties, except the Faculty of Forestry, Technical University of Zvolen, recorded a decline in frontier technology in this time period, respectively they did not notice any technological change in innovation. The Faculty of Forestry, the Technical University in Zvolen, as the only one in this period to improve border technology by bringing innovations to teaching process and volume of publications. The worst case is the Faculty of Agrobiology and Food Resources, Slovak University of Agriculture in Nitra, which recorded a decline in productivity and efficiency of innovation, which degraded the quality of teaching and publishing.

2009-2011

In this period the Faculty of Biotechnology and Food Sciences, Slovak University of Agriculture in Nitra recorded improvements in all areas, whether in terms of productivity, efficiency or innovation. These improvements have been achieved, in particular, by an increasing number of publications and quotations, by an increased number of PhD students, but also by improvements in education. Other faculties failed to improve innovations, thereby achieved a decline in border shift indicator. On the other hand, all faculties reached positive catch-up, what is attributed mainly to effectiveness in managerial management interventions.

Table 5. Efficiency assessment of faculties of AGRONOMY, 2005-2015

Faculty	2005 - 2008			2009 - 2011			2012 - 2015		
	Basic MI	Catch-up	Border shift	Basic MI	Catch-up	Border shift	Basic MI	Catch-up	Border shift
1. UoVMaPiK	0.94	1	0.94	0.82	1	0.82	0.94	0.99	0.95
2. FoF, T Ui Z	1.02	1.01	1.01	1.09	1.15	0.95	1.19	1.09	1.09
3. FoAaFR, S Uo AiN	0.55	0.62	0.89	0.84	1.02	0.82	1.22	1.26	0.97
4. FoWSaT, TUiZ	1.3	1.52	0.85	0.81	1.02	0.8			
5. FoHaLE, S UoAiN	1.5	1.78	0.85	1.01	1.27	0.8	2.23	1.91	1.17
6. FoBaFS, SUoAiN	1.43	1.64	0.87	1.14	1.09	1.05	1.19	1.22	0.98

1. University of Veterinary Medicine and Pharmacy in Kosice, 2. The Faculty of Forestry, Technical University in Zvolen 3. Faculty of Agrobiology and Food Resources, Slovak University of Agriculture in Nitra, 4. The Faculty of Wood Sciences and Technology at the Technical University in Zvolen, 5. The Faculty of Horticulture and Landscape Engineering, Slovak University of Agriculture in Nitra, 6. The Faculty of Biotechnology and Food Sciences, Slovak University of Agriculture in Nitra

Source: own calculations.

2012-2015

In this period, we can see an improvement in four out of five faculties. The Faculty of Forestry, Technical University of Zvolen and the Faculty of Horticulture and Landscape Engineering, Slovak University of Agriculture in Nitra have improved in all 3 areas, thus in the productivity, in the efficiency and in the technological change. Faculty of Agrobiology and Food Resources, Slovak University of Agriculture in Nitra and the Faculty of Biotechnology and Food Sciences at the Slovak University of Agriculture in Nitra have improved in overall productivity and relative efficiency, decline was observed in technological change. The University of Veterinary Medicine and Pharmacy in Kosice recorded a decline in all three areas. This decrease was due to the fact, that the faculty had worsened the ratio of students to professors compared to 2012, slightly worsened in the number of PhD students, and the biggest share of the drop in the three monitored areas was mainly due to the inadequate publishing activity and also by obtaining a smaller amount of domestic and foreign grants compared to 2012.

3.4 Technology

2005-2008

During this period, we can observe decay of border shift in all faculties, except for the Faculty of Chemical and Food Technology, Slovak University of Technology in Bratislava, which has achieved an improvement in frontier technology (Table 6). On the contrary, in relative efficiency, which affects the efficiency of the faculty, we have seen improvements. Improvements have been attributed to positive management interventions, most notably by the Faculty of Electrical Engineering and Computer Science of the Technical University of Kosice and the Faculty of Electrical Engineering at the University of Zilina, which have been able to increase their publishing activity effectively and have also achieved higher volumes of domestic and foreign grants. In the field of overall productivity improvement, we can highlight the Faculty of Electrical Engineering and Computer Science of the Technical University of Kosice, which achieved the greatest progress of total productivity compared to other faculties during the monitored period. Faculty of Environmental and Manufacturing

Technology, Technical University of Zvolen, Faculty of Materials, Metallurgy and Recycling of Technical University of Kosice, Faculty of Industrial Technologies, University of Dubcek in Trencin and Faculty of Architecture, Slovak University of Technology in Bratislava noticed a decrease in overall productivity and efficiency, but also a deterioration in the introduction of technological change and innovation.

Table 6. Efficiency assessment of faculties of TECHNOLOGY, 2005-2015

Faculty	2005 - 2008			2009 - 2011			2012 - 2015		
	Basic MI	Catch-up	Border shift	Basic MI	Catch-up	Border shift	Basic MI	Catch-up	Border shift
1. FoCaFT, SUoTiB	1.07	1	1.07	0.83	1.02	0.81	1.33	1	1.33
2. FoEEaIT, SUoTiB	1.01	1.1	0.92	0.67	0.88	0.76	2.24	1.17	1.92
3. FoEaMT, TUiZ	0.2	0.28	0.71	0.59	0.63	0.95	1.14	0.55	2.08
4. FoMEPCaGT, UoK	1.03	1.17	0.88	0.63	0.76	0.83	1.46	0.9	1.61
5. FoM,MaR, TUKE	0.73	0.79	0.93	0.58	0.78	0.75	1.33	0.89	1.49
6. FME, TUKE	1.09	1.33	0.82	0.37	0.42	0.87	3.52	2.14	1.64
7. FoEEaI, TUKE	1.33	1.68	0.79	0.85	0.97	0.88	1.53	0.9	1.69
8. FME. UoZ	0.93	1.15	0.81	1.28	1.35	0.95	1.16	0.8	1.45
9. FoIT, ADUoT	0.37	0.42	0.88	0.99	1.06	0.93	1.1	0.94	1.17
10. FoCE, SUoTiB	0.99	1.18	0.84	0.58	0.75	0.78	1.8	1	1.79
11. FoA, SUoTiB	0.61	0.78	0.78	0.5	0.54	0.93	3.22	1.91	1.68
12. FoME, T TUKE	1.12	1.4	0.8	0.63	0.83	0.76	1.18	0.57	2.06
13. FoCE, TUKE	1.12	1.32	0.85	1.35	1.6	0.84	1.43	0.94	1.52
14. FoE, SUoAiN	0.9	1.15	0.79	1.5	2.01	0.75	1.09	0.67	1.63
15. FoEE, UoZ	1.26	1.63	0.77	1.42	1.6	0.89	1.31	0.84	1.56
16. FoMT, TUKE	1.05	1.37	0.77	0.53	0.61	0.88	2.96	1.98	1.5
17. FoSE, UoZ	0.86	1.13	0.76	3.23	3.82	0.85	1.07	0.77	1.39
18. FoCE, UoZ	1.15	1.56	0.73	0.79	0.85	0.94	1.9	1.28	1.1
19. FoMSaI, UoZ				0.88	1.04	0.84	1.32	0.9	1.47
20. FoIaIT, SUoTiB				0.49	0.81	0.61	2.48	1.61	1.53
21. FoMSaT, SUoT iB				1.64	1.84	0.89	0.5	0.35	1.43
22. FoA, TUKE				0.59	0.84	0.7	2.47	1.26	1.96
23. FM, ADUoT				1.76	2.45	0.72			
24. FoI, P-EU							0	1	0

1. Faculty of Chemical and Food Technology, Slovak University of Technology in Bratislava, 2. Faculty of Electrical Engineering and Information Technology, Slovak University of Technology in Bratislava, 3. Faculty of Environmental and Manufacturing Technology, Technical University in Zvolen, 4. Faculty of Mining, Ecology, Process Control and Geotechnologies, Technical University of Kosice, 5. Faculty of Materials, Metallurgy and Recycling of the Technical University of Kosice, 6. Faculty of Mechanical Engineering, Technical University of Kosice, 7. Faculty of Electrical Engineering and Informatics of the Technical University of Kosice, 8. Faculty of Mechanical Engineering at the University of Zilina, 9. Faculty of Industrial Technologies, Alexander Dubček University of Trencin, 10. The Faculty of Civil Engineering, the Slovak University of Technology in Bratislava, 11. The Faculty of Architecture, Slovak University of Technology in Bratislava, 12. Faculty of Mechanical Engineering, Technical University of Kosice, 13. The Faculty of Civil Engineering of the Technical University of Kosice, 14. The Faculty of Engineering, Slovak University of Agriculture in Nitra, 15. The Faculty of Electrical Engineering, The University of Zilina, 16. Faculty of Manufacturing Technologies of the Technical University of Kosice, 17. Faculty of Security Engineering, The University of Zilina, 18. Faculty of Civil Engineering, The University of Zilina, 19. Faculty of Management Science and Informatics, The University of Zilina, 20. Faculty of Informatics and Information Technologies, The Slovak University of Technology in Bratislava, 21. The Faculty of Materials Science and Technology, Slovak University of Technology in Bratislava, 22. Faculty of Aeronautics of the Technical University of Kosice, 23. Faculty of Mechatronics, Alexander Dubček University of Trencin, 24. The Faculty of Informatics, The Pan-European University

Source: own calculations.

2009-2011

Among the technological faculties the most noticeable is Faculty of Security Engineering, The University of Zilina which improved productivity in comparison to all other faculties in the monitored period. Improvements were also noted by faculties Faculty of Mechanical Engineering at the University of Zilina, Faculty of Civil Engineering of the Technical

University of Kosice, Faculty of Engineering, Slovak University of Agriculture in Nitra, The Faculty of Electrical Engineering, The University of Zilina, Faculty of Materials Science and Technology, Slovak University of Technology in Bratislava, Faculty of Mechatronics, Alexander Dubček University of Trencin. All of these faculties have positively influenced the effectiveness of the faculty by effective management interventions. However, the Faculty of Security Engineering, University of Zilina, has improved the efficiency of the faculty, but it did not bring any technological change, what even lead to a decline in frontier technology and innovation. Same pattern is observed at all faculties.

2012-2015

In given years 2012-2015, all faculties except the Faculty of Materials Science and Technology of the Slovak University of Technology in Bratislava achieved an improvement in total productivity. However, the Faculty of Informatics, The Pan-European University, had not available data in entry and exit criteria, so we cannot work properly with these data. Likewise, all faculties, except The Faculty of Informatics, The Pan-European University, have seen progress and improvements in border technologies, thus innovations in the monitored period. The highest improvement in overall productivity was achieved by the Faculty of Mechanical Engineering, Technical University of Kosice which also recorded the most significant improvement in positive management interventions. At the monitored border shift criterion, the Faculty of Environmental and Production Technology, Zvolen Technical University, achieved the highest improvement in border technology. Faculty of Environmental and Manufacturing Technology, Zvolen Technical University, has achieved this positive technological change by the improvement of teaching and by innovations, what lead to a higher publishing activity compared to the baseline period.

3.5 Natural

2005-2008

In this period, we can observe the most significant improvement in overall productivity at the Faculty of Natural Sciences, Matej Bel University, which within three years achieved an extreme improvement in obtaining grants (Table 7). This success was done by faculty management, which performed positive interventions and influenced the effectiveness of the faculty. Faculty of Natural Science, University of Zilina has also seen improvement in frontier technology efficiency when it has made significant improvements in the field of PhD students, where it improved the annual average of the number of PhD graduates to the number of professors and associate professors. Faculty of Natural Sciences of the Comenius University in Bratislava, Faculty of Science, Pavol Jozef Safarik University in Kosice and Faculty of Ecology and Environmental Sciences, Technical University in Zvolen recorded a decline in the technological change of efficiency and overall productivity. The Faculty of Mathematics, Physics and Informatics of the Comenius University in Bratislava has been in a state of stagnation in relative efficiency, but has experienced a slight improvement in teaching, as well as improvements in publications and citations, as well as in grants acquisition. The Faculty of Natural Sciences, University of Saints Cyril and Methodius, recorded in 2005 a zero points in PhD assessment by ARRA, so the Malmquist index cannot be calculated and therefore the results were not evaluated.

Table 7. Efficiency assessment of faculties of NATURAL, 2005-2015

Faculty	2005 - 2008			2009 - 2011			2012 - 2015		
	Basic MI	Catch-up	Border shift	Basic MI	Catch-up	Border shift	Basic MI	Catch-up	Border shift
1. FoMPaI, C UiB	1.02	1	1.02	0.82	1	0.82	0.93	1	0.93
2. FoNS, CUiB	0.53	0.6	0.88	1.14	1.33	0.85	0.88	0.88	1
3. FoS, PJSUiK	0.76	0.9	0.84	1.03	1.32	0.78	1.19	1	1.19
4. FoEaES, TUiZ	0.47	0.53	0.88	2.54	3.27	0.78			
5. FoNS, UoCP	1.39	1.61	0.87	1.28	1.55	0.83	1.12	1.02	1.1
6. FoNS, MBU	3.5	4.18	0.84	0.94	1.36	0.69	1.08	0.91	1.18
7. FoNS, UoZ	1.61	2.33	0.69	4.3	5.31	0.81	0.63	0.46	1.35
8. FoNS, UoSCM	0	1	0	0.25	0.63	0.4	1.11	1	1.11

1. Faculty of Mathematics, Physics and Informatics of the Comenius University in Bratislava, 2. Faculty of Natural Sciences of the Comenius University in Bratislava, 3. Faculty of Science, Pavol Jozef Safarik University in Kosice, 4. Faculty of Ecology and Environmental Sciences, Technical University in Zvolen, 5. Faculty of Natural Sciences, University of Constantine the Philosopher, 6. Faculty of Natural Sciences, Matej Bel University, 7. Faculty of Natural Science, The University of Zilina, 8. Faculty of Natural Sciences, The University of Saints Cyril and Methodius

Source: own calculations.

2009-2011

In period of 2009-2011, the most significant improvements in overall productivity were recorded by the Faculty of Ecology and Environmental Sciences, the Technical University in Zvolen and the Faculty of Natural Sciences of the University of Zilina. This improvement in overall productivity has been achieved in both cases by the proper intervention of the management, namely with a proper focus on the acquisition of grant resources, but also by publishing publications and quotations. In this period, we can see that all faculties have seen a decline in frontier technology, so they did not bring innovations in any factor that could have a positive impact on the productivity and efficiency.

2012-2015

In this period, more than half of faculties improved their overall productivity compared to other faculties. The most significant improvement was achieved by the Faculty of Science, Pavol Jozef Safarik University in Kosice, even if has stagnated in management interventions, but has also been able to integrate innovations into PhD studies, and also significantly increased grant success. Least successful faculty, the Faculty of Natural Science, The University of Zilina, recorded a biggest drop in overall productivity over the baseline period. This decline was mainly due to improper management interventions that affected the overall efficiency of the faculty even if the successful innovation processes has been introduced.

3.6 Medicine

2005-2008

In the period 2005-2008, the improvement of all four faculties compared to baseline period can be observed (Table 8). The best improvement was achieved at the Faculty of Medicine of Pavol Jozef Safarik University in Kosice, which was able to make a significant improvement in publishing and grant acquisition in optimal learning change. This improvement was achieved through the correct interventions of the management and the introduction of new innovations, either in teaching or in scientific activities. We can also observe all four

faculties' results in the area of border technology improvement between these two periods. The most significant improvement being achieved in this area by the Faculty of Medicine, the Comenius University in Bratislava, which was able to innovate especially the course of doctoral study.

Table 8. Efficiency assessment of faculties of MEDICINE, 2005-2015

Faculty	2005 - 2008			2009 - 2011			2012 - 2015		
	Basic MI	Catch-up	Border shift	Basic MI	Catch-up	Border shift	Basic MI	Catch-up	Border shift
1. FoP, CUiB	1.43	1	1.43	0.44	1	0.44	1.09	1	1.09
2. JFoM, CUiB	1.11	0.95	1.17	0.6	1.2	0.59	1.06	0.95	1.11
3. Fo M, PJSUiK	1.7	1.34	1.27	0.7	1	0.7	0.95	1	0.95
4. FoMiB, CUiB	1.08	0.84	1.28	0.86	2.04	0.42	1.11	1.08	1.03
5. FoHaSW, TUiT				0.75	1.12	0.66	1.19	1.12	1.06
6. SEUoHa S W				0.68	0.74	0.91			
7. FoSSaH, CPUiN				0.6	0.72	0.84	1.22	1.13	1.08
8. FoH, UoP				1.53	1	1.53	0	0.13	0
9. FoH, CUiR				0.39	0.44	0.89	0.15	0.58	0.26
10. FoH, A DUoT							0.38	1	0.38

1. Faculty of Pharmacy, Comenius University in Bratislava, 2. The Jessenius Faculty of Medicine, Comenius University, 3. Faculty of Medicine at Pavol Jozef Safarik University in Kosice, 4. Faculty of Medicine in Bratislava of Comenius University in Bratislava, 5. Faculty of Health care and Social Work, Trnava University, 6. St. Elisabeth University of Health Care and Social Work, 7. Faculty of Social Sciences and Health Care, Constantine the Philosopher University in Nitra, 8. Faculty of Health Care of the University of Presov, 9. Faculty of Health, Catholic University in Ruzomberok, 10. Faculty of Healthcare, Alexander Dubček University of Trencin

Source: own calculations.

2009-2011

Within period of 2009-2011, expect the Faculty of Health Care of the University of Presov, all faculties reported a drop in total productivity compared to other faculties. In the field of innovations only the Faculty of Health Care of the University of Presov recorded improvements, while other faculties have seen a decline in frontier technology. However, the Faculty of Medicine of the Comenius University in Bratislava experienced an extreme improvement in management intervention, which had a positive influence on the effectiveness of the faculty, especially in the field of doctoral study.

2012-2015

During the period of 2012-2015, four faculties out of ten were able to improve in all 3 criteria. The highest improvement in overall productivity can be seen at the Faculty of Social Sciences and Health Care, Constantine the Philosopher University in Nitra, which exceeded all other faculties in all its values. This faculty has seen very positive management interventions. Faculty was able to achieve a significant increase in publications and citations and innovations in teaching and research, as well as increasing the amount of grants to the creative worker ratio. Only the Faculty of Health in the Catholic University in Ruzomberok registered a significant decrease in overall productivity, in relative efficiency and also in introducing new innovations. The results of the Faculty of Health Care of the University of Presov are not

fairly noticeable, because in 2012 the entry value for the PhD study criteria was zero, thus we are not able to calculate the Malmquist index.

3.7 Miscellaneous

2009-2011

Among the faculties in the group Miscellaneous (Table 9), the Malmquist index showed that the majority of faculties reported a drop in total productivity, only the Faculty of Political Science and International Relations, Matej Bel University stagnated and the Faculty of European Studies and Regional Development, Slovak University of Agriculture in Nitra considerably improved overall productivity compared to other faculties. Faculty of European Studies and Regional Development, Slovak University of Agriculture in Nitra also managed to improve the effectiveness of management intervention, with which it was able to innovate research strategy, and therefore it meant an increase in publications and quotes, as well as grant acquisitions. Innovations have been improved by the Faculty of International Relations of the University of Economics in Bratislava and the Faculty of Political Science and International Relations, Matej Bel University, which have improved the field of science and research.

Table 9. Efficiency assessment of faculties of MISCELLANEOUS, 2005-2015

Faculty	2005 - 2008			2009 - 2011			2012 - 2015		
	Basic MI	Catch-up	Border shift	Basic MI	Catch-up	Border shift	Basic MI	Catch-up	Border shift
1. FoIR, UoEiB				0.5	0.48	1.06	1.28	1.26	1.01
2. FoPSaIR, MBU				1	0.77	1.29	0.27	0.29	0.93
3. FoSaES, CUiB				0.98	1	0.98	0.97	1	0.97
4. FoESaRD, SUoAiN				6.23	4.83	1.29	0.77	1	0.77
5. FoMMC, Uo SsCaMiT				0.37	0.42	0.88	0.76	0.74	1.02
6. FoCES, CP UiN				0.58	0.8	0.73	1.23	1.04	1.18
7. FoPA, PJS UiK				0.58	1	0.58	0.12	0.31	0.39
8. FoSaER, ADUoT				0.3	0.8	0.38	1.43	2.59	0.55
9. UoCE, Skalica							1.28	2	0.64
10. FoSE, UoZ							2.54	2.2	1.15

1. Faculty of International Relations of the University of Economics in Bratislava, 2. The Faculty of Political Science and International Relations, Matej Bel University, 3. Faculty of Social and Economic Sciences, The Comenius University in Bratislava, 4. Faculty of European Studies and Regional Development, Slovak University of Agriculture in Nitra, 5. The Faculty of Mass Media Communication, The University of Ss. Cyril and Methodius in Trnava, 6. Faculty of Central European Studies, The Constantine the Philosopher University in Nitra, 7. Faculty of Public Administration, Pavol Jozef Safarik University in Kosice, 8. Faculty of Social and Economic Relations, Alexander Dubček University of Trencin, 9. University of Central Europe, Skalica, 10. Faculty of Security Engineering, University of Zilina

Source: own calculations.

2012-2015

During this period half of faculties was able to improve overall productivity, the other half saw a decline in overall productivity. For the catch-up criterion, thus relative efficiency, five faculties have experienced improvement, two faculties stagnated and three faculties declined

in relative efficiency. Only four faculties have seen improvements in frontier technology between time periods. The best result was achieved by the Faculty of Safety Engineering at the University of Zilina, which was able to reduce the number of teachers per 100 students in the field of effective teaching and also managed to increase the number of publications in international databases. The Faculty of Public Administration, University of Pavel Jozef Safarik in Kosice and the Faculty of Political Sciences and International Relations of Matej Bel University, which had dropped in all three of the monitored criteria, noted shortcomings in the reduction of publishing activity and citations as well as in the extreme reduction of the amount of domestic and foreign grants.

3.8 Education

2009-2011

In the group of faculties of education (Table 10) during 2009-2011, the Faculty of Education, Comenius University in Bratislava, managed to increase the overall productivity by several correct management interventions. Specifically, faculty managed to increase the resources obtained from the grant agencies per the creative worker more than 5 times. In this time period, however, border technology in the group of faculties of education has seen a decline. The Faculty of Education, J. Selye University, in 2009, reached a zero rating for the PhD students admission criterion, with which the Malmquist Index fails to work. For this reason, data are incorrect for the Faculty of Education, J. Selye University. We still want to point out the Faculty of Education, The University of Ss. Cyril and Methodius in Trnava, as the only recorded improvement in frontier technology through innovations, which it was able to implement mainly in the area of education.

Table 10. Efficiency assessment of faculties of EDUCATION, 2005-2015

Faculty	2005 - 2008			2009 - 2011			2012 - 2015		
	Basic MI	Catch-up	Border shift	Basic MI	Catch-up	Border shift	Basic MI	Catch-up	Border shift
1. FoPEaS, CUiB				0.8	0.87	0.92	1.09	1.33	0.82
2. FoE, MBU				1.23	1.35	0.91	0.94	1.15	0.81
3. FoS, UoPiP				1.17	1.63	0.72	1.02	1	1.02
4. FoE, TUiT				0.92	1	0.92	0.83	1	0.83
5. FoE, CUiB				4.43	4.65	0.95	0.58	0.71	0.82
6. FoE, UoPiP				0.65	0.92	0.71	0.97	1.04	0.92
7. FoE, UoSs.CaMiT				1.21	1.14	1.05	1.04	1.26	0.82
8. FoE, JSU				0	0.48	0	0.77	0.95	0.8
9. FoE, CUiR				1.25	1.54	0.81	1.21	1.48	0.81

1. Faculty of Physical Education and Sport, Comenius University in Bratislava, 2. Faculty of Education, Matej Bel University, 3. Faculty of Sports, University of Presov in Presov, 4. Faculty of Education, Trnava University in Trnava, 5. Faculty of Education, Comenius University in Bratislava, 6. Faculty of Education, University of Presov in Presov, 7. Faculty of Education, The University of Ss. Cyril and Methodius in Trnava, 8. Faculty of Education, J. Selye University, 9. Faculty of Education, Catholic University in Ruzomberok

Source: own calculations.

2012-2015

During period 2012-2015, only three faculties experienced improvements in all three criteria. The most significant improvement in overall productivity was recorded by the Faculty of Education at the Catholic University in Ruzomberok, which also experienced the most significant improvement in relative efficiency by management interventions which positively affected the effectiveness of the faculty. These positive improvements were mainly due to the increased number of publications and citations as well as the increase in the amount of funds received from domestic and foreign grants. The worst was the Faculty of Education at the Comenius University in Bratislava, which recorded a significant drop in all three criteria. This deterioration was achieved due to a reduction in the amount of received funding by up to half compared to 2012.

3.9 Law

2009-2011

Among the faculties of law (*Table 11*), the best performer in the Malmquist Index is the Faculty of Law of the Trnava University in Trnava, which improved its efficiency by increasing the number of publications and citations, as well as by improving education. Mentioned facts lead to improvement in frontier technology over time. The Faculty of Law, Pavol Jozef Safarik University in Kosice, although the stagnation in the effectiveness of the faculty, managed to improve overall productivity by means of innovations, especially in the area of grant acquisition. Faculty of Law, Matej Bel University, compared to other faculties, experienced a significant decrease in total productivity through incorrect management interventions, but managed to introduce innovations in doctoral studies during this period.

Table 11. Efficiency assessment of faculties of LAW, 2005-2015

Faculty	2005 - 2008			2009 - 2011			2012 - 2015		
	Basic MI	Catch-up	Border shift	Basic MI	Catch-up	Border shift	Basic MI	Catch-up	Border shift
1. FoL, CUiB				0.99	0.76	1.29	0.86	0.75	1.16
2. FoL, TUiT				2.49	1.18	2.11	1.16	1	1.16
3. FoL, PJ SUiK				1.07	1	1.07	0.92	0.97	0.95
4. FoL, MB U				0.4	0.37	1.08	0.38	0.9	0.42
5. FoLaw, PEU							0.6	0.66	0.91

1. Faculty of Law at Comenius University in Bratislava, 2. Faculty of Law of the Trnava University in Trnava, 3. Faculty of Law, Pavol Jozef Safarik University in Kosice, 4. Faculty of Law, Matej Bel University, 5. Faculty of Law, Pan-European University

Source: own calculations.

2012-2015

The Faculty of Law of the Trnava University in Trnava achieved productivity gains in the Malmquist index, as well as an improvement in border shift. In the catch-up, this faculty has seen stagnation in relative efficiency. These values were achieved by improving the doctoral study and increase in grant resources per the creative worker. Other faculties recorded decreases in all criteria, whether in overall productivity, relative efficiency or border

technology. Only the Faculty of Law at Comenius University in Bratislava has improved in border shift criteria by improvement in innovation, but has also worsened in other indicators.

Conclusions

Although more specific studies focused on European countries are needed to take into account institutional specificities, some policy recommendations resulting from this framework may be generalized to other higher education systems. In the case of other researches, it would be useful to gain microeconomic data for assessing professional career paths for post-graduate students in order to improve the assessment of universities. The main findings of our studies are:

Within group of ECONOMICS we observe that in period of 2009-2011 the majority of faculties attaint the values of Catch-up and Border shift higher than one, what tells us that faculties are well progressing and balanced. But in period of 2012-2015 we observe the overall decline in Catch-up, thus decline of efficiency of majority of faculties. In terms of Border shift, thus innovations, all faculties except College of International Business ISM Slovakia in Presov perform well. And therefore, in period of 2012-2015, majority of faculties are innovative, but not efficient.

In group of PHILOSOPHICAL faculties, we observe during 2009-2011, that only two faculties are efficient and only two are innovative. Over time, all of faculties became efficient, but no innovations are observed within the group.

Faculties clustered in group of AGRONOMY are during all three time cuts rather efficient than innovative. But we observe that in all considered time cuts the Basic Malmquist index is superior to 1, what suggest quasi balance of faculties of agronomy.

Group of TECHNOLOGY is the most abundant group of faculties. In period of 2005-2008 we state that vast majority of faculties is efficient, but only one is innovative. In period of 2009-2011, we observe the same pattern. But over time, in period of 2012-2015, faculties lost their effectiveness on one hand, but on the other hand, all faculties have become innovative and reached fair score of Basic Malmquist index.

In cluster of NATURAL sciences, we document during 2005-2008 the efficiency of majority of faculties, but weak innovations within the group. In period of 2009-2011 we observe the same pattern. Over time, in 2012-2015 we observe the significant amelioration in terms of innovativeness of faculties within the group and also fair score in efficiency.

In group of MEDICINE we document following: during 2005-2008, all faculties were innovative and half of them also efficient. Over time, in 2009-2011 we observe significant disintegration in terms of innovations, but strong effectiveness of faculties. In last time cut, thus during 2012-2015 we observe amelioration in innovations and also well performance in terms of efficiency of decision-making units.

In cluster of MISCELLANOUS, we observe mainly amelioration of effectiveness of faculties. Over time, faculties also improved their innovation potential and overall Malmquist index.

In subset of faculties of EDUCATION, we note that majority of faculties maintained their efficiency over time, but the innovation potential of the group remained weak.

In group of LAW we observe over time the decay in terms of innovativeness of faculties and also the worsening on the side of effectiveness.

We cannot identify general pattern that dominate among all groups, what is logically result of the heterogeneity of groups and faculties. But we can infer from our results that faculties are able to adapt to ranking criteria with aim to score as good as possible in rankings.

The results of presented research provide important information for policy makers and competent regulator who should reflect on present status of this issue in Slovakia, and should by taking them into account to support the appropriate efficiency of universities through eligible policy decisions.

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SLOVAKIJOS AUKŠTOJO MOKSLO INSTITUCIJŲ TECHNINIO EFEKTYVUMO IR PRODUKTYVUMO POKYČIŲ RAIDA 2005–2015 M.: MALMQUIST INDEKSO METODAS

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SANTRAUKA

Pasitelkus Malmquist indeksą, buvo atlikta Slovakijos fakultetų efektyvumo ir inovacijų potencialo analizė. Buvo išskirtos devynios fakultetų grupės: Ekonomikos, Filosofijos, Agronomijos, Technologijos, Gamtos mokslų, Medicinos, Įvairių studijų, Švietimo ir Teisės. Tyrimo įvesties kintamieji yra studentai, dėstytojai ir doktorantūros studijos. Išvesties kintamieji yra leidiniai, citatos ir dotacijos. Pagrindinė išvada: Slovakijos fakultetai pasižymi didesnėmis galimybėmis nei novatoriškumu. Buvo nustatytas bendras, tarp visų fakultetų grupių dominuojantis modelis. Išsiaiškinta, kad fakultetai, tikslingai siekdami geresnių reitingų, gali prisitaikyti prie reitingavimo kriterijų.

REIKŠMINIAI ŽODŽIAI: Malmquist indeksas, efektyvumas, inovacijos, fakultetai, Slovakija.