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Efficiency of the research and development activities of technical universities in Poland

Introduction

In the modern globalised knowledge-based economy, economic growth and development have been determined for more than thirty years now by knowledge creation and diffusion, and by use of research results and research and development efforts (R&D). Together with human capital, these have become the most important production factors. These have also been expressed in endogenous models of economic growth based on R&D activity and human capital. Such models were authored by Romer (1990a; 1990b), Jones (1995), Eicher and Turnovsky (1999) and Aghion and Howitt (1992; 1999). Despite certain differences, the models suggest that technical and organisational progress, and consequently innovation-based economic growth, arise from the accumulation of knowledge in the economy (created by human capital and R&D capital). This is confirmed by study results not only for highly developed countries but also for countries characterised by a low level of innovation (Cioacă, Nedelcu, 2015).

As Czerniak (2013) points out, R&D expenditure, along with its size and structure by entity and type, represents one of the most important factors determining the innovativeness of an economy. It makes it possible to reduce the

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technology gap in respect of the most innovative countries (innovation leaders) and to maintain a strong position in terms of R&D in the knowledge-based economy. Research and development is an essential element for the creation of innovation, and it additionally makes it possible to acquire and use new knowledge from the outside at the micro- and macroeconomic levels (Prodan, 2005).

Knowledge is gathered, developed and used as society increases spending on science, the R&D sector and education. This is fostered by proper socioeconomic policy, cultural and social mentality (including tolerance and openness to new ideas) oriented towards entrepreneurship and innovation, as well as by cooperation using well-developed intellectual and social capital (Florczak, 2009; 2013). In line with those assumptions, the basis for innovative and competitive achievements and economies are: research and development, technology transfer, technology diffusion, and creation of new solutions (with secured permanent acceleration of the economic growth dynamic due to non-decreasing capital productivity). The results of studies by Spencer (2001), Mok (2005), Kodama (2008) and Khalozadeh *et al.* (2011) confirm that in order to support these processes, universities must be engaged in the creation of strong multilateral ties between science and business and in knowledge and technology transfer from scientific and R&D institutions to the industry.

According to Kuna-Marszałek and Lisowska (2013), "social and economic growth largely depends on the level and quality of research and development activity and on the extent to which the results of this activity are used to drive the economy" (Kuna-Marszałek, Lisowska, 2013, p. 31). In this context, important drivers include not only public and private spending on research and development in the economy but also the ability of the economy to effectively utilise such spending to create knowledge and technology, and to transfer such knowledge and technology to the economy. Analysis of innovation rankings for various countries and the details of the created synthetic measures of innovation (e.g. the summary innovation indices (SII) in the ranking of European Innovation Scoreboard (EIS)) reveal the importance of the size and structure of R&D expenditure, having attractive open R&D systems and ties between science and industry for the values of the respective measures and for the position of each country in the ranking (*European Innovation Scoreboard*, 2019).

In Poland, R&D activity is pursued by various entities from the R&D sector. These include technical state universities, which formed the subject of the studies for this paper. The 21st century assumption is that they should act as third-generation universities (entrepreneurial universities) and, in addition to their basic tasks connected with education and research, they should also commercialise knowledge, i.e. reduce specific technical or organisational knowledge and the related know-how to practice. At the same time they are expected to build strong ties with business entities, including industrial enterprises (Wissema, 2005; Szmal, 2012; Nowacki, 2013). Their R&D activity may take the form of basic research (experimental or theoretical work), industrial research (former applied research) and, within academic entrepreneurship, in a way also developmental research. The use of the work results of scientists from technical universities is, in addition to accumulating new knowledge, also in developing innovations (process, product or service innovations), either on their own or in collaboration with enterprises, or in substantial modernising of the existing solutions. The R&D spending of these universities (coming primarily from public funds but also increasingly subsidised by the private sector) should lead to results evaluated based on the measures of the effect and impact of the technology transfer processes (Seppo, Lilles, 2012; Wunsch-Vincent, 2012). The efficiency of the R&D activity of universities may show how far they have implemented the concept of an entrepreneurial university. This efficiency is measured using various methods (Rutkowska, 2013). One of them is Data Envelopment Analysis (DEA) – a non-parametric method for assessing relative efficiency.

The purpose of the paper is to use the DEA method to measure the R&D efficiency of technical state universities. The added value of the paper is the application of an output-oriented dynamic SBM model for that purpose, with variable returns to scale (Tone, Tsutsui, 2010).

Literature overview

The research overview performed by De Witte and López-Torres (2017) suggests that the educational sphere, in a broad sense of the term, including universities, is usually analysed using the non-parametric DEA method. Liu *et al.* (2013) claim that education is one of the five most often analysed research areas within the DEA methodology. It must be noted that the studies focus mainly on the teaching activity of universities rather than their R&D activity. Even analyses of the R&D activity focus mostly on the theoretical aspect of it, i.e. scientific publications or the awarded research grants, and much less on practical results having the potential to be implemented in economic practice, such as patents for example.

Anderson, Daim and Lavoie (2007) examined the efficiency of technology transfer to economic practice by adopting the following as data: income and number of licences, number of start-ups, patent applications and registrations, and total spending on research. Similar studies regarding knowledge transfer and research were conducted by Berbegal-Mirabent (2018), who analysed R&D spending and the number of employees, research projects and publications. Some authors simultaneously use data from various areas of university activities. One example of such an approach includes research by Chuanyi, Xiaohong, and Shikui (2016), who analysed the number of conferred master's degrees, doctoral degrees, the number of publications and patents. Flegg *et al.* (2004) focused on the income from research activity and the number of conferred bachelor's, master's and doctoral degrees. Leitner *et al.* (2007) used the following data: the number of publications and monographs, patents and income from external sources. Yang, Fukuyama and Song (2018) analysed the value of the funds allocated for R&D, the value of the public funding for universities, the number of patents, publications, students, people working on R&D projects and the value of revenue from the sale of patents. So far in Poland only Wolszczak-Derlacz (2013) have analysed the implementation efficiency of universities, based on the following variables: number of patent applications and registrations, number of university professors and total revenue. The analysis by Wolszczak-Derlacz (2013) covered the 2001–2008 period. Several system changes have been introduced to the higher education and science sector since then, which is why the R&D activity of universities should be studied based on more recent data.

Research methodology

In order to properly conduct the empirical study, first the scope of the R&D activities of universities as regulated in legislation was characterised. The Polish Higher Education Act (Obwieszczenie Marszałka…, 2017) states, first, that a university has the right to conduct scientific research and development work and to define their directions, and, second, that a university's basic tasks are to conduct research and development works, provide research services and transfer knowledge to the economy.

Research and development activity is defined in the Polish Act on Science Financing Rules (Obwieszczenie Marszałka.., 2018), after Fascarti Manual 2015 (2018), as a creative activity that includes research or development works undertaken systematically in order to increase knowledge transfers and use knowledge resources for new applications. The act (Obwieszczenie Marszałka.., 2018) defines research and divides it into:

a) basic research – original research, experimental or theoretical works undertaken primarily in order to gain new knowledge about the bases of certain phenomena and observable facts without focusing on direct commercial applications,
b) applied research – research works undertaken to gain new knowledge, oriented primarily towards practical applications,
c) industrial research – research to gain new knowledge and skills in order to develop new products, processes and services or make significant improvements to the products, processes and services; the research takes into account the creation of new components of complex systems, construction of prototypes in a laboratory environment or in an environment simulating the existing systems, especially to assess the usefulness of particular types of technology, and construction of the pilot lines necessary for those studies, also in order to obtain evidence in the case of generic technologies.

Furthermore, the aforesaid Act also defines the scope of development works, which is: acquiring, merging, shaping and using the currently available knowledge and skills in the area of science, technology and business activity as well as other knowledge and skills to plan production and create and design new, modified or improved products, processes and services, except for works that involve routine and periodic changes in products, production lines, manufacturing processes, existing services and other operations in progress, even if such changes have the nature of improvements.

The study focuses on the practical aspects of R&D activity that influence the economic sphere and the innovation level of the country. As a result, the studied entities were selected through purposive sampling to make sure they best reflect the R&D activity of universities. Two main criteria were taken into account. In the first place, the DEA method requires a relatively homogeneous set of entities. In the second place, the nature and scope of the R&D activity must be considered – it needs to be continuous, which should show that this type of activity is important for the university and allows it to regularly derive effects from the R&D activity. Furthermore, it has to be possible to present the research results for more than one year. The study encompasses a homogeneous group of 14 out of 18 technical universities (Table 1), excluding Gdańsk University of Technology, Częstochowa University of Technology, Kielce University of Technology and Koszalin University of Technology, due to a lack of data.

Table 1. Technical universities covered by the study

DMU	Name of university
U1	West Pomeranian University of Technology in Szczecin
U2	Warsaw University of Technology
U3	Białystok University of Technology
U4	University of Bielsko-Biała
U5	Silesian University of Technology
U6	Tadeusz Kościuszko University of Technology
U7	AGH University of Science and Technology
U8	Lublin University of Technology
U9	Łódź University of Technology
U10	Opole University of Technology
U11	Poznań University of Technology
U12	Kazimierz Pułaski University of Technology and Humanities
U13	Rzeszów University of Technology
U14	Wrocław University of Technology

Source: own study.

The universities used for the study were assigned the following variables: U1–U14. In order to analyse only the practical dimension of the R&D activity, the basic research pursued by the technical universities was left out.

Note that the process of securing legal protection for a new solution (invention, utility model etc.) consists of two main stages. During the first one, the entity files an application for the new solution to the Patent Office, and then, following a positive verification by the Patent Office, it receives a patent. In view of the above, the analysis encompasses the R&D activity of universities in these two areas. This is why two corresponding empirical models were adopted. The first model (M1) applies to the activity of universities in the registration of new solutions, while the second one (M2) includes only patent-secured solutions that can be used in business practice.

The output adopted for M1 is the total number of patent applications (number of applications filed by the university with the Polish patent office and the number of invention applications filed with foreign patent offices) – Y_1. The output for M2 is the total number of patent registrations (number of patents secured with the Polish patent office and the number of patents secured with foreign patent offices) – Y_2. The data used in the empirical study comes from reports on the R&D activities of universities (PNT-01/s) obtained as a result of applying to state universities for access to public information. In order to preserve data consistency in the years under analysis, data for the period from 2015 to 2017 were used. The adopted research period is directly connected with the EU funds available within the current 2014–2020 Financial Framework. At this point it should be noted that, according to the data provided by the Polish Ministry of Science and Higher Education (RAD-on, 2020), the share of EU funds in the total funds awarded to and used by universities for scientific projects differed for particular years. The largest share, of over 35% was recorded in 2015, in the next year it was only 10%, and in 2017 more than 15%. Nonetheless, such funds represent one of the four main sources of financing for scientific projects. Furthermore, the selection of the years 2015–2017 as the studied period makes it possible to illustrate the situation following the system transformations implemented in 2011 and 2014 but preceding the current higher education and science reform enacted in 2018.

Data for several years permit the analysis of the changes taking place in time based on the DEA methodology, which offers several measurement approaches, such as window analysis or the Malmquist index. Yet, all the models have their limitations. First of all, they fail to take into account inter-period data which may be transferred between periods or which may affect subsequent periods. Secondly, they focus on separate efficiency estimations for periods which are independent of each other (Tone, Tsutsui, 2010). It must also be noted that the process of investment planning and implementation within the R&D activity often extends beyond one specific year, which results in resources being carried forward over the whole investment period and thus changing the figures for subsequent years. This is why the standard models available within the DEA methodology, which involve measurement in one period on a statistical basis (e.g. CCR, BCC, SBM and other), and the two already mentioned models are not suitable for the R&D

activity. These shortcomings are addressed by dynamic DEA models, which take into consideration both inter-period variables and long-term measurements, and account for the interdependencies between particular years. Tone and Tsutsui (2010) suggested a dynamic SBM model (Figure 1) which meets the above criteria, and this was the model chosen for the present empirical study.

The advantage of a dynamic SBM model is the possibility of estimating efficiency for specific years, as well the general, total efficiency in the whole period under analysis, which is crucial from the perspective of long-term planning of innovative investments.

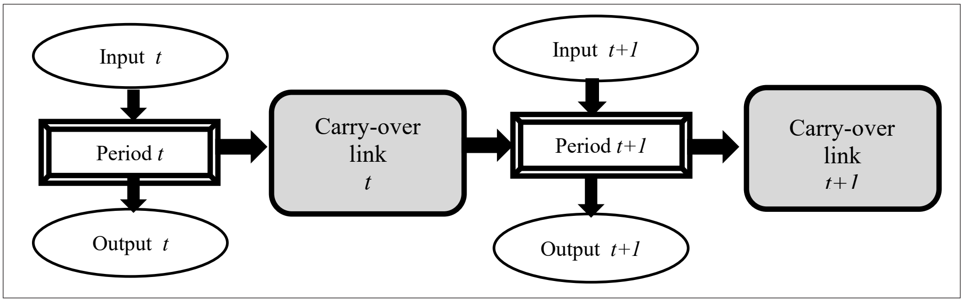

Figure 1. Structure of the dynamic SBM model

Source: Tone and Tsutsui (2010).

Individual years of an R&D investment are linked through the financial resources allocated for that purpose, which is why the current and investment outlays for applied research, industrial research and development works have been adopted as the carry-over links ($C\text{-}OL_1$) for the subsequent years covered by the study. In the case of outlays, the number of people engaged in the university's R&D activity (X_1) has been captured in two empirical models (M1, M2). This resource represents the intellectual potential of the entity without which it is impossible to create new solutions. Table 2 presents the variables assigned to particular empirical models. Table 3 presents selected descriptive characteristics of the variables.

Table 2. Variables adopted for efficiency testing in empirical models

Variable	Model of activity M1	Model of implementation M2
X_1 – number of people engaged in the R&D activity	+	+
$C\text{-}OL_1$ – total current and investment expenditure on applied research, industrial research and development works	+	+
Y_1 – total number of patent applications	+	–
Y_2 – total number of patent registrations	–	+

Source: own study.

Table 3. Descriptive characteristics of the variables adopted for the study

Years	Characteristic	Variables			
		X_1	$C\text{-}OL_1$	Y_1	Y_2
2015	Min.	262	1563	1	1
	Mean	1135	59237	81	39
	Max.	2431	237626	232	88
	SD	712	76252	71	33
2016	Min.	270	1433	1	2
	Mean	1156	35032	63	58
	Max.	2548	110153	118	145
	SD	748	36017	39	44
2017	Min.	281	1382	1	2
	Mean	1169	38220	59	50
	Max.	2547	129519	108	116
	SD	770	40302	39	38

Source: own study.

The DEA model is used to establish technical efficiency. It means either achieving as high a production level as possible with the current expenditure or a specific level of production with expenditure as low as possible (Prędki, 2012). Its estimation requires defining the model orientation and the returns to scale. The purpose of universities within their R&D activity is to maximise outputs (generate the largest number of applications and patents) rather than to minimise the resources. This is why the DEA model is output-oriented, with maximisation of the activity outputs for specific expenditure. The relevant literature (Cooperet et al., 2007) notes that if diverse, non-ratio data are used, a model with variable returns to scale should be implemented. In connection with the above, the empirical study was ultimately conducted based on an output-oriented dynamic SBM model with variable returns to scale (Dynamic SBM-V-O).

Study results and their interpretation

The average level of total efficiency (2015–2017 period) in M1 regarding the patent application activity was 65%, and in M2 for patent registration it was 55%. In turn, average efficiencies in particular years of the analysis were higher than the average total efficiencies (except for the 2015 efficiency calculated with M1 data). In the subsequent years (2015–2017) they were 58%, 72% and 72% respectively for M1 and 58%, 59% and 61% for M2. The results point to the low R&D efficiency of universities. Figure 2 presents the efficiency results for M1. Only four universities achieved a 100% efficiency in the analysed period. These were the following: West Pomeranian University of Technology in Szczecin (U1), University of Bielsko-Biała (U4), Lublin University of Technology (U8) and Wrocław University of Science and Technology (U14).

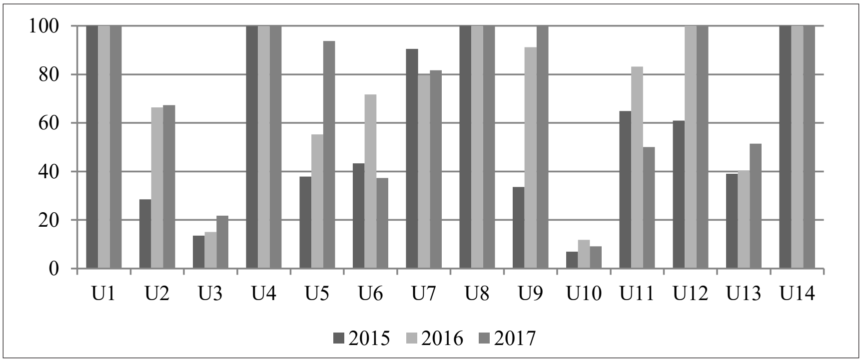

Figure 2. Efficiency in M1

Source: own study.

This shows that the universities are committed to continuing the registration of new solutions and that the situation of the entities is stable, regardless of changes in the environment and in other entities. The lowest efficiencies in the 2015–2017 period were achieved by Opole University of Technology (U10) and Białystok University of Technology (U3). For six universities, the efficiency continued to increase in 2016 and 2017 versus 2015. For three universities, the efficiency dropped in 2017 versus 2015. For two universities the ratio grew in 2017 versus 2015 to the full efficiency level (100%). These were Łódź University of Technology (U9) and Pulaski University of Technology and Humanities (U2). This shows that these technical universities improved their R&D efficiency in terms of patent applications.

A different picture of university efficiency was obtained in M2, with the results presented in Figure 3. Only three universities achieved a full 100% efficiency in the period, i.e.: University of Bielsko-Biała (U4), AGH University of Science and Technology (U7) and Lublin University of Technology (U8).

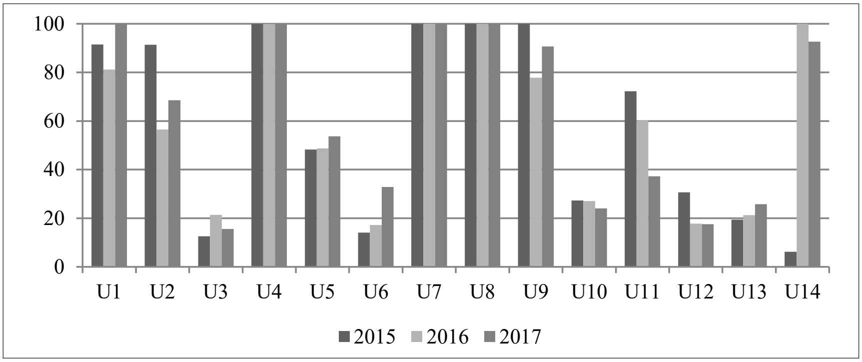

Figure 3. Efficiency in M2

Source: own study.

As many as five universities had low efficiency (below 50%) in the 2015–2017 period. Two universities achieved a 100% efficiency in one of the periods but then recorded an efficiency drop in the subsequent year. These were: Łódź University of Technology (U9) and Wrocław University of Science and Technology (U14). For three universities, i.e. West Pomeranian University of Technology in Szczecin (U1), Warsaw University of Technology (U2) and Łódź University of Technology (U9), an interesting phenomenon was observed – an abrupt drop in efficiency in 2016 with higher efficiency in the remaining years. The situation was opposite for Białystok University of Technology (U3), with an abrupt efficiency increase in 2016 versus 2015 and 2017. A constant efficiency growth trend was observed in the period for the Silesian University of Technology (U5), Cracow University of Technology (U6) and Rzeszów University of Technology (U13). A constant R&D efficiency drop was recorded for Opole University of Technology (U10) and Poznań University of Technology (U11).

Efficiency evaluation requires considering the activity of the universities in the long term due to the extended (often longer than one calendar year) creative process within R&D and the lengthy process of legally securing new solutions. Figure 4 presents benchmarking between total efficiency ratios from the 2015–2017 period in M1 and M2. The correlation coefficient between total efficiency in the M1 and M2 models was moderate – 0.56. This means that the R&D efficiency of universities in terms of patent applications only partially translates to patent registration efficiency. The total efficiency results presented in Figure 4 point to the presence of three efficiency groups, differing from one another.

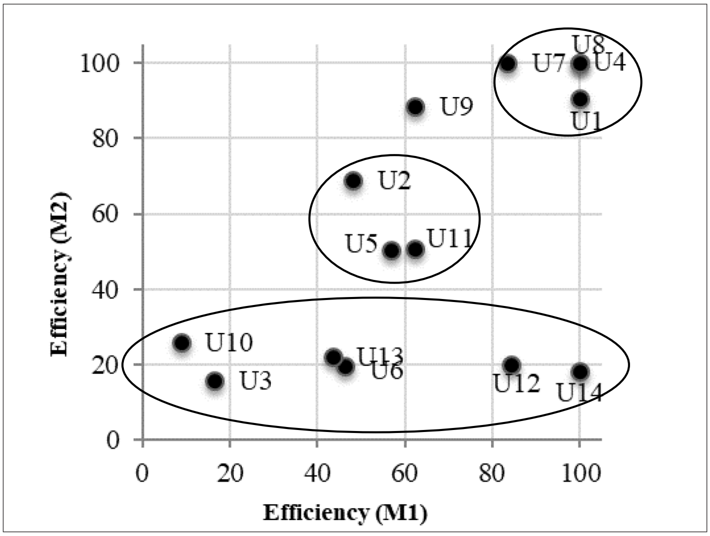

Figure 4. Benchmarking of total efficiency in M1 and M2

Source: own study.

Group one is characterised by the lowest efficiency in M2 but by dispersed efficiency in M1. Group two has similar figures for both empirical models. Group three includes the highest efficiency levels in M1 and M2, with slight deviations in these two units. The latter means that these universities both file more patent applications, with higher expenditure for that purpose, and they secure more patent registrations than other universities. This also shows that the R&D activity of the universities is stable and that they have prepared the right conditions for the continuous creation of new solutions.

The lowest total R&D efficiency for both models was achieved by Białystok University of Technology (U3) and the highest concurrently by the University of Bielsko-Biała (U4) and Lublin University of Technology (U8). Notably, the efficiency ratio of Łódź University of Technology (U9) is between the groups with the medium and the highest efficiency, which may suggest that the entity is committed to achieving better R&D results and joining the top group. Two pairs of universities, i.e. the Silesian University of Technology (U5) plus Poznań University of Technology (U11) and Cracow University of Technology (U6) plus Rzeszów University of Technology (U13), were observed to have highly similar results, at least for one empirical model. This may suggest that the entities treat each other as reference points for R&D resources and research.

At the end of the study, the DEA efficiency results were cross-referenced with the average level of expenditure of particular units (Figure 5). After all, entities may be efficient whether their potential is high or low. Such an approach makes it possible to identify "strong" entities, i.e. ones that are characterised by a high R&D potential and are efficient at the same time.

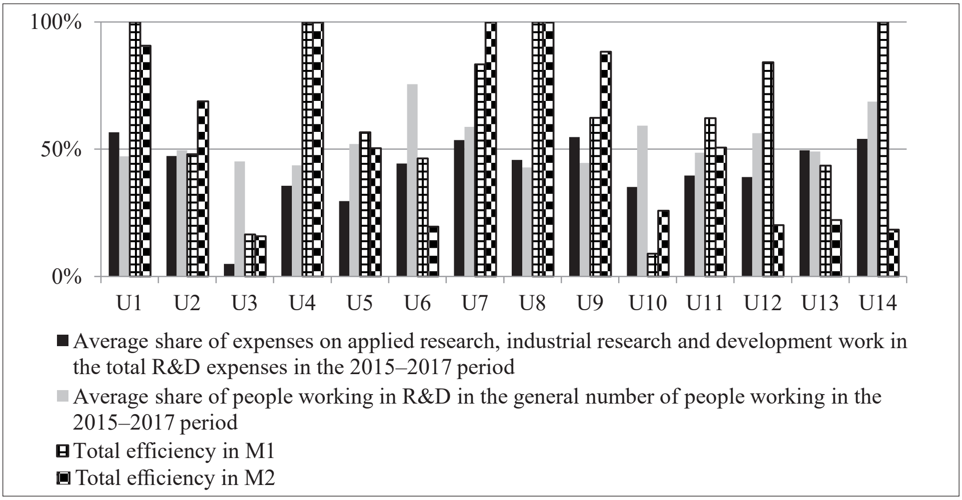

Figure 5. Benchmarking of total efficiency in M1 and M2 with average levels of expenditure

Source: own study.

The study results show that the following entities are efficient at least in one model and are characterised by an above-average R&D potential: AGH University of Science and Technology (U7) and Wrocław University of Science and Technology (U14). In the 2015–2017 period, the average share of those working in R&D in the total number of employees was 53%, and the share of expenditure on applied research, industrial research and development works in the total R&D expenditure was 42%. However, one must not forget that the study only applied to the analysis of applied research, industrial research and development works, which represented a minor part of the total expenditure allocated by universities for R&D in the 2015–2017 period. This was on average 47% (2015), 43% (2016) and 36% (2017). It must be noted that total R&D expenditure was characterised by abrupt variability, their mean value for the years in question being: PLN 188,593,800 (2015), PLN 121,273,700 (2016) and PLN 167,268,000 (2017). The average share of current expenditure in total R&D expenditure grew year-on-year, at 66% (2015), 84% (2016) and 90% (2017).

The types of R&D activity analysed in this paper are significant due to the results of the expenditure in the form of patent applications and patent registrations. They undoubtedly represent the contribution of technical universities to improving the innovativeness not only for higher education schools but for the whole economy as well. They may also be used by industrial and service enterprises as ready product or process innovations; once launched in the market, they may be used by enterprises in a given sector to prepare new solutions and, through diffusion of innovation, they may stimulate the emergence of inter-sectoral innovations. A technical university may benefit from a higher R&D efficiency by selling its intellectual property rights (e.g. a patent, know-how). Such efficiency has a positive impact on the competitive position of such an entity on the market of research universities, and it improves its teaching possibilities. Considering the presented advantages of a high R&D efficiency for universities, it is rather disconcerting that the share of expenditure for that purpose in the total structure of R&D expenditure was reduced in the period under study.

Conclusions

The paper measures the R&D efficiency of 14 of the 18 state universities of technology in Poland for the 2015–2017 period. The study used data from GUS (Statistics Poland) reports on the R&D activities of universities. The efficiency was measured using the DEA method, with a dynamic SBM model. The model made it possible to simultaneously define the R&D efficiency for particular years and the total efficiency for the whole analysed period. The results of that assessment in the case of the activity model (M1) indicate low R&D efficiency of technical universities as measured by the maximisation of their patent applications for a specific level of expenditure (people working in R&D and total current and investment expenditure on applied research, industrial research and development works). Only four universities achieved the maximum efficiency of 100% in the period under study (U1, U4, U8 and U14). The efficiency of the remaining studied entities was lower, with particularly low efficiency levels (10–20%) identified for two universities (U3 and U10). It can also be noticed that the 2015–2017 period witnessed a positive growth trend for average efficiency measures in the M1 model – with efficiency increasing from 58% to 72%. This was a result of improved values for that ratio for the majority of the studied universities in that period.

Considering another aspect of the R&D activity, i.e. successful registration of patents for inventions in the M2 efficiency assessment model, it can be noticed that only three universities achieved a 100% efficiency in terms of implementations (patent registrations) in the whole period under study (U4, U7, U8). Two of them were from the group of universities with the highest efficiency in M1. This points to a moderate correlation between patent application efficiency and patent registration efficiency. For this measure of efficiency, the average results for particular years exhibited a growth trend, at 58%, 59% and 61% respectively.

Assessment of total efficiency in M1 and M2 leads to the conclusion that only four technical universities achieved the highest efficiency in the 2015–2017 period in terms of both models (activity and implementations), and one university exhibited a commitment to achieving the best results possible and joining the top universities. Unfortunately, a major part of the studied universities (U3, U6, U10, U12, U13, U14) had very low total efficiency. The situation differed for particular universities – some had low efficiency in patent applications and in patent registrations, others were quite successful in applications, but their patent registration efficiency was very low.

The presented study results show that technical state universities have to face many challenges if they want to improve their R&D efficiency. Expenditure for that purpose should increase both total and partial efficiency in terms of activities and implementations in the majority of the studied entities. The number of technical universities with lower efficiency should continue to drop. The relevant literature and the experience of highly developed countries show that improving the R&D efficiency of universities is conducive to establishing powerful and lasting relations between R&D units and enterprises. This is why future directions of study should include an efficiency assessment of the ties between the R&D units of Polish universities and industry in terms of joint patents, joint publications, and membership in industrial clusters. Collaboration between science and the economy in this area should help improve the efficiency of R&D expenditure, increase the innovation ratios of the country, address Poland's limitations in achieving better results in the EIS rankings and also eliminate the technology gap and accelerate economic growth and development.

Bibliography

Aghion, Ph., Howitt, P. (1992). A Model of Growth through Creative Destruction. *Econometrica*, *60/2*, 323–351. DOI:10.2307/2951599.

Aghion, Ph., Howitt, P. (1999). *Endogenous Growth Theory*. London: MIT Press.

Anderson, T. R., Daim, T. U., Lavoie, F. F. (2007). Measuring the efficiency of university technology transfer. *Technovation*, *27*, 306–318. DOI: 10.1016/j.technovation.2006.10.003.

Berbegal-Mirabent, J. (2018). The influence of regulatory frameworks on research and knowledge transfer outputs: An efficiency analysis of Spanish public universities. *Journal of Engineering and Technology Management*, *47*, 68–80. DOI: 10.1016/j.jengtecman.2018.01.003.

Chuanyi, W., Xiaohong, L., Shikui, Z. (2016). The Relative Efficiencies of Research Universities of Science and Technology in China: Based on the Data Envelopment Analysis and Stochastic Frontier Analysis. *Eurasia Journal of Mathematics, Science and Technology Education*, *12*(10), 2753–2770. DOI: 10.12973/eurasia.2016.02302a.

Cioacă, S., Nedelcu, A. C. (2015). R&D activities' impact on economic growth: case study on Romania. *International Journal of Education and Research, 3*(3), 569–578.

Cooper, W. W., Seiford, L. M., Tone, K. (2007). *Data Envelopment Analysis. A Comprehensive Text with Models, Applications, References and DEA-Solver Software*. New York: Springer. DOI: 10.1007/978-0-387-45283-8.

Czerniak, J. (2013). *Polityka innowacyjna w Polsce. Analiza i proponowane kierunki zmian*. Warszawa: Difin.

De Witte, K., López-Torres, L. (2017). Efficiency in education: a review of literature and a way forward. *Journal of the Operational Research Society*, *68*(4), 339–363. DOI: 10.1057/jors.2015.92.

Eicher, T. S., Turnovsky, S. J. (1999). Non-scale models of economic growth. *Economic Journal*, *109*, 349–415. DOI: 10.1111/1468-0297.00454.

European Innovation Scoreboard (2019). Luxembourg: European Commission. Retrieved from: https://ec.europa.eu/docsroom/documents/38781 (2020.11.04).

Flegg, A. T., Allen, D. O., Field, K., Thurlow, T. W. (2004). Measuring the efficiency of British universities: a multi-period data envelopment analysis. *Education Economics*, *12*, 231–249. DOI: 10.1080/0904529042000258590.

Florczak, W. (2009). Koncepcja wzrostu endogenicznego i gospodarki opartej na wiedzy w naukach ekonomicznych. *Studia Prawno-Ekonomiczne*, LXXX, 215–239.

Florczak, W. (2013). Modelowanie zrównoważonego rozwoju w makroekonomicznych modelach gospodarki Polski. *Acta Universitatis Lodzienzis Folia Oeconomica*, *294,* 319–369.

Jones, C. (1995). R&D Based Models of Economic Growth. *Journal of Political Economy*, *103*(4), 759–784. DOI: 10.1086/262002.

Khalozadeh, F., Kazemi, S. A., Movahedi, M., Jandaghi, G. (2011). Reengineering University – Industry Interactions: Knowledge–based Technology Transfer Model. *European Journal of Economics, Finance and Administrative Sciences, 40*, 47–58.

Kodama, T. (2008). The role of intermediation and absorptive capacity in facilitating University-industry linkages an empirical study of TAMA in Japan. *Research Policy, 37*(8), 1224–1240. DOI: 10.1016/j.respol.2008.04.014.

Kuna-Marszałek, A., Lisowska, R. (2013). Działalność badawczo-rozwojowa jednostek naukowych i badawczo-rozwojowych w regionie łódzkim. *Studia Prawno-Ekonomiczne*, t. LC, 29–46.

Leitner, K.-H., Prikoszovits, J., Schaffhauser-Linzatti, M., Stowasser, R., Wagner, K. (2007). The impact of size and specialisation on universities' department performance: a DEA anal sis applied to Austrian universities. *Higher Education*, *53*, 517–538. DOI: 10.1007/s10734-006-0002-9.

Liu, J. S., Lu, L. Y. Y., Lu, W-M., Lin, B. J. Y. (2013). A survey of DEA applications. *Omega, 41*, 893–902. DOI: 10.1016/j.omega.2012.11.004.

Mok, K. H. (2005). Globalization and educational restructuring. University merging and changing governance in China. *Higher University*, *50*, 57–88. DOI: 10.1007/s10734-004-6347-z.

Nowacki, F. (2013). Aktywność przedsiębiorcza uniwersytetu trzeciej generacji – uniwersytet czy przedsiębiorstwo. In: D. Burawski (Ed.), *Uniwersytet trzeciej generacji. Stan i perspektywy rozwoju* (pp. 25–38). Poznań: Europejskie Centrum Wspierania Przedsiębiorczości.

Obwieszczenie Marszałka Sejmu Rzeczypospolitej Polskiej z dnia 30 października 2017 r. w sprawie ogłoszenia jednolitego tekstu ustawy – Prawo o szkolnictwie wyższym (DzU 2017 poz. 2183).

Obwieszczenie Marszałka Sejmu Rzeczypospolitej Polskiej z dnia 8 grudnia 2017 r. w sprawie ogłoszenia jednolitego tekstu ustawy o zasadach finansowania nauki (DzU 2018 poz. 87).

Podręcznik Frascati 2015. Zalecenia dotyczące pozyskiwania i prezentowania danych z zakresu działalności badawczo-rozwojowej. (2018). Warszawa: GUS.

RAD-on (2020). Projekty naukowe w wybranym roku. Retrieved from: https://radon.nauka.gov.pl/raporty/szkolnictwo-wyzsze-i-nauka (2020.11.04).

Prędki, A. (2012). Geneza zbiorów możliwości produkcyjnych wykorzystywanych w DEA. *Zeszyty Naukowe Uniwersytetu Ekonomicznego w Poznaniu*, *241*, 126–137.

Prodan, I. (2005). Influence of Research and Development Expenditures on Number of Patent Applications: Selected Case Studies in OECD Countries and Central Europe, 1981–2001. *Applied Econometrics and International Development*, *5–4*, 5–20.

Romer, P. (1990a). Endogenous technological change. *Journal of Political Economy*, *98*(5), 71–102.

Romer, P. M. (1990b). Human capital and growth: theory and evidence. *Carnegie Rochester Conference Series on Public Policy*, *32,* 251–286. DOI: 10.1016/0167-2231(90)90028-J.

Rutkowska, A. (2013), Teoretyczne aspekty efektywności – pojęcie i metody pomiaru. *Zarządzanie i Finanse*, *11*(1, 4), 439–453.

Seppo, M., Lilles, A. (2012). Indicators measuring university-industry cooperation. *Discussion on Estonian Policy*, *20*(1), 204–225. DOI: 10.15157/tpep.v20i1.782.

Spencer, J. W. (2001). How relevant is university-based scientific research to private high-technology firms? A United States – Japan comparison. *Academy of Management Journal*, *44*, 432–440. DOI: 10.2307/3069465.

Szmal, A. (2012). Identyfikacja dóbr intelektualnych podlegających komercjalizacji. *Zeszyty Naukowe Politechniki Śląskiej. Seria: Organizacja i Zarządzanie*, *60*, 321–333.

Tone, K., Tsutsui, M. (2010). Dynamic DEA: A slacks-based measure approach. *Omega, 38*, 145–156. DOI:10.1016/j.omega.2009.07.003.
Wissema, J. G. (2005). *Technostarterzy dlaczego i jak?* Warszawa: PARP.
Wolszczak-Derlacz, J. (2013). *Efektywność naukowa, dydaktyczna i wdrożeniowa publicznych szkół wyższych w Polsce – analiza nieparametryczna*. Gdańsk: Wydawnictwo Politechniki Gdańskiej.
Wunsch-Vincent, S. (2012). Accounting for science–industry collaboration in innovation: existing metrics and related challenges. In: S. Dutta (Ed.), *The Global Innovation Index 2012. Stronger innovation linkages for global world* (pp. 97–108). Fontainebleau: WIPO.
Yang, G.-L., Fukuyama, H., Song, Y.-Y. (2018). Measuring the inefficiency of Chinese research universities based on a two-stage network DEA model. *Journal of Informetrics*, *12*(1), 10–30. DOI: 10.1016/j.joi.2017.11.002.

Summary

In the 21st century knowledge-based economy, long-term economic growth and development depend on the ability to use the knowledge and technology so as to create product, process, organisational, marketing and even social innovations. The knowledge and technology, human resources and social capital (facilitating the transfer of technology from the world of science to the economy), comprise the most important production factors today. Research and development (R&D) activities are among the diverse determinants affecting the economy's ability to innovate. They are carried out by public technical universities. One of the tasks that these entities face is to conduct basic, industrial (applied) research and development works. Their results can then be transferred to industrial and service enterprises as novel solutions. Research and development activities of universities are financed mainly from public sources, which suggests the need to assess the efficiency of this task. This can be done with the use of various methods, e.g. the non-parametric DEA method.

The purpose of the paper is to measure the efficiency of research and development activities of public technical universities in Poland with the aid of the DEA method. The fourteen universities which in the years 2015–2017 reported to the Ministry of Science and Higher Education (MNiSW) were included in the study. The efficiency of the universities in filing new patent solutions and being granted patents was analysed. The results acquired indicate very low and low efficiency of most Polish technical universities. This is due both to a small number of patent applications and a small number of patents granted. In the examined period, the group of most efficient technical universities in both aspects comprised 4 to 5 universities.

Keywords: R&D, efficiency, universities, DEA.

Efektywność działalności badawczo-rozwojowej uczelni technicznych w Polsce

Streszczenie

W gospodarce XXI w. opartej na wiedzy, długookresowy wzrost i rozwój gospodarczy zależą od umiejętności wykorzystywania wiedzy i technologii do tworzenia innowacji produktowych, procesowych, organizacyjnych, marketingowych, a nawet społecznych. Wiedza i technologia, kapitał ludzki oraz społeczny (umożliwiający transfer technologii ze świata nauki do gospodarki), stanowią dziś najważniejsze czynniki wytwórcze. Wśród różnych determinant wpływających na zdolność gospodarki do innowacji znajduje się działalność badawczo-rozwojowa (B+R) realizowana przez publiczne szkoły wyższe, m.in. uczelnie techniczne. Jednym z zadań tych podmiotów jest prowadzenie badań podstawowych, przemysłowych (stosowanych) i prac rozwojowych. Ich rezultaty powinny trafiać do przedsiębiorstw przemysłowych i usługowych jako możliwe do wykorzystania nowe rozwiązania. Działalność badawczo-rozwojowa szkół wyższych jest finansowana głównie ze źródeł publicznych, co skłania do próby oceny efektywności wykonywania tego zadania. Można to zrealizować za pomocą różnych metod, np. nieparametrycznej metody DEA.

Celem artykułu jest pomiar za pomocą metody DEA efektywności działalności badawczo-rozwojowej publicznych uczelni technicznych w Polsce. Do badania przyjęto 14 uczelni, które podlegały w latach 2015–2017 Ministerstwu Nauki i Szkolnictwa Wyższego (MNiSW). Przeanalizowano efektywność szkół wyższych odnośnie do zgłaszania nowych rozwiązań patentowych oraz uzyskanych patentów. Uzyskane wyniki wskazują na bardzo niską i niską efektywność większości polskich szkół technicznych. Wynika to zarówno z małej liczby zgłoszeń patentowych, jak i małej liczby uzyskiwanych patentów. W badanym okresie grupa najbardziej efektywnych uczelni technicznych w obu aspektach liczyła jedynie 4–5 jednostek.

Słowa kluczowe: B+R, efektywność, szkoły wyższe, DEA.

JEL: O31, I21, I22, C14.