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COST EFFICIENCY OF ADMINISTRATIVE SERVICE IN PUBLIC HIGHER EDUCATION IN POLAND

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Purpose: The aim of the study is to determine changes in the cost efficiency of the administration of public higher education in Poland.
Design/methodology/approach: The biennial cost Malmquist productivity index was used to study changes in cost efficiency of 58 public higher education institutions in 2014-2016. The results were presented for 6 groups of universities, according to the Ministry of Science and Higher Education in Poland classification.
Findings: The research shows that out of 6 groups of institutions accepted for the study, 2 achieved an increase and 1 a decrease in the Malmquist cost index in both study periods. Changes in the Malmquist cost index in the analyzed period are small as the index ranged from 0.98 to 1.06. Both component overall efficiency change and cost-technical change contributed to the change in the Malmquist index level.
Research limitations/implications: The main limitation of the study are the analysis of changes in cost efficiency only. Additionally, only public universities supervised by the ministry responsible for higher education were studied. Future research should include changes in allocative efficiency using the Malmquist index. In addition, a larger research sample should be considered, taking into account other public universities, including medical, arts, etc., and non-public universities.
Practical implications: The considerations presented are relevant to public university authorities. The article indicates the need to assess cost effectiveness in evaluating the functioning of a higher education institution. This belongs to the responsibilities of management control in terms of effectiveness and efficiency of HEIs and spending of public funds. Information on the variation of cost efficiency between HEIs, assigned to 6 groups, may become a stimulus to conduct an assessment of this economic category in a given unit and strive to improve it.
Originality/value: The added value of the article is the use for the first time of the cost Malmquist index to examine higher education. Also, the use of a modified version of the cost Malmquist index to estimate efficiency assuming variable returns-to-scale.

Keywords: Cost, Efficiency, Malmquist, DEA, Higher education.

Category of the paper: Research paper.

1. Introduction

Higher education plays an extremely important role in every country, because it educates staff for the needs of the economy and influences the R&D activity and innovation of the country. Due to the role of the higher education system, it has been changed and reformed several times in Poland in the last 10 years in order to adapt it to new conditions and socio-economic expectations, both domestic and international. The first major reform was implemented in 2011, followed by further reforms in 2014, 2016 and 2018.

It is worth emphasizing that cost issues in higher education have gained importance in recent years due to the deepening decline in the number of students, which translates into an increase in costs. According to Statistics Poland (2017), employee salaries constitute as much as 57% of the costs of public institutions. However, while the compensation of academic teachers has a substantive justification, because this group of employees performs the basic tasks of the institution in the field of teaching and research, the high compensation of other employees is quite controversial. It is worth noting that higher education institutions receive from the didactic subsidy only funds for the salaries of teaching staff from the Ministry of Higher Education and Science. Whereas the salaries of administrative staff are financed from the higher education institutions' own revenues, mainly from teaching revenues (77.9% of total revenues) (Statistics Poland, 2017).

However, it should be noted that, as part of their autonomy, higher education institutions were free to make changes to salaries of administrative staff at their discretion, so it is important to check whether they have used this option, as the remuneration system should be adjusted to the labor intensity and results achieved by employees.

In the twenty-first century, there are many opportunities to automate the tasks and processes of higher education institution administration, using widely available, advanced ICT tools (Williamson, 2020), thus reducing the costs of institution operation. In Poland, modern IT solutions are introduced both at the level of higher education institutions and at the level of the ministry responsible for higher education.

Modern IT solutions are available at universities for such areas as admissions, student registry, HR and payroll, and management of courses of study (Janczyk-Strzała, 2018). Ryttberg and Geschwind (2021) indicate that IT solutions will successfully contribute to more efficient performance of standard repetitive and routine tasks, and thus create new ways of organizing work. However, in the future, it is expected that HEIs will embrace more complex IT solutions "such as artificial intelligence (AI) and cognitive computing (CC); augmented reality (AR), virtual reality (VR), and mixed reality (MR); Internet of Things (IoT); and blockchain" (Visvizi et al., 2019, p. 1) "to improve the overall efficiency of HEIs" (Visvizi et al., 2019, p. 5). It is important to note that the pandemic period has shown that some administrative work in public sector can be done remotely. Although the technical possibilities

were already available much earlier, the mental limitations of the management staff meant that the solution of remote working was not used (Iwaniuk et al., 2021).

Whereas, at the ministry level, the POL-on system was implemented, i.e. POL-on, i.e. The Integrated System of Information on Science and Higher Education in Poland (Janczyk-Strzała, 2018). It is worth emphasizing that each change in the system of higher education in Poland influenced the functioning of both teaching and research activities, e.g., in the field of service and reporting through the POL-on system.

Casu and Thanassoulis (2006) indicate that too little attention is focused on the efficiency of university administrative staff, much less on assessing cost efficiency. Moreover, Prędki (2015) points out the study of non-profit entities subsidized from the state budget in terms of cost efficiency is of key importance. It results, first of all, from the assumptions of management control in terms of effectiveness and efficiency of the higher education institution's operation. Secondly, it results from the Public Finance Act, which also applies to public higher education. The act emphasizes that making public expenditure should be carried out in a purposeful and cost-effective manner, with principles of obtaining the best results from given inputs, aimed at achieving the assumed goals. "The society should be able to know how to evaluate the effectiveness of state funding of science" (Łącka, 2013, p. 87).

On the other hand, the increase in salary costs may be due to organizational changes in higher education administration towards the so-called professionalization of the workforce.

The aim of the study is, therefore, to determine changes in the cost efficiency of the administration of public universities in Poland. The added value of the article is the use for the first time of the cost Malmquist index to examine higher education. Also, the use of a modified version of the cost Malmquist index to estimate efficiency assuming variable returns-to-scale.

2. Research background of higher education administrative services

Organizational changes that have been observed in higher education for several years are a result of increased competition, differentiation of university missions and their internationalization (Sułkowski et al., 2020). Baltaru and Soysal (2018) indicate that the implementation of the extended and differentiated missions of universities is one of the main factors influencing the development of university administrative bodies. Research conducted on a sample of British (Wolf, Jenkins, 2020), Norwegian (Gornitzka, Larsen, 2004), Danish (Stage, Aagaard, 2019), and Australian HEIs (Croucher, Woelert, 2021) suggests that changing the functioning of HEIs, directly impacts changes in administrative staff towards a more professionalized workforce. The noted trend in higher education varies in scope, duration of implementation, and impact on other areas of entity operations.

Gornitzka and Larsen (2004) noted two main patterns of change in university administration. The first pattern concerned changes in the size of the administrative staff, and the second pattern concerned qualitative changes that can be interpreted as the professionalization of the administrative staff. Stage and Aagaard (2019) observed that the number of specialized and highly educated employees in university administration has increased, while less expensive positions, relatively decreased. Baltaru's study (2019) shows that universities that moderately increase the proportion of administrative staff (not teachers) demonstrate higher student graduation rates, but no significant differences can be observed in terms of research quality, good honors degrees, and graduate employability. Croucher and Woelert (2021) indicate that a number of global studies undertaken in recent years have noted a trend of increasing proportions of non-academic staff in universities and a shift towards more highly skilled and remunerated non-academic roles. In contrast, the results of their study (Croucher, Woelert, 2021) provide partial confirmation of these observations in Australian universities as well. The authors (Croucher, Woelert, 2021) report that while the proportion of non-academic positions in Australian universities has remained largely stable, there has been a striking and uniform increase in management positions, with a significant decline in lower level and less costly administrative support roles.

3. Literature review

The study of various types of efficiency in the sphere of education is most often carried out using the non-parametric Data Envelopment Analysis (DEA) method or the parametric Stochastic Frontier Analysis (SFA) method. Górecka et al (2021) following Nazarko et al. (2008), indicate that a view has formed in the literature that the DEA method is most appropriate for estimating efficiency when we do not have price or cost information, while SFA is most appropriate when we have this information. The analysis by Rhaiem (2017) shows that the vast majority of research is conducted with the use of the DEA method. On the other hand, the review of educational research by De Witte and López-Torres (2017) shows that they are very diverse in many respects. However, researchers usually measure the efficiency of educational entities separately in individual years using the DEA method, and less frequently they analyze the change in efficiency between years using the Malmquist index.

The authors examining the efficiency or productivity of higher education adopted various categories of data, depending on the purpose of the analyzes. Most studies that include the number of higher education administrative staff or their costs are included among many other variables when estimating the overall efficiency of higher education. Extremely few studies examine the efficiency of higher education administration itself (Brzezicki, 2020; Tran et al., 2020). Summary of previous studies is shown in Table 1.

Table 1.
Previous research on efficiency and productivity of higher education

Autor	Inputs (I)/Outputs (O)/Prices (P)	Methodology
Agasisti and Salerno (2007)	I: costs for academic staff, costs for non-academic staff, other costs (no salaries) O: number of students enrolled in: scientific courses (no medicine), non-scientific courses, medical courses, PhD courses and external funds for research per researcher	CCR, BCC
Agasisti and Bianco (2009)	I: costs for academic staff, costs for non-academic staff, costs for all staff, other costs and total costs O: total number of students, Ph.D. students, students enrolled in scientific courses, non-scientific courses, external funds for research activities	SFA, DEA: BCC
Abramo et al (2011)	I: academic staff: full professors, associate professors, assistant professors O: standardized number of citations of publications P: salary costs of research staff	Cost DEA
Tochkov et al. (2012)	I: academic staff, floor area, library items, research funds O: all students, domestic students, foreign students, unemployment, starting salary, publications, citation index P: academic salary, operating costs	BCC, Cost DEA,
Edvardse et al. (2017)	faculty employees, administration and other employees for outlays, publishing points, Ph.D. students, study points for courses of a lower or higher degree	Malmquist index
Wolszczak-Derlacz (2018)	I: total revenue, academic staff, administration staff, and total students O: publications and graduates	Malmquist index
Brzezicki (2020)	I: number of non-teacher employees O: the number of students, doctoral students and teachers	SBM, Global Malmquist index SBM
Tran et al. (2020)	I: total number of administrative staff, O: total number of students, the total number of academic staff, total operating expenditure	SFA
Górecka, et al. (2021)	I: value of fixed assets, research and teaching staff and other non-teaching staff O: total revenue from teaching and research activities P: average salary of a teaching and research employee, average salary of another employee (non- teacher)	SFA, Cost DEA

Note: publications ranked by year of publication.

Source: own elaboration base on literature.

It should be emphasized that due to the difficult access to detailed data on higher education, especially financial ones, authors using the DEA method, or the Malmquist index often measured efficiency to a very limited extent. It is worth noting that public institutions are usually not tested in terms of cost efficiency (but also profit efficiency), i.e., taking into account the prices of inputs or types of costs, as is the case with profit-oriented market enterprises. Usually, only technical efficiency is analyzed, i.e. the possibility of minimizing the inputs while maintaining the established outputs (input-oriented models) or maximizing the obtained outputs with given inputs (output-oriented models). On the other hand, in the cost efficiency study, the DEA methodology analyzes the potentially lowest costs incurred by the unit in relation to the actual costs of the unit (Prędki, 2015). In other words, „The cost efficiency of a producer using input vector x to produce output vector y when input prices are w is measured by the ratio

of minimum cost to actual cost" (Lovell et al., 1994, p. 182). As Sengupta and Sahoo (2006, p. 36) rightly points out, "Nonparametric cost efficiency models in data envelopment analysis (DEA) are more flexible in the sense that cost data are usually available even for public sector (nonprofit) enterprises and overall cost minimization may be used as an efficiency criterion, where output price data are not available".

Only a few studies analyzed the cost efficiency of higher education using the DEA method (Abramo et al., 2011; Tochkov et al., 2012; Górecka et al., 2021). So far, however, changes in cost efficiency have not been measured using the cost Malmquist index. The literature review shows that the Malmquist index study of changes in the efficiency of higher education concerned only the analysis of technical efficiency. Therefore, the found research gap should be filled.

In Poland, so far only one study has been carried out using quantitative methods (e.g. DEA), which has been directly devoted to the efficiency of higher education administration in terms of its size. In the study by Brzezicki (2020), attention was drawn to efficiency of public higher education administration staff in Poland. The author (Brzezicki, 2020) in his research indicates that the level of employment in the administration of higher education institutions was related primarily to systemic changes in higher education. However, this work focuses only on technical efficiency (static approach: DEA method and dynamic approach: Malmquist index was used) in this area, and therefore it was noted in it that future research directions should take into account the measurement of cost efficiency of higher education institution administration. It was decided to overcome the limitations of previous studies (Brzezicki, 2020) and measure the cost efficiency of higher education administration in dynamic terms. Therefore, it seems reasonable to carry out this type of analysis.

4. Research methodology

Charnes et. al. (1978) introduced DEA, which is a non-parametric method to measuring the efficiency of decision-making units (DMU) with multiple inputs and multiple outputs using mathematical programming. In the first model namely CCR or CRS developed by Charnes et al. (1978) assumed constant returns-to-scale. Then Banker et al. (1984) presented a model with variable returns-to-scale, namely BCC or VRS.

Under the DEA method, only technical efficiency can be estimated if there is no information on the prices of inputs or products of the DMUs tested. On the other hand, when information on price or cost of inputs is available, then the cost efficiency can be estimated (Cooper et al., 2007).

Initially, the DEA models were not adapted to dynamic analysis of efficiency, therefore Caves et al. (1982), using the earlier work of Malmquist (1953), introduced a measurement of the change in productivity over time using the so-called Malmquist index. Next Färe et al. (1992) proposed its calculation using the DEA method. Originally, Färe et al. (1992) decomposed this index into two components, assuming constant returns-to-scale (CRS). In the next work by Färe et al. (1994) decomposed into three elements, assuming variable returns-to-scale (VRS). However, as noted in Grifell-Tatjél and Lovell (1995), the Malmquist index may incorrectly measure changes in productivity over time, assuming variable returns-to-scale (VRS). Moreover, in this case there may not be finite values of the so-called intertemporal measures, which are components of the index under consideration (Cooper et al., 2007).

In order to overcome the above-mentioned problem, several modifications of the classic Malmquist index were proposed, assuming variable returns-to-scale, e.g. sequential Malmquist index (Shestalova, 2003), global Malmquist index (Pastor, Lovell, 2005) and the biennial Malmquist index (Pastor et al., 2011). It should be noted, however, that sequential Malmquist (Shestalova, 2003) ignores the natural technological regression during the study and, therefore, does not indicate negative technological changes. In the case of global Malmquist (Pastor, Lovell, 2005), it is difficult to constantly add a new period to the survey, which entails the need to calculate the index multiple times. The Malmquist index biennial does not pose such problems (Pastor et al., 2011).

All the above-mentioned modifications to the Malmquist index concerned the measurement of changes in technical efficiency. Therefore, Maniadakis and Thanassoulis (2004), proposed the cost Malmquist index to measure changes in cost efficiency between period t and t +1. Cost Malmquist index was use when DMU are cost minimizers and input prices are known. Then Tohidi et al. (2012) proposed a combination of both solutions, i.e. the global Malmquist index (Pastor, Lovell, 2005) with cost Malmquist index (Maniadakis, Thanassoulis, 2004), calling this construct global cost Malmquist productivity index. Next Tohidi and Tohidnia (2014) proposed biennial cost Malmquist productivity index (CM) as:

$$CM_V^B = \frac{w^B x_j^{t+1} \Big/ C_V^B\left(y_j^{t+1}, w^B\right)}{w^B x_j^{t} \Big/ C_V^B\left(y_j^{t}, w^B\right)} \tag{1}$$

where biennial cost function is defined as $C_V^B\left(y, w^B\right) = \min\left\{w^B x \middle| (x, y) \in T_V^B, w^B > 0\right\}$. The input price vector is $w^B \in R_+^m$, input vector $x_j \in R_+^m$ and output vector $y_j \in R_+^s$.

The biennial cost Malmquist productivity can be decomposed into overall efficiency change (OEC) and cost-technical change (CTC) as:

$$CM = OEC \times CTC, \tag{2}$$

where overall efficiency change (Tohidi, Tohidnia, 2014) is:

$$OEC_V^B = \frac{w^{t+1}x_j^{t+1} \Big/ C_V^{t+1}\left(y_j^{t+1}, w^{t+1}\right)}{w^t x_j^t \Big/ C_V^t\left(y_j^t, w^t\right)} \tag{3}$$

and cost-technical change (Tohidi, Tohidnia, 2014) is:

$$CTC_V^B = \frac{CM_V^B}{OEC_V^B} = \frac{\dfrac{w^B x_j^{t+1}}{C_V^B\left(y_j^{t+1}, w^B\right)} \Big/ \dfrac{w^{t+1}x_j^{t+1}}{C_V^{t+1}\left(y_j^{t+1}, w^{t+1}\right)}}{\dfrac{w^B x_j^t}{C_V^B\left(y_j^t, w^B\right)} \Big/ \dfrac{w^t x_j^t}{C_V^t\left(y_j^t, w^t\right)}} \tag{4}$$

Maniadakis and Thanassoulis (2004, p. 401) indicate that „OEC component captures input between period t and t+1. In the terminology of Färe et al. (1992, 1994) this measure indicates whether the production unit ‘‘catches up’’ the cost boundary when going from period t to period t+1”. In other words, OEC “is the technological gap between the VRS cost frontier of period t and the VRS biennial cost frontier of time periods t and t +1 along the ray $\left(x_j^t, y_j^t\right)$” (Stage, Aagaard, 2019, p. 27). Maniadakis and Thanassoulis (2004, p. 401) indicate that CTC „measures the shift of the cost boundary evaluated at the input mixes x^t and x^{t+1}”.

Values for the Malmquist index and its components greater than 1 indicate an increase, less than 1 indicate a decrease, and 1 indicate no change. Therefore, 1 is the cut-off value that separates progress from regress and indicates no such change over the period under review.

5. Data and DMU

The choice of variables for the study was guided primarily by the aim of the analysis undertaken, as stated in the introduction, as well as the categories used in the literature on the subject to analyze the efficiency of higher education. The only input was the average number of administration staff (x_1). On the other hand, the results include the values characterizing the three main groups of internal stakeholders of an academic institution for whom administrative services perform their various tasks. The first output included in the study is the total number of students (y_1), the second is the total number of doctoral students (y_2), and the third and last result is the total number of academic teachers (y_3). This cost efficiency study of administrative staff uses the conceptual framework proposed by Casu and Thanassoulis (2006) and Brzezicki (Brzezicki, 2020).

In order to measure cost efficiency, it is also necessary to determine the input cost (price), which in this case is the average compensation of other employees in a given year (p_1). For each institution, the value of the average compensation of other employees was determined by dividing the cost of compensation in a given year by the number of employees. The list of variables used in the empirical study is presented in Table 2.

Table 2.
Variables use in study

Variable	Description
Inputs	
x_1	number of administration staff
Outputs	
y_1	total number of students
y_2	total number of doctoral students
y_3	total number of academic teachers
Cost of input	
p_1	average compensation remuneration of administration staff

Source: own elaboration.

Descriptive statistics of the variables used in the study are presented in Table 3. Data for the study for 2014-2016 were obtained from the Ministry of Science and Higher Education, upon request for disclosure of public information.

Table 3.
Statistical descriptions for variables use in study

	2014		2015		2016	
Variable	**Mean**	**SD**	**Mean**	**SD**	**Mean**	**SD**
Inputs						
x_1	911	733	898	731	880	717
Outputs						
y_1	15991	10525	14932	10271	14748	10120
y_2	565	656	560	649	599	768
y_3	1077	814	1069	818	1073	827
Cost of input						
p_1	47	6	51	7	51	8

Notes: Mean – arithmetic average, SD – standard deviation.

Source: own elaboration.

The 58 public higher education institutions supervised by the Ministry of Science and Higher Education in Poland were accepted for the empirical study (Table Z1 in Appendix). However, the obtained results of the analysis were averaged and presented within groups of institutions of a similar nature according to the Ministry of Science and Higher Education classification, namely (see Table Z1): universities (U, 18 units), technical universities (UT, 18 units), economic universities (EU, 5 units), pedagogical universities (UPe, 5 units), natural and agricultural universities (UPrz, 6 units) and the Academies of Physical Education (AWF, 6 units).

6. Empirical results

Using the CM will allow to determine whether the cost efficiency in higher education has changed in the analyzed period. In turn, its decomposition into two components will also enable the identification of factors affecting the improvement or deterioration of productivity.

Figure 1 shows the cost Malmquist index results for the expression (CM − 1) in the years 2014-2016. The average CM level in 2014/2015 was 1.000, and in the following period 2015/2016 it increased to 1.014. The results show an increase in CM productivity as the values are greater than 1 and indicate progress. The largest increase in CM was recorded in economic universities (EU) in 2015/2016 (1.065), and a decrease in technical universities (UT) in 2014/2015 (0.980). In the case of the group of economic universities (EU: 1.001 and 1.065) and academies of physical education (AWF: 1.045 and 1.041), an increase in CM productivity was recorded in both study periods. On the other hand, technical universities (UT) recorded a decrease in CM productivity in both periods (0.980 and 0.998 respectively). Varying results were obtained for universities (U) where there was a slight decrease in 2014/2015 (0.996), and in 2015/2016 an increase in CM productivity (1.018). The opposite situation was observed in teaching universities (UPe), where first there was an increase (1.019), and then in 2015/2016 a decrease in CM productivity (0.987).

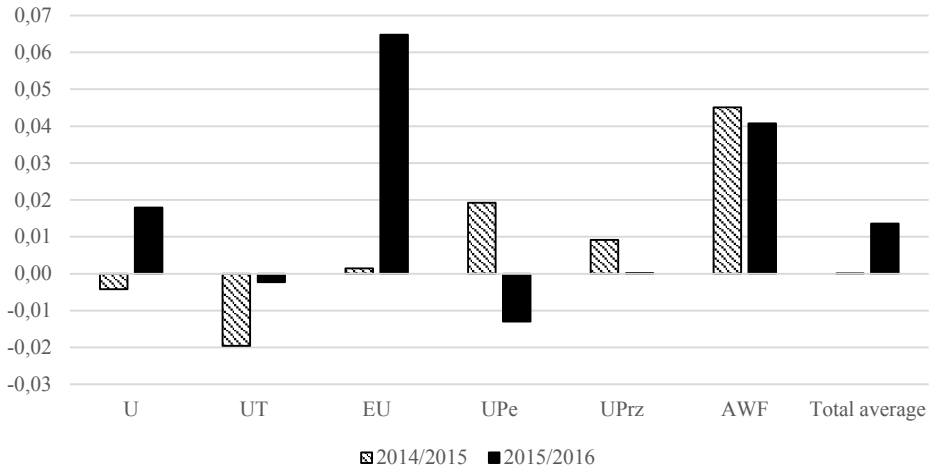

Figure 1. Change CM. Note: the graph shows the difference from the cutoff value of 1, i.e. CM – 1. Source: own elaboration.

According to the research assumption, CM was decomposed into two components. Overall efficiency change is presented in Figure 2 (for the expression OEC − 1), and cost-technical change is presented in Figure 3 (for the expression CTC – 1). In both periods (2014/2015 and 2015/2016), the average values of overall efficiency change (0.981 and 0.999) indicate a decrease. The largest decrease in overall efficiency change was recorded in the group of natural and agricultural universities (UPrz) in 2014/2015 (0.959) and 2015/2016 (0.960). On the other hand, the largest increase was observed in the group of physical education academies (AWF: 1.089) and economic universities (UE: 1.075) in 2015/2016. For almost all university groups, overall efficiency change had the same impact in both periods, only in the case of pedagogical universities (UPe) there was a decrease in 2014/2015 (0.994), and then a slight increase in 2015/2016 (1.004).

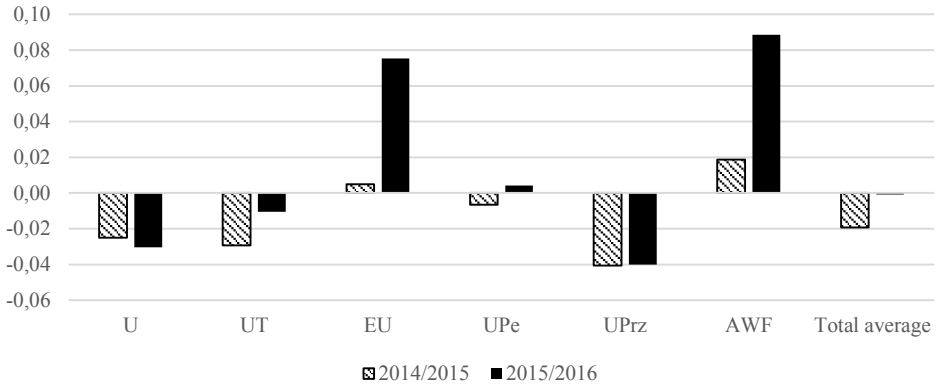

Figure 2. Decomposition CM to overall efficiency change. Note: the graph shows the difference from the cutoff value of 1, i.e. OEC value – 1. Source: own elaboration.

Average values of cost-technical change (1.023 and 1.051) indicate an increase in the analyzed years. The largest increase in cost-technical change was recorded in the group of science universities (UPrz) in 2014/2015 (1.053) and universities (U) in 2015/2016 (1.051). On the other hand, the largest decrease (0.957) was observed in the group of physical education academies (AWF) in 2015/2016. The increase in cost-technical change in both periods was observed in universities (U), universities of technology (UT) and natural and agricultural universities (UPrz). On the other hand, in the case of pedagogical universities (UPe) and academies of physical education (AWF), an increase was recorded in 2014/2015 (1.026 and 1.026 respectively), and then in 2015/2016 a decrease (0.983 and 0.957 respectively). Only economic universities (EU) recorded a decrease in cost-technical change in both study periods (0.997 and 0.990 respectively).

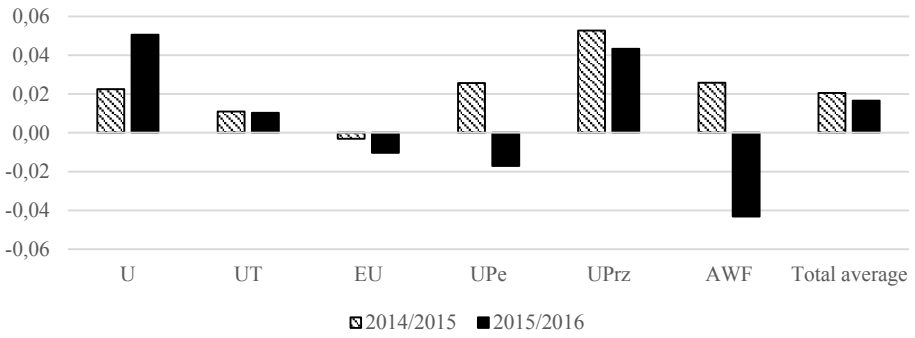

Figure 3. Decomposition CM to cost-technical change. Note: the diagram shows the difference from the cutoff value of 1, i.e. CTC value – 1. Source: own elaboration.

The increase in CM productivity of economic universities (EU) and physical education academies (AWF) was influenced by the increase in overall efficiency change in both periods. On the other hand, the decrease in the CM index of universities (U) and technical universities (UT) in 2014/2015 was caused by a decrease in the overall efficiency change component. In the case of science universities (UPrz), the increase in cost-technical change resulted in a slight increase in CM. The increase in CM of pedagogical universities in 2014/2015, as well

as the decrease in CM in 2015/2016 was dictated primarily by analogous changes in the cost-technical change component.

7. Conclusions

The conducted research shows that out of 6 groups of higher education institutions admitted to the study, 2 were characterized by an increase and 1 by a decrease in the CM index in both study periods. The probable reason for the differences between groups of universities is the current state of development of a given organization and, consequently, the different current needs and tasks performed by universities. On the other hand, in the case of 3 groups of institutions, the CM indicator varied in the analyzed years. Changes in the CM level in the analyzed period 2014/2015-2015/2016 are small. The maximum CM increase was just 1.065 and the maximum decrease was 0.980. In the case of OEC and CTC components, there were also slight changes in their values. The difference between the highest and the lowest OEC values was 0.129, and in the case of the CTC it was 0.096. Only the EU and AWF on their own initiative improved their cost efficiency in two periods. Other higher education institutions have misused their autonomy and lowered their cost efficiency. For the majority of higher education institutions, the shift of the efficiency frontier caused by systemic changes in higher education had a positive impact on their cost efficiency. A different situation was observed for the EU in two periods and in UPe and AWF in one period.

The authors are aware of the limitations of this study. First, only changes in cost efficiency were analyzed. Secondly, only public higher education was examined, which is a fundamental restriction. Finally, thirdly, the quality of work of higher education institution administration has not been analyzed. Therefore, this research should be developed in future analyzes. In the future, it is planned to use other extensions of the Malmquist index to measure changes in revenue, profit and allocation efficiency in higher education. Moreover, a more detailed decomposition of the Malmquist index should be made in order to analyze what components influence the changes in efficiency over time.

It should be emphasized, however, that this research filled the gap in the literature. First, only a few studies focused on university administration employees. Secondly, the costs of the administration of higher education institutions have not been properly analyzed in relation to many studies of academic teachers. Finally, thirdly, the newer version of the Malmquist index was used for the cost efficiency analysis, and not for technical efficiency, for which it was previously mainly used.

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Appendix

Table Z1.
List of higher education in Poland accepted for the study

DMU	Name
P1	University of Warsaw
P2	University of Białystok
P3	University of Gdańsk
P4	Adam Mickiewicz University in Poznań
P5	Jagiellonian University in Kraków
P6	University of Łódź
P7	Maria Curie-Skłodowska University in Lublin
P8	Nicolaus Copernicus University
P9	Opole University
P10	University of Szczecin
P11	University of Silesia
P12	Rzeszów University
P13	University of Warmia and Mazury
P14	University of Wrocław
P15	Cardinal Stefan Wyszyński University
P16	University of Zielona Góra
P17	Kazimierz Wielki University in Bydgoszcz
P18	Jan Kochanowski University in Kielce
P19	West Pomeranian University of Technology in Szczecin
P20	Warsaw University of Technology
P21	Białystok University of Technology
P22	University of Technology and Humanities in Bielsko-Biała
P23	Częstochowa University of Technology
P24	Gdańsk University of Technology
P25	Silesian University of Technology
P26	Kielce University of Technology
P27	Koszalin University of Technology
P28	Cracow University of Technology
P29	AGH University of Science and Technology
P30	Lublin University of Technology
P31	Łódź University of Technology
P32	Opole University of Technology
P33	Poznań University of Technology
P34	Kazimierz Pulaski University of Technology and Humanities in Radom
P35	Rzeszów University of Technology
P36	Wrocław University of Technology
P37	University of Economics in Katowice
P38	Cracow University of Economics
P39	Poznań University of Economics
P40	Warsaw School of Economics
P41	Wrocław University of Economics
P42	Maria Grzegorzewska Academy of Special Education
P43	Jan Długosz University in Częstochowa
P44	Pedagogical University of Cracow
P45	Pomeranian University in Słupsk
P46	Siedlce University
P47	Warsaw University of Life Sciences
P48	UTP University of Science and Technology in Bydgoszcz
P49	University of Agriculture in Kraków
P50	University of Life Sciences in Lublin

Cont. table Z1

P51	Poznań University of Life Sciences
P52	Wrocław University of Environmental and Life Sciences
P53	Gdańsk University of Physical Education and Sport
P54	Jerzy Kukuczka Academy of Physical Education in Katowice
P55	University of Physical Education in Kraków
P56	Poznań University of Physical Education
P57	Józef Piłsudski University of Physical Education in Warsaw
P58	University School of Physical Education in Wrocław

Note: group of: universities (P1-P18), technical universities (P19-P36), economic universities (P37-P41), pedagogical universities (P42-P46), natural and agricultural universities (P47-P52) and the Academies of Physical Education (P53-P58).

Source: own study.