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THE IMPACT OF R&D EXPENDITURES ON BIOECONOMY INNOVATIVENESS

WPŁYW NAKŁADÓW NA DZIAŁALNOŚĆ B+R NA INNOWACYJNOŚĆ BIOGOSPODARKI

Key words: R&D expenditures, innovation, bioeconomy, biotechnology

Słowa kluczowe: nakłady na działalność B+R, innowacje, biogospodarka, biotechnologia

Abstract. The paper aims at empirical evaluation of the impact of R&D expenditures on the bioeconomy innovativeness. The research is based on the cross-sectional analyses of correlation and regression between the value of biotech R&D expenditures and the number of biotech patents granted in the EU countries. In particular, the study attempts to assess a relative effectiveness of R&D expenditures in public and business sectors. The data for the analysis were extracted from the OECD Statistical Database and Eurostat Database covering the period 2009-2014. Given the availability of data the examined sample covers 11 countries. The results indicate a positive and statistically significant impact of biotech R&D expenditures on bioeconomy innovativeness in the pooled sample of countries and suggest a higher effectiveness of private sources of funding.

Introduction

Contemporarily, bioeconomy starts to gain an ever growing importance as a sector of innovation-driven economy. According to OECD, bioeconomy is an economy where a significant share of economic output is created by biotechnology [*The Bioeconomy*… 2009, p. 19]. Biotechnology provides a stream of innovations that are needed to meet the global challenges connected with growing population, environmental pressure and rapid depletion of natural resources. It can increase the supply and environmental sustainability of food, feed, provide renewable energy, improve water quality and the health of people and animals, as well as help maintain biodiversity [*The Bioeconomy*… 2009, p. 20]. The significance of biotechnology is acknowledged in the main development policy document for Europe for forthcoming years – Europe 2020 Strategy, where bioeconomy is considered to be a key element for smart and green growth. The Strategy predicts that creation of biotechnology innovations should allow Europe to improve the management of its renewable biological resources and to open new and diversified markets in food and bio-based products [*Communication from the Commission*… 2012, p. 2]. The expected boosting of bioeconomy's innovative performance is heavily dependent on intensification of research and development (R&D) activities in the biotech sector, which requires bearing adequate expenditures.

The economic literature commonly asserts that creation of innovations is to the large extent determined by the R&D activities. A conjecture that R&D activity might be an impulse for innovations was formulated over half a century ago, and its positive verification was provided by numerous empirical investigations [see e.g. Artz et al. 2010, Matras-Bolibok 2008, Hall, Bagchi-Sen 2002, Jaffe 1989, Mansfield 1991]. It seems evident that the magnitude of the impact of R&D activities on the ability to generate innovations is dependent not only on the value of expenditures born in that purpose but also on the sources of funding. The funds for R&D activities might come from either the private business sector (domestic or foreign) or the public sector, including government agencies or universities. As most enterprises are profit-oriented it can be expected that their expenditures should be more efficient in terms of created innovations. It is worth to point out, however, that the public expenditures on R&D are equally important as they often induce the private activities in this area

[Clausen 2009]. The economic analyses on the impact of public financial support for innovations have not revealed the "crowding-out" effect between public and private spending [Hall, Maffioli 2008]. On the contrary, the absence of subsidies may in fact constrain some firms (mainly small and operating in low technology sectors) from engagement in R&D activities [Gonzàlez and Pazò 2008]. Public funding with a civilian objective actually has a positive effect on the elasticity of business R&D and is successful in enhancing business R&D with higher social returns [Guellec, Pottelsberghe de la Potterie 2004].

As the empirical evidence suggests, an increase of the public financing for R&D above 0.4-0.6% of GDP results, on average, in a 3-4 times faster growth in private expenditures. Below that critical level the R&D units are able to afford only the basic research [Gaczek 2004, p. 8]. Moreover, given the fact that biotech R&D activity involves, to large extent, research conducted on living organisms it is inevitably connected with a particularly high exposure to risk and unpredictable results. Aforementioned considerations indicate that public support is indispensable and this source of funds should therefore, have a certain share in the overall R&D expenditures.

Despite an extant literature on the relationships between R&D expenditures and the innovative performance, to date no study has attempted to investigate this issue in the context of the European biotech sector, regarding a particularly interesting aspect of this problem – the relative impact of diverse sources of funds. Given the above, the present paper aims at empirical investigation of the impact of R&D expenditures on the innovative performance in the European biotech sector, with respect to the sources of funds used. In order to address these issues the following set of hypotheses was formulated:

– H1: R&D expenditures have positive impact on the output of innovations measured by the number of patents granted,
– H2: Private biotech R&D expenditures are more effective than the public ones.

Material and methods

In order to achieve the aim and test both hypotheses formulated in the present study the cross-sectional analyses of correlation and regression between the value of biotech R&D expenditures and the number of biotech patents granted in the examined countries were employed. Given the time-consuming nature of the research and development processes the adopted research framework assumed the existence of a one-year lag between the R&D expenditures and the subsequent output of patents granted. To ensure a relative comparability of the value of R&D expenditures in the pooled sample, they were measured in purchasing power parity (PPP) U.S. dollars.

The data on the value of biotech R&D expenditures, separately for the business and public sectors were extracted from the OECD Statistical Database [http://www.oecd.org/sti/inno/key-biotechnologyindicators.htm], whereas the number of biotech patents granted were extracted from Eurostat Database [http:// ec.europa.eu/eurostat]. According to the OECD's data collection procedures the data on R&D expenditures covered the years 2009, 2011, and 2013 (or the latest available years). Given the assumed lag between those expenditures and granting of patents, the data on the number of patents were taken from the years 2010, 2012, and 2014, respectively. Due to the incompleteness of the database the combined data on the one-year lagged R&D expenditures in the business and public sectors and the number of patents granted yielded the final pooled sample of 11 countries (Czech Republic, Denmark, Germany, Italy, Netherlands, Norway, Poland, Portugal, Slovakia, Slovenia, and Spain) with 32 country-year observations.

The first stage of the research involved an estimation of the Pearson linear correlation coefficients between the value of R&D expenditures and the output of patents granted, conducted separately for the business and public sectors. The obtained estimates were then tested for the statistical significance.

In the second stage, a linear multiple regression analysis was conducted for the pooled sample of countries aiming at capturing the relative responsiveness of the number of biotech patents granted to the changes in the value of R&D expenditures made in each of the investigated sectors, respectively. Taking into account the aforementioned lag between the expenditures and the output of patents, the following regression model was constructed:

$$PG_t = \alpha_0 + \alpha_1 BERD_{t-1} + \alpha_2 GERD_{t-1} + \varepsilon_t$$

where: PG_t – the number of biotech patents granted in year t, $BERD_{t-1}$ – the value of biotech R&D expenditures in the business sector in the year t-1, $GERD_{t-1}$ – the value of biotech R&D expenditures in the public sector in the year t-1, α_0 – intercept, α_1, α_2 – regression coefficients, ε_t – error term.

Given the first hypothesis of the study, the values of both regression coefficients were expected to be positive, as larger R&D expenditures should result in a higher output of biotech patents. Following the second hypothesis, the efficiency of private R&D expenditures ought to be higher than public ones, therefore the estimate of the parameter α_1 was expected to be larger than the one of α_1. The introduction of the error term served for capturing the impact of potential other factors than the explanatory variables included in the model.

Results of research

Table 1 presents the estimates of Pearson linear correlation coefficient between the one-year-lagged biotech R&D expenditures in business and public sectors and the number of patents granted in the pooled sample of countries over the analysed period.

The results of the conducted correlation analysis revealed relatively strong positive and statistically significant relationships between the values of one-year-lagged biotech R&D expenditures and the number of biotech patents granted, thus supporting the first hypothesis of the present study. Contrary to the expectations, public expenditures seemed to be more strongly related to the output of biotech patents. According to the Fischer Z-transformation test r, however, the difference between the correlation coefficients turned out to be statistically insignificant due to a small number of observations in the sample.

In the next stage of the research a multiple linear regression analysis was employed to

Table 1. Estimates of the Pearson linear correlation coefficients between business and public biotech R&D expenditures and the the number of biotech patents granted (pooled sample)
Tabela 1. Współczynniki korelacji liniowej Pearsona pomiędzy prywatnymi i publicznymi nakładami na działalność B+R a liczbą uzyskanych patentów w dziedzinie biotechnologii (dane panelowe)

Variable/ *Zmienna*	Correlation with/ *Korelacja z* PG_t	*p*-value/ *Wartość p*	Number of observations/ *Liczba obserwacji*
$BERD_{t-1}$	0.820**	0.000	32
$GERD_{t-1}$	0.919**	0.000	32

Source: own study
Źródło: opracowanie własne

Table 2. Estimations of multiple linear regression between business and public biotech R&D expenditures and the output of biotech patents granted (pooled sample)
Tabela 2. Wyniki estymacji wielorakiej regresji liniowej pomiędzy prywatnymi i publicznymi nakładami na działalność B+R w dziedzinie biotechnologii a liczbą uzyskanych patentów (dane panelowe)

Parameter/statistic *Parametr/statystyka*	Evalue/ *oszacowanie/ wartość*	t-statistic/ *statystyka t-Studenta*	*p*-value/ *wartość p*	Collinearity statistics *Statystyki współliniowości*	
				tolerance/*wskaźnik tolerancji*	VIF
α_0	-3.058	-0.454	0.653		
α_1	0.060	3.320	0.002	0.451	2.216
α_2	0.032	7.474	0.000	0.451	2.216
R^2	0.888				
Adj. R^2	0.880				
F-statistic	114.826		0.000		
N	32				

Source: own study
Źródło: opracowanie własne

investigate the joined impact of the private and public R&D expenditures on the actual biotech innovative performance. The results of the estimation of the constructed regression model are presented in Table 2.

The constructed regression turned out to be statistically significant at the 0.01 level. The combined variation of the lagged R&D expenditures in the both investigated sectors was able to explain almost 89% of the observed variability in the number of biotech patents granted in the examined sample of countries. Additionally, the estimated value of the variance inflation factor (VIF) and the corresponding tolerance level indicate that the multicollinearity of explanatory variables was not significant.

The results of estimation of the model's parameters clearly support the first hypothesis of the present study, as both regression coefficients turned out to be positive and statistically significant at the 0.01 level. This means that increases in both business and public R&D expenditures resulted in a higher number of biotech patents granted in the following year. The estimated value of the parameter α_1 was almost two times greater than that of the parameter α_2, which suggests a much higher efficiency of private R&D expenditures on biotechnology, thus providing some support for the second hypothesis of the study. On average, an increase in the business R&D expenditure of $100 mln (PPP), *ceteris paribus*, resulted in about six new biotech patents granted in the following year, whereas the same increase of public expenditures, other things equal, was able to generate only three patents.

It is worth to point out, however, that the interpretation of the estimates of the constructed model's parameters might not be as straightforward as it would seem. An apparently lower efficiency of the public R&D expenditure might be attributable to the fact that a significant part of public funds in this area is allocated for basic research, which usually does not have a direct practical or commercial application that could be patented. On the other hand, the results of a body of knowledge built through basic research might be indispensable for applied research that could finally result in some new patents.

Conclusions

The expected boosting of bioeconomy's innovative performance in Europe is heavily dependent on intensification of research and development (R&D) activities in the biotech sector. The analysis conducted in the paper revealed positive and statistically significant impact of biotech R&D expenditures on bioeconomy innovativeness in the pooled sample of countries. Moreover the results of research indicate a higher effectiveness of private sources of funding. An apparently lower efficiency of the public R&D expenditures might be attributable to the fact that a significant part of public funds in this area is allocated for basic research, which usually does not have a direct commercial application that could be patented. On the other hand, a body of knowledge built through the basic research might be indispensable to enable conducting applied research.

The paper is not exempt from limitations that result from the incompleteness of OECD statistical database. Enhancing the database should allow to apply more robust statistical analyses.

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Streszczenie

Celem artykułu była ocena wpływu nakładów na działalność B+R w dziedzinie biotechnologii na innowacyjność biogospodarki. Do badania wykorzystano przekrojową analizę korelacji i regresji pomiędzy wartością nakładów na działalność B+R i liczbą uzyskanych patentów w dziedzinie biotechnologii w krajach członkowskich UE. Podjęto próbę określenia relatywnej efektywności nakładów na działalność B+R pochodzących z publicznego i prywatnego sektora. Badanie oparto na danych panelowych pozyskanych z baz statystycznych OECD i Eurostatu dla lat 2009-2014. Ze względu na ograniczoną dostępność i kompletność danych próba badawcza obejmowała 11 krajów. Przeprowadzone analizy wykazały dodatni i statystycznie istotny wpływ nakładów na działalność B+R w dziedzinie biotechnologii na innowacyjność biogospodarki w badanej grupie krajów oraz na wyższą efektywność prywatnych źródeł finansowania.

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