

Academic Advancement Efficiency Measurement in Polish Universities Including a Division into Voivodships

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Abstract

The aim of this article is an attempt to measure the efficiency of academic advancement in a regional conceptualization (division according to voivodships) in Polish higher education. In making this attempt a non-parametric DEA method has been used introducing three models: doctoral, doctoral-supplemental, and post-doctoral. Knowledge concerning academic advancement efficiency is significant in developing the economy of particular regions. On the other hand, the results may lead to knowledge, models and tools transfer from regions with higher levels of efficiency to those with low levels of efficiency (convergence efficiency).

Keywords: higher education, academic advancement, efficiency evaluation, non-parametric DEA method

JEL: I21, I23

Introduction

Human capital constitutes a major factor that creates an economy that is based on knowledge (Chojnicki and Czyż 2006, 85). Its development is due to increase of human capital as a resource and a potential link to the transfer of knowledge to an economy. A basic definition for an educational process in higher education should be assigned to the academic-didactic staff that takes part in this process and is directly connected with it including: full professors, associate professors, assistant professors, and assistants. A structure of academic-didactic staff is presented in figure 1. The most numerous group is composed of assistant professors—more than 53%. Then there is a group of professors (30%) and assistants (16%). In 2015, nearly 1% were associated professors—their number decreased from 1 167 to 648 job positions. In general, in Poland in 2012–2015 the number of academic workers decreased from 101 000 to 96 000 referring to full-time job positions.¹

The number of academic staff, its structure and finally its abilities define a qualitative dimension of teaching. It is important to mention that while writing about academic advancement we cannot focus only on academic teachers. We should bear in mind that there are external people—economic

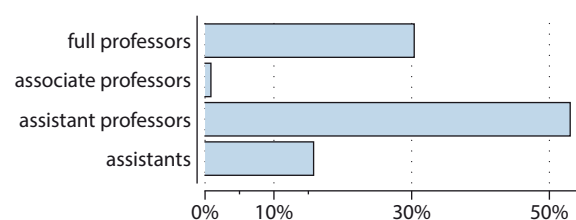


Fig. 1. Structure of academic teaching staff in Polish public universities in 2015

1. [In the journal European practice of number notation is followed—for example, 36 333,33 (European style) = 36 333.33 (Canadian style) = 36,333.33 (US and British style).—Ed.]

practitioners—that do not stay at a university but are strongly interested in their own academic development that they use for an activity of, for instance, the local economy.

The aim of this article is to test efficiency measurement of academic advancement of human capital taking into consideration an administrative division of Poland (division according to voivodships) at universities. The authors propose three original efficiency models—input oriented (characteristic for units that are not productive). The measurement has been conducted with the usage of a quantitative tool—the non-parametric DEA method. Efficiency measurement is vital not only for productive units but also for those that exist in very specific economic conditions, e.g. universities. Efficiency evaluation in a quantitative depiction should be a basic tool for making economic decisions. The more detailed evaluation the more thorough and accurate economic information is provided. Efficiency refers to many areas of unit activities. We should agree with Drucker that efficiency is an attribute of working that conditions functioning and a development of a unit (Drucker and Ehrlich 1976). It constitutes its positive feature of working and an effect, intended or not, is evaluated in a positive way if it favors a development of an organization, including public entities (Malik 2004, 17). An improvement of academic advancement definitely influences development in educational quality which constitutes a major aim of the strategy of every university.

1 DEA method and its usage in efficiency evaluation— theoretical outline of a problem

The DEA method was presented for the first time by Charnes, Cooper and Rhodes in 1979 in “Measuring the Efficiency of Decision-Making Units.” In the literature it appeared at the end of the 1970s but it was based mainly on a conceptualization of efficiency that had been worked out twenty years earlier by Farrell. The usage of the DEA method (Ćwiąkała-Małys 2010, 105–112; Ćwiąkała-Małys and Nowak 2009, 234–243) in practice was possible due to the significant development of computer programming. Mainly the usage of programmes such as: EMS or Win4DEAP enables us to solve issues of linear programming for any analyzed unit, particularly in a situation of rich data. In the DEA method, we can distinguish two functions:

- maximization of effects with upper constraint of input size, and
- minimization of inputs with lower constraint of effect size.

A solution of a goal function with the usage of linear programming allows us to determine an efficiency curve (which is also called a production frontier) which is a so called envelope where there are many of the most effective units of a researched group. In the case of units that belong to an envelope their efficiency measurement equals 1, below an envelope efficiency measurement is lower than 1 and indicates an inefficiency level. As for technical efficiency measurement, we take a Debreu-Farrell measurement which is described as a difference between level 1 and a possible, maximal reduction of inputs where there is a technical possibility of producing the determined size of inputs. Efficiency defined in this way takes values from a (0,1) range (Fried, Lovell, and Schmidt 1993, 10).

In a DEA analysis the units that are analyzed are decision-making units, so called DMU—universities—non-productive organizations. In the literature it is stated that a group of DMU should meet the following requirements:

- the number of researched units should exceed three times the number of variables that constitutes the sum of the number of inputs and effects so as to provide a sufficient number of degrees of freedom
- an increase of input leads to an increase of effects so there is a significant plausible correlation between these variables
- DMUs should be homogenous (Bowlin 1998)

As to determining efficiency of a DMU, it means that you should solve one DEA model. Solving generates an efficiency index for an analyzed DMU. If a DMU is ineffective a solution defines a set of model objects (so called benchmarks)² together with assigned optimal values of measures that

2. Benchmarking—a constant and systematic method of development and improvement of unit activities that

inform us as to how this ineffective DMU should work — whether to reduce the inputs or to increase effects to improve efficiency. The main DEA model with a radial efficiency measure is a model of constant returns to scale, in the literature also known as CCR which is shown in figure 2.

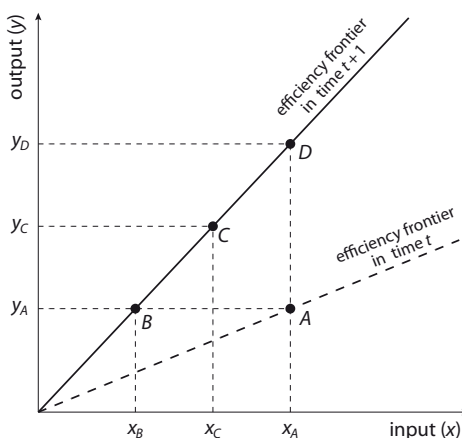


Fig. 2. The frontier and measurement of efficiency in the simplest CCR model

In a DEA model a basis for efficiency measurement is a dependence

$$(1) \quad \max \sum_{r=1}^s \mu_r y_{r0} / \sum_{i=1}^m v_i x_{i0}$$

with limitations: $\forall j \quad \sum_{r=1}^s \mu_r y_{rj} / \sum_{i=1}^m v_i x_{ij} \leq 1, \forall r \forall i \quad \mu_r v_i \geq 0$;
or a dependence

$$(2) \quad \min \sum_{i=1}^m v_i x_{i0} / \sum_{r=1}^s \mu_r y_{r0}$$

with limitations: $\forall j \quad \sum_{i=1}^m v_i x_{ij} / \sum_{r=1}^s \mu_r y_{rj} \geq 1, \forall r \forall i \quad \mu_r v_i \geq 0$.

Formula 1 constitutes a basis for efficiency evaluation which is input oriented, formula 2 determines efficiency that is effects oriented.

2 The usage of a Malmquist index with efficiency changes in time — theoretical outline of a problem

In theory and in practice a very significant problem is a comparison of efficiency changes in time. Therefore, the Malmquist (1953) index is used, which was introduced in the article “Index Numbers and Indifferences Surfaces.” The Malmquist efficiency index (Ćwiąkała-Małys 2010, 105–112; Ćwiąkała-Małys and Nowak 2009, 234–243) serves to compare gained inputs with effects in two different time scopes according to a given formula:

$$(3) \quad M = \frac{y^{t+1}/x^{t+1}}{y^t/x^t},$$

where:

y^{t+1}/x^{t+1} — efficiency of a unit in time $t + 1$,

y^t/x^t — efficiency of a unit in time t .

If, $M < 1$ then efficiency of a unit is decreasing with time. Equality $M = 1$ tells us that efficiency is constant in time. Efficiency of a DMU is increasing when $M > 1$.

means confronting efficiency measured on the basis of productivity, quality and experience with results of the units and organizations that can be treated as models.

It is very similar in the case of efficiency measurement, where there are two indices of efficiency:

- input oriented Malmquist index — differences in efficiency follow from differences in minimal inputs that are necessary to generate a given level of an output; an idea of constructing Malmquist efficiency which is input oriented in a CCR model is presented in figure 3.

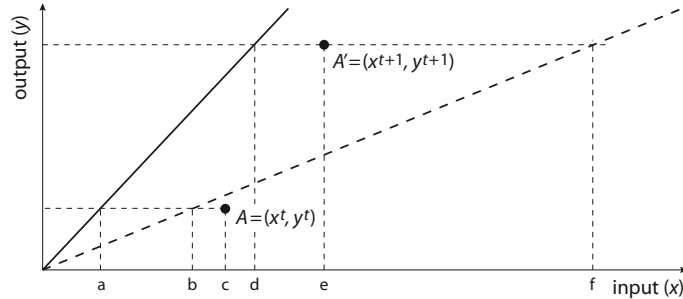


Fig. 3. Construction of a Malmquist efficiency index which is input oriented

Therefore, the Malmquist index in efficiency measurement which is input oriented takes the following form:

$$(4) \quad M_I = \underbrace{\frac{\theta_I^{t+1}(x^{t+1}, y^{t+1})}{\theta_I^t(x^t, y^t)}}_{TE_I} \sqrt{\underbrace{\frac{\theta_I^t(x^{t+1}, y^{t+1})}{\theta_I^{t+1}(x^{t+1}, y^{t+1})} \cdot \frac{\theta_I^t(x^t, y^t)}{\theta_I^{t+1}(x^t, y^t)}}_{TP_I}}$$

where:

$\theta_I^t(x^{t+1}, y^{t+1}) = f/e$ — input oriented efficiency for A unit for data from t + 1 period and technology in time t distinguished in model CCR,

$\theta_I^{t+1}(x^{t+1}, y^{t+1}) = d/e$ — input oriented efficiency for A unit in time t + 1 distinguished in model CCR,

$\theta_I^t(x^t, y^t) = b/c$ — input oriented efficiency for a decision making unit A in time t distinguished in model CCR,

$\theta_I^{t+1}(x^t, y^t) = a/c$ — input oriented efficiency for A unit for data from t and technology in time t + 1 distinguished in model CCR.

- output oriented Malmquist index — differences in efficiency are treated as differences in a level of a maximal effect for given levels of inputs; the idea of constructing a Malmquist efficiency index which is output oriented in a CCR model is presented in figure 4.

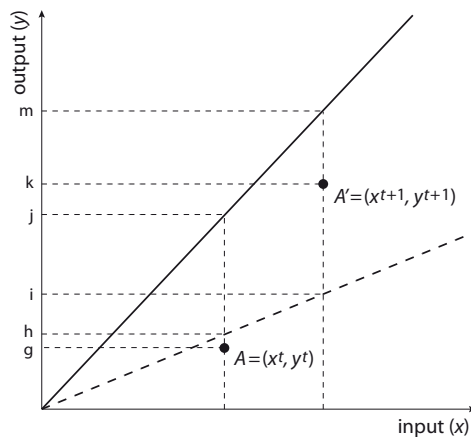


Fig. 4. Construction of a Malmquist efficiency index which is output oriented

Therefore, a Malmquist index in efficiency measurement, output oriented, takes the form:

$$(5) \quad M_O = \underbrace{\frac{\theta_O^{t+1}(x^{t+1}, y^{t+1})}{\theta_O^t(x^t, y^t)}}_{TE_O} \sqrt{\underbrace{\frac{\theta_O^t(x^{t+1}, y^{t+1})}{\theta_O^{t+1}(x^{t+1}, y^{t+1})} \cdot \frac{\theta_O^t(x^t, y^t)}{\theta_O^{t+1}(x^t, y^t)}}_{TP_O}}$$

where:

$\theta_O^t(x^{t+1}, y^{t+1}) = k/i$ — output oriented efficiency for A unit for data from $t + 1$ period and technology in time t distinguished in a model CCR,

$\theta_O^{t+1}(x^{t+1}, y^{t+1}) = k/m$ — output oriented efficiency for A unit in time $t + 1$ distinguished in a model CCR,

$\theta_O^t(x^t, y^t) = g/h$ — output oriented efficiency for a decision making unit A in time t distinguished in a model CCR,

$\theta_O^{t+1}(x^t, y^t) = g/j$ — output oriented efficiency for A unit for data from t and technology in time $t + 1$ distinguished in a model CCR.

3 Measurement and evaluation of efficiency of academic advancement

An attempt to measure efficiency of academic advancement at Polish universities, for the use of the paper, has been conducted and based on a dedicated research group. This group was composed of decision-making units (DMU) which are 16 voivodships for which there has been three efficiency models composed and presented in table 1.

Tab. 1. Specification of models of academic advancement efficiency evaluation

Type of a model	Inputs	Effects	Model parameters
Doctoral model (I)	The number of post-graduate students, the number of scholarships for the best post-graduate students	The number of post-graduate degrees granted	Input oriented model with an assumption of constant returns to scale (DEA CRS)
Doctoral model — supplemental (II)	Participants of post-graduate studies per 10 thousand citizens	The number of post-graduate degrees granted	Input oriented model with an assumption of constant returns to scale (DEA CRS)
Post-doctoral model (III)	The number of post-graduate students	The number of post-doctoral degrees granted	Input oriented model with an assumption of constant returns to scale (DEA CRS)

These models constitute a compromise between an assumed analysis objective and available data which enable us to conduct a proper deduction. Unquestionable effects, in objective research, are the number of post-graduate degrees granted and the number of post-doctoral degrees granted. On the other hand, given inputs are:

- the number of post-graduate students,
- the number of scholarships for post-graduate students,
- index of participants of post-graduate studies per 10 thousand citizens, and
- the number of post-graduate degrees granted.

They do not exhaust all possible combinations that can be obtained, however, according to the author's evaluation, all the variables used constitute objectively substantive elements in a situation of effects analysis.

The units studied — the decision making (DMU) — are voivodships, that is why an appropriate symbol was assigned to each voivodship:

Dolnośląskie DMU ₁	Podkarpackie DMU ₉
Kujawsko-Pomorskie DMU ₂	Podlaskie DMU ₁₀
Lubelskie DMU ₃	Pomorskie DMU ₁₁
Lubuskie DMU ₄	Śląskie DMU ₁₂
Łódzkie DMU ₅	Świętokrzyskie DMU ₁₃
Małopolskie DMU ₆	Warmińsko-Mazurskie . . . DMU ₁₄
Mazowieckie DMU ₇	Wielkopolskie DMU ₁₅
Opolskie DMU ₈	Zachodniopomorskie DMU ₁₆

The results of an academic advancement efficiency measurement gained with the usage of the first of the proposed models are presented in the following table (tab. 2). They indicate that an average observed level of efficiency from 2012 to 2015 was on a similar level of 0,771. However, the number of efficient voivodships increased from 2 to 3 but only Kujawsko-Pomorskie Voivodship, in the analyzed time, was a fully effective unit. On the other hand, it is worth mentioning that in the researched period of time the minimal value of efficiency decreased (0,480 in 2012 to 0,350 in 2015)—which indicates that with constant average value the differentiations in the group of voivodships are bigger. Among the researched voivodships only in six cases (DMU₁, DMU₇, DMU₈, DMU₁₀, DMU₁₂, DMU₁₄)—did a ranking place improve, comparing 2012 and 2015.

Definitely, a different range of values is obtained with the usage of a supplemental model (tab. 3). In the analyzed period of time there is only one voivodship that is fully efficient—2012 Wielkopolskie Voivodship; 2013–2015 Śląskie Voivodship. Average efficiency observed decreased from 0,528 to 0,498—similarly to a minimal value from 0,147 to 0,107. In a group of 16 voivodships only 7 improved their efficiency (DMU₁, DMU₂, DMU₃, DMU₉, DMU₁₀, DMU₁₂, DMU₁₄) by taking higher places in a ranking.

Figure 5 shows a dispersion of average values of an academic advancement efficiency index, obtained with the usage of the basic model (I) and supplemental one (II). On the basis of this, a group of voivodships was distinguished which in an objective analysis gained a value higher than 0,5 in the case of two models. The group was composed of the following voivodships: Śląskie, Wielkopolskie, Mazowieckie, Kujawsko-Pomorskie, Małopolskie, Dolnośląskie and Łódzkie. The weakest, that is, the one with the lowest average efficiency values according to the models, is Opolskie Voivodship.

A change in values of efficiency in time, measured with a usage of a Malmquist index shows that efficiency of an analyzed group decreased—an average value of the TFPCH index was lower than 1 (tab. 4). In both models there were 7 voivodships (DMU₁, DMU₂, DMU₇, DMU₉, DMU₁₀, DMU₁₂,

Tab. 2. Results of an academic advancement efficiency measurement with the usage of a doctoral model (I)

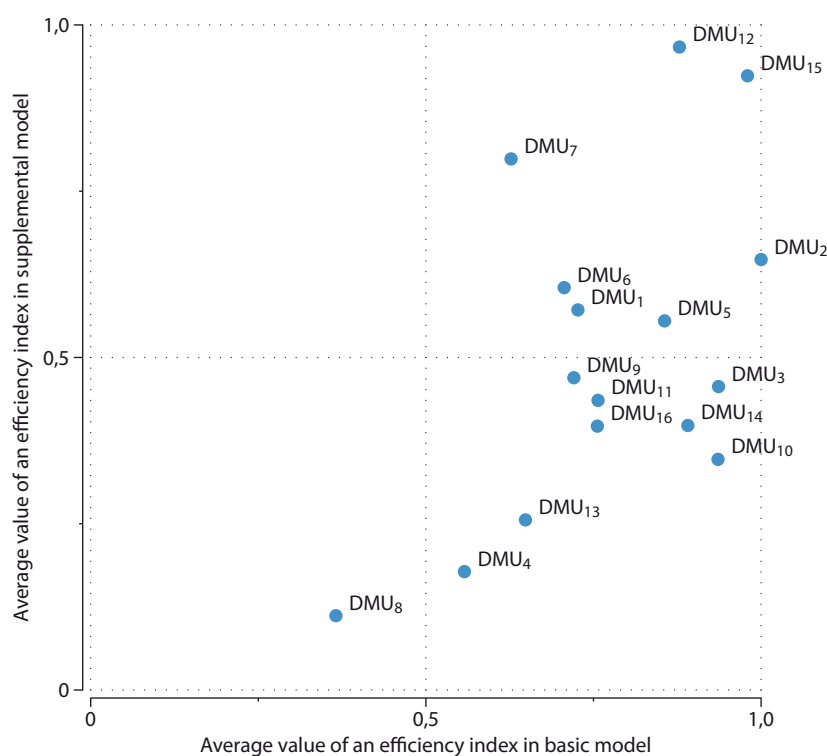
DMU	2012		2013		2014		2015		Average
	Result	Ranking	Result	Ranking	Result	Ranking	Result	Ranking	
DMU ₁	0,651	14	0,749	9	0,756	9	0,751	10	0,727
DMU ₂	1,000	1	1,000	1	1,000	1	1,000	1	1,000
DMU ₃	0,924	3	1,000	1	0,862	8	0,960	4	0,937
DMU ₄	0,655	13	0,697	11	0,528	15	0,350	16	0,558
DMU ₅	0,797	7	0,769	8	1,000	1	0,858	8	0,856
DMU ₆	0,713	11	0,741	10	0,671	10	0,700	12	0,706
DMU ₇	0,577	15	0,621	14	0,557	13	0,753	9	0,627
DMU ₈	0,480	16	0,218	16	0,422	16	0,354	15	0,369
DMU ₉	0,858	5	0,582	15	0,575	12	0,868	7	0,721
DMU ₁₀	0,857	6	0,988	4	0,898	6	1,000	1	0,936
DMU ₁₁	0,754	9	0,945	6	0,625	11	0,703	11	0,757
DMU ₁₂	0,666	12	0,973	5	0,874	7	1,000	1	0,878
DMU ₁₃	0,885	4	0,651	13	0,550	14	0,508	14	0,649
DMU ₁₄	0,783	8	0,871	7	1,000	1	0,909	6	0,891
DMU ₁₅	1,000	1	1,000	1	0,993	4	0,926	5	0,980
DMU ₁₆	0,743	10	0,688	12	0,902	5	0,690	13	0,756
<i>Average</i>	0,771		0,781		0,763		0,771		
<i>Minimum</i>	0,480		0,218		0,422		0,350		
<i>Average inefficiency</i>	0,739		0,730		0,709		0,718		
<i>Effective DMU</i>	2		3		3		3		

Note: Input oriented DEA CRS model; inputs: number of post-graduate students, number of scholarships for the best post-graduate students; effects: number of post-graduate degree granted.

Tab. 3. Results of an academic advancement efficiency measurement with the usage of a supplemental model (II)

DMU	2012		2013		2014		2015		Average
	Result	Ranking	Result	Ranking	Result	Ranking	Result	Ranking	
DMU ₁	0,562	7	0,572	6	0,584	6	0,568	6	0,572
DMU ₂	0,651	5	0,711	4	0,597	5	0,630	4	0,647
DMU ₃	0,481	10	0,427	10	0,448	8	0,469	9	0,456
DMU ₄	0,208	15	0,242	15	0,154	15	0,108	15	0,178
DMU ₅	0,585	6	0,489	7	0,632	4	0,514	8	0,555
DMU ₆	0,679	4	0,589	5	0,580	7	0,572	5	0,605
DMU ₇	0,795	3	0,788	3	0,773	3	0,838	3	0,799
DMU ₈	0,147	16	0,072	16	0,121	16	0,107	16	0,112
DMU ₉	0,552	8	0,415	11	0,350	12	0,561	7	0,470
DMU ₁₀	0,319	14	0,401	13	0,306	13	0,361	12	0,347
DMU ₁₁	0,502	9	0,484	8	0,367	11	0,389	11	0,436
DMU ₁₂	0,867	2	1,000	1	1,000	1	1,000	1	0,967
DMU ₁₃	0,350	13	0,280	14	0,199	14	0,194	14	0,256
DMU ₁₄	0,353	12	0,428	9	0,413	10	0,397	10	0,398
DMU ₁₅	1,000	1	0,895	2	0,893	2	0,906	2	0,924
DMU ₁₆	0,397	11	0,402	12	0,430	9	0,358	13	0,397
Average	0,528		0,512		0,490		0,498		
Minimum	0,147		0,072		0,121		0,107		
Average inefficiency	0,497		0,480		0,456		0,465		
Effective DMU	1		1		1		1		

Note: Input oriented DEA CRS model; inputs: participants of post-graduate studies per 10 thousands of citizens; effects: number of post-graduate degrees granted.

**Fig. 5.** A comparison of average academic advancement efficiency index values in doctoral models

Tab. 4. Results of a Malmquist index measurement in models (I) and (II)

DMU	Malmquist index basic model (I)			Malmquist index supplemental model (II)		
	EFFCH	TECHCH	TFPCH	EFFCH	TECHCH	TFPCH
DMU ₁	1,049	0,982	1,031	1,004	1,028	1,032
DMU ₂	1,000	1,032	1,032	0,990	1,028	1,017
DMU ₃	1,013	0,928	0,940	0,992	1,028	1,019
DMU ₄	0,811	1,020	0,828	0,804	1,028	0,826
DMU ₅	1,025	0,959	0,983	0,958	1,028	0,985
DMU ₆	0,994	0,935	0,929	0,945	1,028	0,971
DMU ₇	1,093	0,926	1,012	1,018	1,028	1,046
DMU ₈	0,904	1,020	0,922	0,898	1,028	0,923
DMU ₉	1,004	1,006	1,010	1,005	1,028	1,033
DMU ₁₀	1,053	1,021	1,074	1,042	1,028	1,071
DMU ₁₁	0,977	0,951	0,929	0,918	1,028	0,944
DMU ₁₂	1,145	0,939	1,075	1,049	1,028	1,078
DMU ₁₃	0,831	1,020	0,848	0,821	1,028	0,844
DMU ₁₄	1,051	1,020	1,072	1,041	1,028	1,069
DMU ₁₅	0,975	0,948	0,924	0,968	1,028	0,995
DMU ₁₆	0,975	1,034	1,009	0,966	1,028	0,993
<i>Average</i>	<i>0,990</i>	<i>0,983</i>	<i>0,973</i>	<i>0,961</i>	<i>1,028</i>	<i>0,988</i>

Tab. 5. Results of academic advancement efficiency measurement with the usage of a post-doctoral model (III)

DMU	2012		2013		2014		2015		Average
	Result	Ranking	Result	Ranking	Result	Ranking	Result	Ranking	
DMU ₁	0,667	7	0,640	10	0,825	4	0,699	7	0,708
DMU ₂	0,666	8	0,772	5	0,739	10	0,553	10	0,683
DMU ₃	0,633	10	0,671	9	0,814	5	0,601	9	0,680
DMU ₄	1,000	1	0,143	16	0,212	16	0,465	11	0,455
DMU ₅	0,701	6	0,910	3	0,657	12	0,868	2	0,784
DMU ₆	0,819	4	1,000	1	0,806	6	0,702	6	0,832
DMU ₇	0,613	12	0,682	8	0,774	8	0,669	8	0,685
DMU ₈	0,610	14	0,991	2	0,605	13	0,373	14	0,645
DMU ₉	0,076	16	0,165	15	0,889	3	0,211	16	0,335
DMU ₁₀	0,612	13	0,507	12	0,715	11	0,744	4	0,645
DMU ₁₁	0,903	3	0,687	7	0,784	7	0,713	5	0,772
DMU ₁₂	0,959	2	0,734	6	0,976	2	0,833	3	0,876
DMU ₁₃	0,163	15	0,344	14	0,395	15	0,243	15	0,286
DMU ₁₄	0,651	9	0,487	13	0,518	14	0,396	13	0,513
DMU ₁₅	0,723	5	0,883	4	1,000	1	1,000	1	0,902
DMU ₁₆	0,625	11	0,635	11	0,747	9	0,417	12	0,606
<i>Average</i>	<i>0,651</i>		<i>0,641</i>		<i>0,716</i>		<i>0,593</i>		
<i>Minimum</i>	<i>0,076</i>		<i>0,143</i>		<i>0,212</i>		<i>0,211</i>		
<i>Average inefficiency</i>	<i>0,628</i>		<i>0,617</i>		<i>0,697</i>		<i>0,566</i>		
<i>Effective DMU</i>	<i>1</i>		<i>1</i>		<i>1</i>		<i>1</i>		

Note: Input oriented DEA CRS model; inputs: number of PhD degree granted; effects: number of post-doctoral degree granted.

DMU₁₄), which according to a Malmquist index, improved their efficiency in the analyzed period of time. A decomposition of a Malmquist index allows us to state that in the case of a supplemental model (II), increase is forced by technological change and equals 1,028 for each analyzed unit. A similar situation is found in the basic model (I) in which a value after fragmentation of an index takes different values in a particular DMU.

In the case of the post-doctoral model (III) as input factor we have: number of post-graduate degrees granted—it is a measure that definitely influences the number of post-doctoral degrees. However, on the other hand, it is a prospective factor (effects will be postponed in time). In this study—due to availability of factual material it was directly assumed that there is a direct influence of inputs number of post-graduate degrees granted—on an analyzed effect (number of post-graduate degrees granted)³.

The average value of an efficiency index in 2012–2015 decreased from 0,651 to 0,593—however, indirect results do not indicate that there is a decreasing trend (tab. 5). In the whole period the model distinguishes only one voivodship which is fully efficient. However, it is worth mentioning that minimal value increased nearly three times from 0,076 in 2012 to 0,2111 in 2015. On the other hand, the average value of inefficiency, in the same period of time, decreased from 0,628 to 0,566, which confirms that the analyzed value is less differentiated in this group of DMU.

Among the analyzed voivodships 5 improved their position in the ranking (DMU₃, DMU₅, DMU₇, DMU₁₀, DMU₁₅). According to the first and the last period of the analysis, the Malmquist index identifies 7 voivodships (DMU₁, DMU₅, DMU₇, DMU₉, DMU₁₀, DMU₁₃, DMU₁₅), in which in 2012–2015 efficiency increased (fig. 6). The highest value of the index is found in Podkarpackie Voivodships and the lowest in Lubuskie Voivodship. A decomposition of an index shows that an increase of efficiency in the post-doctoral model (III) is due to a simple change of efficiency (tab. 6).

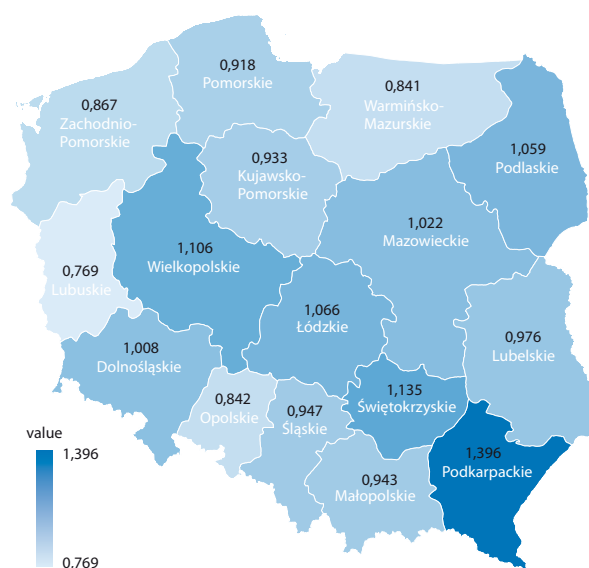


Fig. 6. Malmquist index values for a post-doctoral model (III)

Summary

Efficiency measurement of academic advancement shows Śląskie Voivodship and Wielkopolskie Voivodship belong to the most effective due to the number of post-graduate degrees granted (comparison of two models I and II). Wielkopolskie Voivodship is also a leader in cases of successful post-doctoral degrees—in 2014 and 2015 it was fully effective in a model (III). Efficiency in the area of academic advancement has a huge influence on development of human capital, which in turn influences economic development of particular regions. However, the level of influence and intensity should be analyzed which is a basis for further analysis in this area.

3. Every year the number of granted post-graduate degree is on the similar level.

Tab. 6. Results of Malmquist index measurement in a post-doctoral model (III)

DMU	EFFCH	TECHCH	TFPCH
DMU ₁	1,016	0,993	1,008
DMU ₂	0,940	0,993	0,933
DMU ₃	0,983	0,993	0,976
DMU ₄	0,774	0,993	0,769
DMU ₅	1,074	0,993	1,066
DMU ₆	0,950	0,993	0,943
DMU ₇	1,030	0,993	1,022
DMU ₈	0,849	0,993	0,842
DMU ₉	1,406	0,993	1,396
DMU ₁₀	1,067	0,993	1,059
DMU ₁₁	0,925	0,993	0,918
DMU ₁₂	0,954	0,993	0,947
DMU ₁₃	1,143	0,993	1,135
DMU ₁₄	0,848	0,993	0,841
DMU ₁₅	1,114	0,993	1,106
DMU ₁₆	0,874	0,993	0,867
<i>Average</i>	<i>0,987</i>	<i>0,993</i>	<i>0,980</i>

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