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The Efficiency of Public and Private Higher Education Institutions in Poland

Abstract: Changes introduced to Poland's education system in 2011 and 2014 amid efforts to adjust it to the needs of the labour market had an effect on the country's institutions of higher learning. This paper provides an analysis of the efficiency of public and private Polish universities and examines the impact of selected factors in the years that followed. To estimate this efficiency, a Banker, Charnes and Cooper (BCC) model of the Data Envelopment Analysis (DEA) method was used. To gauge the impact of environmental variables on the efficiency of universities, a truncated regression analysis was performed. The results of the study indicate that public universities were more efficient in terms of the number of graduates they produced but less efficient when considering the level of graduate salaries. The opposite was true for private institutions. The level of efficiency was affected by variables related to specific universities and the socio-economic situation of the region in which they operate. The study analyses the efficiency of educational activities of public and private universities, both in terms of the number of graduates and the quality of education and in the context of the labour market. The analysis also considers the level of graduate earnings.

Keywords: efficiency, higher education, DEA, bootstrap, two-stage analysis

JEL classification codes: C14, I22, I23

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Efektywność publicznych i prywatnych szkół wyższych w Polsce

Streszczenie: Wprowadzone w 2011 i 2014 roku zmiany systemowe dotyczące dostosowania kształcenia do potrzeb rynku pracy wpłynęły na sytuację w szkolnictwie wyższym w kolejnych latach. W niniejszym artykule dokonano pomiaru efektywności polskich uczelni publicznych i prywatnych oraz oszacowano wpływ poszczególnych determinant na poziom efektywności uczelni. Do pomiaru efektywności wykorzystano model BCC należący do metody DEA. Natomiast do oszacowania wpływu zmiennych środowiskowych na poziom efektywności uczelni wykorzystano regresję uciętą. W badaniu przeanalizowano efektywność działalności dydaktycznej uczelni publicznych i prywatnych zarówno w zakresie liczebności, uwzględniając liczbę absolwentów, jak i jakości edukacji w kontekście rynku pracy, ujmując wartość zarobków absolwentów po ukończeniu edukacji akademickiej. Wyniki badania wskazują, że uczelnie publiczne były bardziej efektywne pod względem liczby absolwentów, ale mniej efektywne pod względem poziomu wynagrodzeń absolwentów. Odwrotnie było w przypadku uczelni prywatnych. Na poziom efektywności wpływały zarówno zmienne związane z samymi szkołami wyższymi, jak i sytuacją społeczno-ekonomiczną regionu, w którym funkcjonują szkoły.

Słowa kluczowe: efektywność, szkolnictwo wyższe, DEA, bootstrap, analiza dwuetapowa

Kody klasyfikacji JEL: C14, I22, I23

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Introduction

Higher education is a driving force of economic development in every country. Universities contribute to the essential components of a knowledge-based economy by providing highly qualified personnel for the job market and by conducting, promoting and supporting research and scientific undertakings. However, the value and potential of higher education needs to be utilised for the economic needs of the home country. Otherwise, resources used to provide an education will be squandered without significant domestic benefits. A report entitled *Addressing Brain Drain: The Local and Regional Dimension*, prepared for the European Committee of the Regions [European Union, 2018], indicates that "in 2017, there were almost 17 million EU28 movers, of which about one-third (32%) were in the 15–34 age bracket" and the top countries of origin were Romania, Poland, Italy and Portugal [EC–DG EMPL, 2018]. According to the report, 25% of EU28 movers with a working age of between 15 and 64 had a tertiary-level education in 2017. "These highly educated European movers favour urban settings and northern areas of the EU (Sweden, Ireland, Estonia, Denmark as well as several regions in the UK). They also usually enjoy very high employment rates (…) In 2017, approximately 4.2 million of EU28 movers with a working age of between 15 and 64 had a tertiary level of education (ISCED11, levels 5–8). This represents 25% of the almost 17 million EU28 movers. The share of highly skilled EU28 movers has been increasing regularly over the period 2014–2017 (…) In absolute terms, the highest number of highly educated movers in 2017 was from Poland (576,300 individuals), Germany (472,700), and Romania (467,500)" (pp. 1 and 12). In the context of the statistics on the migration of educated people, of note is the efficiency of higher education institutions in regions of Poland from which the largest numbers of graduates leave for other geographies.

The goal of the study is to measure the educational efficiency of public and private universities in Poland and to assess the impact of various variables on their efficiency.

Review of the literature on the DEA method: efficiency in education

The DEA method has been widely accepted among researchers around the world. A growing number of publications use this method to study efficiency [Emrouznejad, Yang, 2018]. According to an analysis by Liu, Lu, Lu and Lin [2013], the education industry is among the five most-analysed research areas that apply the DEA method. However, only a small portion of studies focus on analysing higher education institutions. Despite this, there is still a substantial number of scientific studies that deal with the efficiency of universities in Europe and around the world. A review of educational research by De Witte and López-Torres [2017] shows that significant studies have been conducted by various scholars at several different levels. For example, Wolszczak-Derlacz [2017] studied various European countries and the United States to compare international data on the efficiency of higher education systems. Meanwhile, Ćwiąkała-Małys [2010] and Brzezicki and Wolszczak-Derlacz [2015a; b] carried out national studies of higher education institutions. Researchers including Pietrzak, Pietrzak and Baran [2016], and Çokgezen [2009] examined the efficiency of individual university faculties. Ćwiąkała-Małys [2010] and Brzezicki and Wolszczak-Derlacz [2015a; b] analysed public universities, while Tochkov, Nenovsky and Tochkov [2012], Çokgezen [2009], and Bangi [2014] analysed private institutions. However, the vast majority of the literature concerns the efficiency of public rather than private higher education institutions. The efficiency of non-public higher education institutions was not measured in Poland, which is a fundamental limitation of the research conducted so far. Variables considered in previous studies have included the number of academic teachers [Barra, Lagravinese, Zotti, 2018], the value of university fixed assets [Brzezicki, Prędki, 2018], the number of students and graduates [Wolszczak-Derlacz, 2017] and university revenue [Selim, Bursalıoğlu, 2015; Brzezicki, Prędki, 2018].

With respect to the employed method of analysis, the models used as part of the DEA method are deterministic, which impedes the analysis of various types of uncertainty associated with data and the adopted model. As a result, the so-called "statistical approach" was necessary within the DEA. This indicates that, under the stochastic version of the DEA, the semi-parametric approach is most often used in the literature; for more information, see Olesen and Petersen [2016]. This approach enables a formal statistical interpretation to be made in relation to the adopted model and provides the tools to estimate the accuracy of efficiency indicators [Brzezicki, Prędki, 2018]. One such tool is bootstrap analysis. The most commonly used method of single-stage analysis is the so-called Simar-Wilson [1998; 2000] homogeneous bootstrap approach. The significance of bootstrap analysis and its variations is noted by Liu, Lu and Lu [2016]. The vast majority of research by higher education institutions was concerned with determining the level of efficiency using the DEA method, though in several cases researchers also considered determining factors affecting performance indicators.

When determining factors were considered, research was carried out using a two-stage analysis procedure: in the first stage, efficiency indicators were calculated using the DEA method; and in the second stage, regression analysis was applied to determine factors affecting efficiency [Tochkov et al., 2012].

Some authors also used the bootstrapping method in the first stage of the analysis to measure the accuracy of DEA performance indicators, e.g. Johnes [2006], while others used the bootstrapping method in both stages [Simar-Wilson procedure, 2007] of the study, e.g. Selim and Bursalıoğlu [2015], Wolszczak-Derlacz and Parteka [2011], Brzezicki and Wolszczak-Derlacz [2015b], and Wolszczak-Derlacz [2017].

In the first stage of their efficiency study, Wolszczak-Derlacz and Parteka [2011] adopted the total number of graduations and the total number of publications as their results. In the second stage, the authors included variables such as GDP per capita, the number of faculties, a dummy variable (which equals 1 if an institution has a medical or a pharmacy faculty, and 0 otherwise), the year of foundation, the share of core funding revenues in total revenue, and the proportion of women in academic staff. In the first stage, Brzezicki and Wolszczak-Derlacz [2015b] assumed the number of conversion graduates and the employers' preference index as the result. On the other hand, the determinants were the share of grants from the Ministry of Science and Higher Education in total income from teaching activities, the ratio of the number of professors and associate professors to the total number of academic teachers, the share of doctoral students to the total number of students, the number of students, and a dummy variable for each type of institution. There was a wide range of variables adopted in the second stage of efficiency analysis. Barra et al. [2018] considered fees collected from students, the year of establishment of a university, GDP (regional level), and the proportion of women among students, whereas Wolszczak-Derlacz [2017] included in their study the year of establishment of a university, GDP, the share of public funds and fees in the total sum of university funds, and the composition of university departments. All these studies, however, have their limitations because, for example, Wolszczak-Derlacz and Parteka [2011] in the first stage included only the number of graduations in the field of teaching, while Brzezicki and Wolszczak-Derlacz [2015b] in one model adopted the number of graduations and the employer preference index. Therefore, a separate analysis should be conducted of institutional efficiency in terms of the number of graduations and variables related to the labour market.

Research methodology

For the empirical study, the non-parametric DEA method was used, as formalised by Charnes, Cooper and Rhodes [1978]. The authors created the first Charnes, Cooper and Rhodes (CCR) model with a constant return to scale, then Banker, Charnes and Cooper [1984] modified the method to form a model with a variable return to scale. However, calculating the efficiency of entities alone does not provide sufficient information to the reader. Therefore, as noted by Simar and Wilson [2007], many authors use a two-stage efficiency analysis. In the first stage, the efficiency results are calculated using the DEA method, then, in the second stage, a regression analysis is performed using the DEA efficiency results from the first stage. The regression analysis takes into account environmental variables, estimating their impact on the overall level of efficiency.

As indicated by Bădin, Daraio and Simar [2014], most studies using this approach in the second-stage estimation employed either the tobit model (censored regression) or ordinary least squares methodology. Unfortunately, as Simar and Wilson [2007] note, neither of these methods has described the underlying Data Generating Process (DGP). In addition, DEA estimates are by default biased estimators of the true efficiency scores. Other more serious drawbacks are that the DEA efficiency estimates are serially correlated and that the error term in the second stage is correlated with the regressors, making standard approaches to inference invalid. Simar and Wilson [2007] developed a semi-parametric bootstrap-based approach to overcome the problems of the traditional two-stage approaches outlined above and also proposed two bootstrap-based algorithms to obtain valid, accurate inference in this framework (p. 8).

Considering these problems, the empirical study carried out in this article was divided into two successive stages. In the first stage, efficiency was measured using the output-oriented BCC model (BCC-O), and in the second stage, the impact of environmental variables on the level of efficiency was estimated. In the first and second stages of the research, the Simar and Wilson [2007] bootstrapping procedure was used. In the literature, the approach used in this study is referred to as a two-stage double bootstrap DEA by Simar and Wilson [2007].

In the first stage, the BCC model was used to measure the technical efficiency of higher education institutions, with a variable return to scale. This is because the literature [Cooper, Seiford, Tone, 2007] states that "if the data set includes numeric values with a large difference in magnitude, e.g., comparing big companies with small ones, the VRS model may be a choice (p. 344)."

Since the analysis adopted variables with a large variation in the size of educational institutions, the DEA model with a variable return to scale was chosen.

In the second stage, in order to estimate the impact of external factors, the regression function was used according to equation (1), in which the technical variable (DEA) previously calculated using the BCC-O model was taken as the dependent variable, taking into account the corrected metre values based on bootstrap (bias-corrected efficiency scores).

$$\widehat{DEA}_i = \alpha + \beta Z_i + \varepsilon_i \tag{1}$$

$\widehat{DEA}_{i,t}$ is estimated bias-corrected efficiency scores, Z_i is a set of potential determinants, β denotes a column vector of coefficients, the estimation of which is the ultimate objective of the empirical analysis, and ε_i is statistical noise whose distribution is restricted by $\varepsilon_i \geq 1 - \alpha - z_1\beta$.

For the empirical calculations in this study, the rDEA package for the R programme was used, based on the two-step double bootstrap second algorithm of Simar and Wilson [2007] – see more detail in: Simar and Wilson [2007]. The two-stage methodology of Simar and Wilson [2007] crucially depends on the validity of the first-stage DEA inputs, which can be separated from the second-stage environmental variables, as stated in their separability condition. Daraio et al. [2018] developed a testing procedure for this separability condition based on the results of the central limit theorem. However, the procedure of Daraio et al. [2018] is sensitive to the particular random sample-split employed. Therefore, Simar and Wilson [2020] developed a modified form that eliminates much of the sensitivity. The study used the latest version of the FEAR package [Wilson, 2008] for the R programme to verify that the separation assumption was met. The function implemented in FEAR uses results from Daraio et al. [2018] and Simar and Wilson [2020] to test the separability condition described by Simar and Wilson [2007].

At each research stage (1st and 2nd stages), two different models (A and B) were used, of which the first (A) concerns the quantitative characteristics of didactics and the second (B) focuses on quality in the context of the labour market, which will be explained in the next part of the article.

Data: higher education and variables for the study

A sample of 59 public universities (P) and 34 private colleges (N) supervised by the Polish Ministry of Science and Higher Education was used in the study (see Table Z1–Z2). When selecting the data for the study, the author chose data and variables used in referenced studies. This study, however, focuses on two aspects of educational activities pursued by universities: the quantitative aspect (i.e. the number of graduates produced) and the quality of education in the context of the labour market, taking into account the level of graduate earnings. Therefore, two empirical models (A and B) were adopted, corresponding to the results of individual educational aspects. The result in model A (quantity model) was assumed as the number of graduates (Y_1), and the level of graduate earnings (Y_2) in model B (quality model). In model A, in terms of the number of graduates (first- and second-cycle studies), data from 2013–2015 was adopted, while in model B, data on earnings from 2014–2016 was adopted. The adoption of such a research convention takes into account the time lapse between graduation and earnings collected by the graduates.

The author accepted the number of graduates as reported by the universities. However, no formal publications quantifying the quality of higher education were available for review. Meanwhile, a standardised assessment method has been developed and implemented in lower-level schools, i.e. primary schools (exam results and educational value added – [EVA]) and secondary schools (vocational exams and secondary school certificates). Brzezicki and Wolszczak-Derlacz [2015a] indicate that the practical assessment of individual higher education institutions, in terms of the results of their teaching activities, is made by employers at a time when graduates transition from education to the labour market (p. 14). Similar opinions are expressed by Rocki [2018]. In contrast, Daraio, Bonaccorsi, and Simar [2015] argue that "more detailed information about the employment rate of graduated students or wages for the first job would provide additional information on the teaching quality and its alignment with the needs of the labor market (p. 437)."

As part of the 2011 reform of Poland's higher education system, universities were obliged to monitor the professional careers of their graduates, and then in 2014 a central system was implemented for monitoring the professional development of higher education graduates using administrative data from the Social Insurance Institution. This data is the basis of the ELA system. Detailed data on the situation of university graduates can be found in the ELA module [2019] belonging to the POL-on database system, which was created after the supplementary reform of 2014. The ELA module contains data on graduates entering the labour market from 2014 to 2017. Another important solution implemented in 2011 was the introduction of a practical education profile, which, by definition, should better meet the expectations of employers. In 2014, a new form of education was introduced: dual studies, based on combining higher education with practice and alternating with internships.

In the case of expenditures, classical factors of production were used for testing, an approach justified by the fact that higher education institutions can be analysed in their role as production units. The first variable is the value of a higher education institution's fixed assets (X_1), as an expression of the physical capital factor. The second variable is academic teachers (X_2), who constitute human capital (extremely important investment). With regard to expenditures (X_1, X_2), data from 2013–2015 was used to reflect the number of graduates (Y_1) admitted as a result of teaching activities in 2013–2015. The variables used in the first research stage are presented in Table 1. It should be noted that universities use the same inputs to carry out both didactic and scientific activities. This means that universities produce not only graduates but also research in the form of peer-reviewed publications. A university may allocate part of its resources (inputs) to the production of research at the expense of graduates (i.e., academic staff focusing less on teaching and more on research). Kuah and Wong [2011] indicate that the real share of resources used to generate output in teaching and research activities should be taken into account. This study uses an approach proposed by Pietrzak and Brzezicki [2017]. Data from Statistics Poland, the state-run statistics agency, on the share of revenue from teaching activities in total operating income was used to determine the proportion of university resources spent to generate the results of teaching activities. In the studied period, the share of teaching revenue ranged from 70.1% to 93.4%. The share of teaching revenue was multiplied by the variables adopted for the study in order to obtain the real share of the expenditure and the corresponding results of teaching activity.

Table 1. Input and output adopted in the first research stage (DEA efficiency)

	Model A		Model B	
Input/Output variable	Input	Output	Input	Output
The value of institution's fixed assets (X_1)	X		X	
Number of academic teachers (X_2)	X		X	
Number of graduates (Y_1)		X		
Salary level of graduates (Y_2)				X

Source: own elaboration.

In the first stage of the research, a study was conducted of the literature and data available in the databases of the Polish Ministry of Science and Higher Education (POL-on) and Statistics Poland (e.g. Local Data Bank – LDB and STRATEG). Several independent factors were also selected that could affect the efficiency of universities. For the second stage of the research, two groups of environmental variables were adopted, those related directly to a specific university and variables significant to the area in which a given university is located. A detailed description of the environmental variables adopted for the study in the second stage is provided in Table 2.

The first group of variables includes the year of establishment of each university (U_rok), which is designed to demonstrate the stability and prestige of a given educational institution in the eyes of the public and employers. Additionally, the amount of practical studies in the total number of available studies (U_Profil) was included. Practical studies were introduced in the higher education system to match the competence of students to the expectations of employers and ensure a higher level of employment for graduates. Subsequently, the proportion of first-level studies in the total number of studies (U_1stop) was adopted. After the introduction of the Bologna system (Level I and Level II studies), those undertaking studies are no longer required to complete a five-year programme. They can complete their academic education at Level 1. Currently, more fields of study are available at Level I than Level II. Therefore the variable would illustrate both the diversity of the educational offering and the flexibility and speed of responding to market needs. It was also decided to include the share of part-time studies in the total number of studies (U_NieST). Although students with full-time employment have the opportunity to upgrade their professional qualifications, this requires greater effort and a significant time commitment from those who want to combine full-time work with university-level studies.

The second group of variables includes mainly data characterising the socio-economic situation of the province in which a given university is located, taking into account the location of the province in the country (W_nr) and assigning a number from 1 to 16 to that province. Provinces differ from each other in various respects (transportation, demographics, social, economic, etc.), which may contribute to additional challenges in obtaining higher results in relation to more developed areas. These variables were adopted to take into account restrictions resulting from a specific location. Another variable considered was the number of cities in a given province (W_lm). This variable would reflect greater employment opportunities for graduates and the greater development potential of the region. It was also decided to take into account the distance from the university's headquarters to the provincial capital (Od_Sto). It was assumed that larger urban centres have greater employment potential as it is relatively quicker and easier to find work there after graduation. This is in part because more employers set up their headquarters in larger cities.

Table 2. Environment variables used in the second stage of research (Regression)

Name	Explanation
U_rok	Year of foundation of institution
U_1stop	Share of first-degree studies in total number of studies
U_NieST	Share of part-time studies in total number of studies
U_Profil	Share of practical profiles in total number of studies
W_nr	Province no. in Poland (location)
W_lm	Number of cities in a given province
Od_Sto	Distance from the university's headquarters to provincial capital
W_Neet	Number of people (aged 15–24) who are not in employment, education or training (NEET)
W_Fzag	Number of companies with foreign capital
W_BiR	Expenditure on R&D *per capita*
W_PKB	GDP *per capita*

Source: own elaboration.

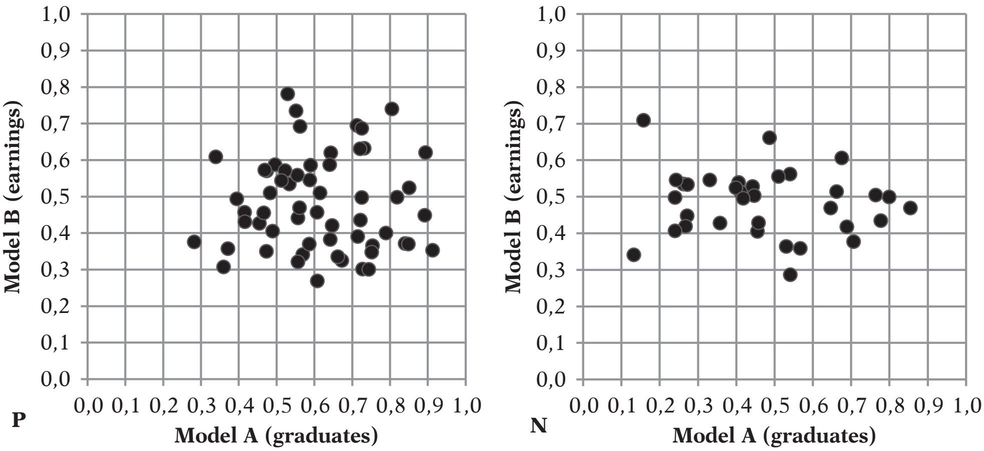
Another variable added to the study defines the number of companies with foreign capital. (W_Fzag). Foreign enterprises often expect higher skills from their employees, which are typically offered by graduates coming from a higher education institution. The state of a province's economy is affected by the general socio-economic situation and lifestyle of the local community. Examples of negative socio-economic behaviours that can be identified include the number of young people who are not in employment, education or training (W_Neet). It was decided to check to what extent this affects the situation of higher education graduates. The last two variables are intended to illustrate the wealth of a given province, hence the GDP per capita (W_PKB) and expenditure on R&D per capita (W_BiR) were included in the study.

In Poland, there is no universal and publicly available database for individual higher education institutions. Statistics Poland provides and publishes only aggregated data. This data cannot be used to measure the efficiency of individual higher education institutions. The data used in this study comes from several sources. The value of fixed assets was obtained from the institutions' financial statements published in the *Monitor Sądowy i Gospodarczy* [https://ems.ms.gov.pl/msig/przegladaniemonitorow] official gazette. Statistical data on the number of academic teachers and graduates was taken from a statistical guidebook entitled *Szkolnictwo wyższe – dane podstawowe* (Higher Education – Basic Data), issued until 2015 by the Polish Ministry of Science and Higher Education. Variables describing the position of graduates on the labour market in terms of remuneration were obtained from reports published as part of the Polish Graduate Tracking System (ELA), which is one of the modules of the POL-on system. Other data about universities in terms of the year of establishment, the number of practical profiles, first-cycle studies and part-time studies was obtained from the POL-on system, including its "register of higher education institutions" and "lists of studies" modules. On the other hand, variables characterising the socio-economic situation of individual Polish provinces, e.g. the number of young people who are not in education, employment or training (NEET) and GDP per capita, were taken from official and free Statistics Poland data available in databases such as LDB and STRATEG.

Empirical results and discussion

As part of the first stage of the research, performance indicators were calculated. Then previously estimated efficiency measures were corrected using the bootstrap analysis. Far more public and private universities achieved 100% efficiency in model A (graduates) than in model B (earnings). In the first quantitative model (A), nine public universities (U1, U6, U37, U38, U42, U45, U53, U54, U59) and seven private entities (N6, N13, N15, N18, N22, N33, N34) were efficient, while in the second qualitative model (B) four public universities (U40, U45, U53, U59) and three non-public ones (N13, N15, N22) were efficient. Some universities (three public: U45, U53, U59, and three non-public: N13, N15, N22) achieved 100% efficiency in both models at least once in any given year. After applying the bootstrap analysis, no unit achieved full 100% efficiency. Figure 1 presents the average efficiency values from 2013/2014–2015/2016 corrected applying the Simar and Wilson [2007] bootstrap analysis. The average level of efficiency of public institutions was 0.62 for model A and 0.48 for model B. However, for private universities the efficiency level was calculated to be 0.47 and 0.48 respectively. The research results indicate that public institutions were more efficient in terms of the number of graduates (model A) yet less efficient with respect to the level of earnings for graduates (model B). The opposite is true for private institutions, which obtained a higher level of efficiency in terms of earnings and lower efficiency with respect to the number of graduates.

Figure 1. Performance indicators for public and private schools (average values for 2013/2015–2014/2016)



Note: Performance indicators adjusted on the basis of Simar and Wilson's bootstrap procedure [2007]. Public universities (P), private universities (N).
Source: own elaboration.

In the second stage of the analysis, the impact of selected environmental variables on the efficiency of universities was estimated, with the results presented in Table 3. The table shows the value of the unloaded parameter (Par.) calculated using the bootstrap analysis as well as the lower (Low) and upper (Upp.) limits of the confidence interval for a confidence level of 0.05. The research approach assumes that inference about the statistical significance of a parameter is considered on the basis of a combination of lower and upper confidence intervals. If the number 0 appears within the confidence interval (the range limits have opposite signs), then there is no statistical significance of the parameter [Wolszczak-Derlacz, 2013].

The research shows that for model A (the number of graduates) for private institutions, the year of establishment of an institution has a significant impact. This may indicate that students choose those educational institutions that have been in existence longer and have an already established position and reputation as well as a lower likelihood of termination of academic activity during the education cycle than in the case of new universities.

Table 3. Determinants of the efficiency of public and private higher education

	Model A (Graduates)						Model B (Earnings Level)					
	Public			Private			Public			Private		
Variable	Par.	Low.	Upp.	Par.	Low.	Upp.	Par.	Low.	Upp.	Par.	Low.	Upp.
U_rok	0.003	–0.00*	0.005	0.097	0.092	0.270	–0.00*	–0.001	0.001	–0.001	–0.024	0.024
U_1stop	3.725	1.319	6.185	4.714	–2.167	12.403	0.523	–1.380	2.183	–0.051	–0.828	0.771
U_NieST	1.342	–0.016	2.737	–2.057	–12.051	6.944	–1.574	–2.432	–0.693	1.241	0.064	2.235
U_Profil	–0.546	–1.194	0.173	2.960	0.648	6.095	–0.285	–0.738	0.184	0.258	–0.029	0.545
W_lm	0.016	0.004	0.026	–0.087	–0.165	0.015	–0.00*	–0.007	0.006	0.011	0.005	0.017
W_nr	–0.044	–0.074	–0.016	–0.108	–0.335	0.200	0.008	–0.012	0.028	0.034	0.018	0.054
Od_Sto	0.001	–0.003	0.005	0.010	–0.020	0.047	–0.005	–0.008	–0.002	0.004	0.00*	0.007
W_Neet	–0.039	–0.117	0.044	–0.602	–1.237	–0.045	0.024	–0.031	0.077	0.045	–0.005	0.114
W_Fzag	0.00*	0.00*	0.00*	0.002	0.00*	0.003	0.00*	–0.00*	0.00*	0.00*	–0.00*	0.00*
W_BiR	–0.001	–0.002	0.00*	–0.014	–0.024	–0.004	–0.00*	–0.001	0.001	0.00*	–0.00*	0.001
W_PKB	–0.00*	–0.00*	–0.00*	0.00*	–0.00*	0.00*	–0.00*	–0.00*	–0.00*	–0.00*	–0.00*	0.00*

Explanation of symbols: * – very small values after the decimal point, which after rounding are invisible in the table. Par. – Parameter, Low. – lower confidence interval, Upp. – upper confidence interval.

Source: own elaboration.

The high percentage of first-level studies in the total number of studies offered as well as the number of cities in the province have a positive effect on the efficiency and number of graduates in public universities (Model A). The number of companies with foreign capital had an insignificant positive effect on efficiency in private and public universities. The location of the province in the country (public university) and the level of socio-economic development (private university) had a negative impact on the efficiency of the university and the number of graduates. This means that educational centres in some regions of the country have an advantage because of their location, which makes it easier for them to achieve a higher level of efficiency in relation to less well-located units. A high number of NEET also adversely affects efficiency in terms of the number of private university graduates. The high proportion of people who are not working or attending school has a negative overall impact on society by lowering the desire for self-development. The level of regional prosperity also negatively affects the efficiency of public universities with respect to the number of graduates. This may also indicate that the labour market is oversaturated with people with a higher education, while qualifications obtained at a higher education institution are not required for the available work.

The high proportion of practical studies in the total number of studies offered and a large number of companies with foreign capital have a positive effect on the efficiency of non-public universities in terms of the number of graduates. However, some variables (number of NEET and R&D expenditures per capita) negatively affect the efficiency of private universities and the number of graduates they produce. This last variable may indicate that people who study part time on weekends and work during the week raise their qualifications to excel in their current job, which typically does not require creativity and innovation but only involves performance of standard tasks.

The level of earnings among graduates from public institutions (Model B) is adversely affected by the high percentage of part-time studies and longer distance from the provincial capital, where it is more difficult to find a job as well as by the size of GDP per capita. This may suggest that the wealth of the province does not translate significantly into the earnings of graduates in relation to people who do not have a higher education. The earnings of non-public university graduates are positively influenced by the high proportion (percentage) of part-time studies, which confirms that people who already work professionally raise their qualifications in order to advance in their career and secure a higher salary.

A large number of cities in the province had a positive effect on the performance of private institutions, which implies that private institutions provide better educational opportunities to students and react faster to the needs of employers. The positive impact of this variable was in evidence even in smaller cities. The variable identifying a province's location also had a positive effect on the resource efficiency of non-public university graduates. This may indicate that non-public universities exist only where they are needed, unlike their public counterparts. The distance from the provincial capital also had a positive effect on the level of earnings, which may indicate that there is a smaller number of highly qualified personnel available in the local labour market.

Conclusions

This study takes a different research approach than most previous studies described in the literature. First, the efficiency of higher education institutions was measured separately in terms of the number of graduates and their salaries. Second, determinants influencing these two efficiency indicators were estimated separately. Third, unlike in most previous analyses, non-public higher education institutions were included in the study. The following conclusions can be drawn from the conducted analysis. Private institutions achieved a higher level of efficiency for graduate earnings than the number of graduates, while public institutions showed the opposite effect. However, the average difference between the efficiency of Models A and B at public universities (0.14) was greater than at non-public universities (0.01). Based on the standard deviation of the efficiency level, it can be stated that the differentiation of public universities between Model A (standard deviation of 0.15) and Model B (standard deviation of 0.13) is smaller than in the case of non-public universities, standing at 0.20 and 0.09 respectively. Efficiency in terms of the number of graduates was affected by the year in which the university was founded, a high percentage of first-level courses in the total number of studies, a high level of practical studies, the number of cities in the province, the location of the university, the number of NEET and companies with foreign capital, R&D expenditures per capita, and the size of GDP per capita. The level of efficiency for earnings was affected by a high percentage of part-time studies in the total number of studies conducted, the size of GDP per capita, the number of cities in the province, the location of the university, and the distance to the provincial capital. Both public and private higher education institutions, when preparing an educational offering for students, should pay more attention to the development of graduates' professional careers as reflected in the ELA system and look for other data sources to illustrate socio-economic needs in Poland and beyond. As Urbanek [2020] indicates, institutions with a high academic prestige are reluctant to implement new solutions or make any changes, which puts them in a worse position vis-à-vis institutions that are willing to change. Meanwhile, changes are both expected by the external environment and supported by the Polish Ministry of Science and Higher Education [Urbanek, 2020].

Future research will be directed at a comparative study of the two-stage analysis of the Simar and Wilson [2007] double bootstrap procedure with robust conditional estimators based on order-m frontiers [Cazals, Florens, Simar, 2002] or the α-order approach [Daouia, Simar 2007] using, for example, a procedure proposed by Bădin, Daraio and Simar [2012] or that developed by De Witte and Kortelainen [2013] to make a comprehensive assessment of the impact of environmental variables on the efficiency of higher education.

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Appendix

Table Z1. List of public universities researched

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, Szczecin
P20	Warsaw University of Technology
P21	Białystok University of Technology
P22	University of Bielsko-Biała

DMU	Name
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
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
P59	Christian Theological Academy in Warsaw

Source: own elaboration.

Table Z2. List of private universities accepted for the survey

DMU	Name
N1	Academy of Humanities Aleksander Gieysztor in Pułtusk
N2	University of Humanities and Economics in Łódź
N3	Koźmiński University in Warsaw
N4	ALMAMER College
N5	Ateneum – University in Gdańsk
N6	Gdańsk University of Humanities in Gdańsk
N7	Katowice School of Economics
N8	University of Humanities and Economics in Włocławek
N9	Kujawy and Pomorze University in Bydgoszcz
N10	Polish-Japanese Academy of Information Technology
N11	SWPS University of Social Sciences and Humanities
N12	Maria Skłodowska-Curie University of Warsaw
N13	Warsaw School of Computer Science
N14	Holy Cross University in Kielce
N15	Gdańsk School of Banking
N16	Poznań School of Banking
N17	Toruń School of Banking
N18	Wrocław School of Banking
N19	Wyższa Szkoła Biznesu – National-Louis University
N20	Academy of Business in Dąbrowa Górnicza
N21	University of Ecology and Management in Warsaw
N22	Białystok School of Economics
N23	University of Economics and Innovation
N24	Bielsko-Biała School of Finances of Law
N25	University of Finance and Management in Białystok
N26	University of Economy in Bydgoszcz
N27	University of Business in Wrocław
N28	Academy of Hospitality and Catering in Poznań
N29	University of Information Technology and Management in Rzeszów
N30	Warsaw Management Academy
N31	College of Enterprise and Administration in Lublin
N32	Katowice School of Technology
N33	University of Management and Administration in Zamość
N34	School of Management and Banking in Kraków

Source: own elaboration.