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External linkages and intellectual assets as indicators of firms' innovation activities: results from the Czech Republic and Poland

JEL Classification: *O30; O52; R11*

Keywords: *indicators of firms' innovation activities; external linkages, intellectual assets; the Czech Republic; Poland*

Abstract

Research background: Firms' innovation activities play an important role in fostering firms' competitiveness and enhancing economic growth of regions and countries. Regarding the significance of the issue, it is essential to explore indicators of firms' innovation activities. Here, special attention was given to external linkages and intellectual assets. In the study, particular emphasis was put on firms from the Czech Republic and Poland as the countries distinguished by similar innovation performance.
Purpose of the article: The aim of this paper is to explore whether external linkages and intellectual assets impact on innovation activities of Czech and Polish firms.
Methods: In the study, the Cobb-Douglas function was employed. The study used data from the European Innovation Scoreboard 2018 with regard to firms' innovation activities. In particular, special stress was put on variables related to external linkages and intellectual assets such as: innovative SMEs collaborating with others, private co-funding of public R&D expenditures, PCT patent applications and trademark applications. The time period was 2008–2015.
Findings & Value added: This paper contributes to the existing literature by providing new insight on issues connected with indicators of firms' innovation activities. The results reveal statistical significance of selected variables connected with external linkages and intellectual assets on innovation activities of Czech and Polish firms. These findings have policy and practical implications. There is a need to further stimulate, among others, the linkages between firms and universities, research organisations, institutional environment.

Introduction

There is a general consensus in the economic literature that innovation plays a critical role in fostering competitiveness of firms, regions and countries (see Tödtling & Grillitsch, 2015, pp. 1741–1758; Asheim *et al*., 2011, pp. 1133–1139). In this regard, innovation leads to economic growth of regions and countries (see Huggins & Thompson, 2015, pp. 103–128). This line of argument enhances the rank of actions stimulating innovation and is highlighted by the European Union's Europe 2020 strategy (European Commission, 2018a, p. 3). The importance of actions fostering innovation is also considered by the knowledge spillover theory, endogenous growth theory and place-based approach. In this respect, special emphasis is put on supporting firms' innovation by regions and countries. The core argument here is a simultaneous relationship between firms' innovation and regions' and countries' economic growth (see Isaksen & Karlsen, 2013, pp. 243–257; Wierzbicka, 2018, pp. 123–139; Wierzbicka, 2016, pp. 343–357). This implies the significance of firms' innovation activities as the base of firms' innovation and competitive advantage and, as a consequence, an important component of regions' and countries' competitiveness (see Edler & Fagerberg, 2017, pp. 2–23). In this context, research attention has focused, among others, on the indicators of innovation activities of firms within a country (see Fritsch & Franke, 2004, pp. 245–255). Here, a number of studies have dealt with linkages between firms and other firms, universities, research organisations, institutional environment as an important indicator of firms' innovation activities (see Ankrah & AL-Tabbaa, 2015, pp. 387–408; Martin & Moodysson, 2011, pp. 170–187). These considerations emphasise the rank of knowledge diffusion processes for firms' innovation and regions' and countries' growth (see Isaken *et al*., 2018, pp. 221–238). When considering the indicators of firms' innovation activities, intellectual assets have also received special attention as knowledge codification (see Asheim *et al*., 2011, pp. 1133–1139). Related to the European Union's Europe 2020 strategy viewpoint, both external linkages and intellectual assets are regarded as important indicators of firms' innovation performance (European Commission, 2018a, p. 8).

Regarding the above, it is important to explore whether external linkages and intellectual assets influence firms' innovation activities. In this respect, particular emphasis was put on firms from the Czech Republic and Poland to understand indicators of firms' innovation activities in the countries distinguished by innovation performance below that of the EU average (see European Commission, 2018a, p. 13). Hence, the aim of this paper is to investigate whether external linkages and intellectual assets impact on

innovation activities of Czech and Polish firms as countries recording similar innovation performance.

To achieve the aim, the Cobb-Douglas function was employed. The empirical analysis was based on data from the European Innovation Scoreboard 2018 (EIS). The time period is 2008–2015.

The paper is structured as follows. The first part concerns a short overview of the literature on indicators of firms' innovation activities with emphasis on external linkages and intellectual assets. The methodology of research is presented in the second part. The third part provides major findings while the fourth part contains discussion. The last part concerns the conclusions.

This study presents new insight on issues regarding indicators of firms' innovation activities. It is very important in terms of creation of the conditions for fostering competitiveness of firms, regions and countries. This paper also completes existing studies by the application of the Cobb-Douglas function in order to find the interactions between exogenous and endogenous indicators of regional development in fostering competitive advantage of firms, regions and countries.

Literature review

It is increasingly widely accepted that firms' innovation activities have become the main source of competitiveness improvement and economic growth of firms (see Tödtling & Grillitsch, 2015, pp. 1741–1758). In this context, following the theoretical discussion, innovation activities of firms are considered to be "the unique competence of firms that cannot easily be copied by others" (Isaken & Karlsen, 2013, p. 244). Another core argument here is that firms' innovation activities can foster competitive advantage of regions and countries (see Edler & Fagerberg, 2017, pp. 2–23; Cieślik & Michałek, 2018, pp. 233–250; Zygmunt A., 2017, pp. 505–521). In this regard, what is significant is cooperation between regions and firms (see Isaken *et al*., 2018, pp. 221–238). For this reason, the issues concerning firms' innovation activities are essential. Hence, according to this line of argumentation, numerous studies focus on firms' innovation indicators (see Bronzini & Piselli, 2016, pp. 442–457; Mendonça *et al*., 2004, pp. 1385–1404) and actions stimulating innovation of firms (see Isaksen *et al*., 2018, pp. 221–238; Fritsch & Franke, 2004, pp. 245–255). These issues are particularly emphasised by the growth theory, knowledge spillover theory and place-based approach. Here, strong emphasis is put on the combination of exogenous and endogenous indicators of regional development in fostering

competitiveness of firms, regions and countries (see Tödtling & Trippl, 2018, pp. 1–17; Balcerzak & Pietrzak, 2016, pp. 66–81; Zygmunt J., 2018, pp. 1175–1184; Barca, 2009, pp. 1–244). Following this, the concept of knowledge spillovers becomes relevant. From this point of view, knowledge spillovers "constitute an important factor in shaping regional conditions for innovation activities" (Fritsch & Franke, 2004, p. 245). This implies the necessity for firms to acquire knowledge from different types of sources (see Isaken & Karlsen, 2013, pp. 243–257). Thus, considering the significance of the issue, the role of networks between, among others, firms and other firms, universities, institutional environment, research organisations is essential. Here, a wide body of empirical literature also assesses the role of innovation outputs generated (see Asheim *et al*., 2011, pp. 1133–1139) as a results of firms' intellectual assets. Both indicators — external linkages and intellectual assets — are specifically considered by the European Union to be crucial for the economic growth and competitiveness of firms, regions and countries (European Commission, 2018a, pp. 8–14). Thus, it is of importance to further study the above indicators of firms' innovation activities.

When considering external linkages, particular attention is given to innovative small and medium-sized enterprises (SMEs) collaborating with others, public-private co-publications and private co-funding of public R&D expenditures (see European Commission, 2018a, pp. 8–14). According to a number of studies, there is a strong reliance on the flow of knowledge between firms and, among others, other firms, research organisations and universities (see Martin & Moodysson, 2011, pp. 170–187). The argument put forward here is that such an external flow of knowledge is crucial to building firms' innovation capability (see Tödtling & Grillitsch, 2015, pp. 1741–1758) and, as a consequence, to enhancing competitiveness of firms, regions and countries (see Edler & Fagerberg, 2017, pp. 2–23). In this regard, the key role is played by innovative collaboration of firms with others (see Rosenbusch *et al*., 2011, pp. 441–457). Here, a wide body of empirical literature assesses the rank of SMEs in economic growth of regions and countries (see Varis & Littunen, 2012, pp. 547–582; Rosenbusch *et al*., 2011, pp. 441–457) since they represent 99% of firms in the European Union (European Commission, 2018b). Without a doubt, as regards firms' collaboration with others, an essential role is played by universities in contributing to knowledge flow. Important in this context is the fact that university-firm linkages may take different forms, depending on firms' needs for knowledge creation and innovation (see Asheim *et al*., 2011, pp. 1133–1139; Ankrah & AL-Tabbaa, 2015, pp. 387–408). In providing scientific knowledge, special emphasis is put on public-private

co-publications (see Yegros Yegros *et al*., 2016, pp. 136–150). This argument builds on the acknowledgement that such publications express "an empirical manifestation of relationships and processes among the research partners" (Tijssen, 2012, p. 2). Apart from public-private co-publications, private co-funding of public R&D expenditures is also an important part of the performance of firms' linkages (see Ankrah & AL-Tabbaa, 2015, pp. 387–408). Following this line of argument, private co-funding of public R&D expenditures may have impact on firms' accessibility to external knowledge inflows and, as a consequence, to firms' R&D capacity.

Regarding intellectual assets, substantial significance is attached to PCT patent applications, trademark applications and design applications (see e.g., European Commission, 2017, pp. 8–14). In this respect, firms' innovation outputs are treated as knowledge codification (see Asheim *et al*., 2011, pp. 1133–1139). Following this, a number of theoretical and empirical studies highlight the impact of innovation outputs on firms', regions' and countries' competitive advantage (see Tödtling & Grillitsch, 2015, pp. 1741–1758). When considering this issue, substantial attention is focused particularly on PCT patent applications (see Allred & Park, 2007, pp. 876–900). Here, PCT patent applications indicate firms' capacity to develop new products and assess "the quality of an innovation" (Bronzini & Piselli, 2016, p. 445). Another strand of literature also emphasises the significance of trademark applications as firms' capacity for innovation (see Mendonça *et al*., 2004, pp. 1385–1404) as well as design applications (see European Commission, 2018a, p. 96).

Research methodology

In order to address the importance of knowledge spillovers in firms' innovation activities, it is crucial to investigate external linkages and intellectual assets. In this regard, special emphasis was put on firms from the Czech Republic and Poland. Since the Czech Republic and Poland differ economically, those countries are distinguished by similar innovation performance (see European Commission, 2018a, p. 13). Thus, the following hypotheses were posed:

H1: *External linkages influence positively innovation activities of firms from the Czech Republic*.

H2: *External linkages influence positively innovation activities of firms from Poland*.

H3: *Intellectual assets have a positive impact on Czech firms' innovation activities*.

H4: *Intellectual assets have a positive impact on Polish firms' innovation activities*.

The data for this study were gathered from the European Innovation Scoreboard 2018 (European Commission, 2018a). Here, special attention was paid to indicators of firms' innovation activities. In this regard, the European Innovation Scoreboard 2018 contains two dimensions related to external linkages and intellectual assets. These dimensions include six specific indicators: innovative SMEs collaborating with others, public-private co-publications, private co-funding of public R&D expenditures, PCT patent applications, trademark applications, and design applications (Table 1).

Above variables are consistent with the endogenous growth theory, knowledge spillover theory and place-based approach. The study uses data concerning the Czech Republic and Poland. The time period was 2008–2015.

The descriptive statistics of diagnostic variables for the Czech Republic and Poland, comprising mean, standard deviation, minimum and maximum, are presented in Table 2 and Table 3.

The collinearity among the diagnostic variables was verified using the graph analysis method (see Bartosiewicz (Ed.), 1980). Here, the findings suggest high levels of collinearity between variables. Following this, the elimination of selected diagnostic variables was necessary. As a consequence, the study concerning Czech firms' innovation activities included private co-funding of public R&D expenditures (X_3) (with regard to external linkages) and PCT patent applications (X_4) and trademark applications (X_5) (concerning intellectual assets). The research regarding Polish firms' innovation activities included innovative SMEs collaborating with others (X_1) (regarding external linkages) and trademark applications (X_5) (in respect of intellectual assets).

In order to explore whether external linkages and intellectual assets influence innovation activities of firms from the Czech Republic and Poland, the Cobb-Douglas function was applied. The usability of this function lies in simplicity (see Piketty, 2014, p. 157) and good adjustment to empirical data. Here, the general formula of the Cobb-Douglas function was used (Borkowski *et al*., 2003):

$$y = b_0 X_1^{b_1} X_2^{b_2}, \ldots, X_k^{b_k} \quad (1)$$

where:
b_0, b_1,…, b_k – constants;
$j=0,\ldots,k$

With regard to the undertaken study, six models were distinguished (three for the Czech Republic and three for Poland). This number of models results from various measurements of firms' innovation activities: (1) percentage of SMEs introducing product or process innovations, (2) percentage of SMEs introducing marketing or organisational innovations and (3) percentage of SMEs innovating in-house. Such measurements of firms' innovation activities are in line with the European Innovation Scoreboard 2018 and result from the diversity of innovation performance (see Żelazny & Pietrucha, 2017, pp. 43–62). Here, the rank of SMEs in economic growth of regions and countries was emphasised. As a consequence, to investigate whether external linkages and intellectual assets impact on innovation activities of Czech firms, the following models were distinguished:

$$\text{Model 1: } y = b_0 X_3^{b_1} X_4^{b_2} X_5^{b_3} ,$$

where:
y – innovation activity of Czech firms, measured as a percentage of SMEs introducing product or process innovations;
X_3 – private co-funding of public R&D expenditures;
X_4 – PCT patent applications;
X_5 – trademark applications;
b_0, b_1,…, b_k – constants,
$j=0,\ldots,k$.

$$\text{Model 2: } y = b_0 X_3^{b_1} X_4^{b_2} X_5^{b_3} ,$$

where:
y – innovation activity of Czech firms, measured as a percentage of SMEs introducing marketing or organisational innovations;
X_3 – private co-funding of public R&D expenditures;
X_4 – PCT patent applications;
X_5 – trademark applications;
b_0, b_1,…, b_k – constants,
$j=0,\ldots,k$.

$$\text{Model 3: } y = b_0 X_3^{b_1} X_4^{b_2} X_5^{b_3} \ ,$$

where:
y – innovation activity of Czech firms, measured as a percentage of SMEs innovating in-house;
X_3 – private co-funding of public R&D expenditures;
X_4 – PCT patent applications;
X_5 – trademark applications;
$b_0, b_1,\ldots, b_k$ – constants,
$j=0,\ldots,k$.

In regard to Poland, the following models were distinguished:

$$\text{Model 1: } y = b_0 X_1^{b_1} X_5^{b_2},$$

where:
y – innovation activity of Polish firms, measured as a percentage of SMEs introducing product or process innovations;
X_1 – innovative SMEs collaborating with others;
X_5 – trademark applications;
$b_0, b_1,\ldots, b_k$ – constants,
$j=0,\ldots,k$.

$$\text{Model 2: } y = b_0 X_1^{b_1} X_5^{b_2},$$

where:
y – innovation activity of Polish firms, measured as a percentage of SMEs introducing marketing or organisational innovations;
X_1 – innovative SMEs collaborating with others;
X_5 – trademark applications;
$b_0, b_1,\ldots, b_k$ – constants,
$j=0,\ldots,k$.

$$\text{Model 3: } y = b_0 X_1^{b_1} X_5^{b_2},$$

where:
y – innovation activity of Polish firms, measured as a percentage of SMEs innovating in-house;
X_1 – innovative SMEs collaborating with others;
X_5 – trademark applications;
$b_0, b_1,\ldots, b_k$ – constants,
$j=0,\ldots,k$.

Next, log transformation of the generated models was conducted on the basis of the following formula:

$$\ln(y) = b_0 + b_1 \ln(X_1) + b_2 \ln(X_2) + \cdots + b_k \ln(X_k) \qquad (2)$$

where:
b_0, b_1,…, b_k – constants;
$j=0,\ldots,k$

To verify the statistical significance of the models, the least-squares regression was used. To control for the autocorrelation, Durbin-Watson test was applied. Where the Durbin-Watson test did not allow to indicate autocorrelation, Student's t-test was used with $n - 2 - 1$ degrees of freedom.

Results

Concerning Czech firms' innovation activities in 2008–2015, a significant impact of variables connected with external linkages and intellectual assets could be found in model 1 and model 2 (Table 4 and Table 5). In line with the obtained results, model 3 shows the lack of statistical significance (Table 6).

With regard to intellectual assets, the results reveal that innovation activities of firms from the Czech Republic were affected by trademark applications (X_5). These findings hold for model 1 and model 2 (Table 4 and Table 5). Here, surprisingly, the study reveals diverse results. With respect to model 2, trademark applications, surprisingly, impact negatively on firms' innovation activities measured as a percentage of SMEs introducing marketing or organisational innovations (Table 5). These findings do not correspond to hypothesis 3 and are in contrast to Mendonça *et al*. (2004, pp. 1385–1404). However, considering model 1, the results provide evidence of a positive impact of trademark applications on innovation activities of firms, described as a percentage of SMEs introducing product or process innovations (Table 4). These findings support hypothesis 3 and are in line with Mendonça *et al*. (2004, pp. 1385–1404). With respect to intellectual assets, what should also be emphasised is the lack of significant impact of PCT patent applications on innovation activities of firms from the Czech Republic, measured as a percentage of SMEs introducing product or process innovations (model 1) and as a percentage of SMEs introducing marketing or organisational innovations (model 2). In this context, the ob-

tained results do not correspond to hypothesis 3 and stand in contrast to, among others, Bronzini and Piselli (2016, pp. 442–457).

Considering external linkages, the obtained results provide evidence about a significant impact of private co-funding of public R&D expenditures (X_3) on Czech firms' innovation activities. These results hold only for model 2 (Table 5). Here, the findings imply, surprisingly, a negative impact of private co-funding of public R&D expenditures on innovation activities of firms, described as a percentage of SMEs introducing marketing or organisational innovations. The obtained results do not support hypothesis 1 and are not in line with, among others, Ankrah and AL-Tabbaa (2015, pp. 387–408).

The results imply that the coefficient of determination for model 1 and model 2 is sufficient to explain innovation activities of Czech firms.

With regard to Poland, the results provide no evidence of statistical significance of model 1 and model 3 due to the occurrence of autocorrelation (Table 7 and Table 8). As a consequence, model 1 and model 3 were excluded from the study.

On the other hand, considering model 2, the coefficient of determination confirms a good model fit in explaining innovation activities of Polish firms (Table 9). With respect to intellectual assets, the findings indicate a strong effect of trademark applications (X_5) on innovation activities of Polish firms in 2008–2015, measured as a percentage of SMEs introducing marketing or organisational innovations (Table 9). Here, surprisingly, the findings suggest a negative influence of trademark applications on innovation activities of firms. These findings do not correspond to hypothesis 4 and are not in line with Mendonça *et al*. (2004, pp. 1385–1404).

Regarding external linkages, the results imply no significant impact of innovative SMEs collaborating with others (X_1). This suggests that innovation activities of Polish firms, described as a percentage of SMEs introducing marketing or organisational innovations, were not associated with external linkages. These results do not correspond to hypothesis 2 and stand in contrast to, among others, Rosenbusch *et al*. (2011, pp. 441–457).

Discussion

The results provide evidence concerning the statistical significance of the impact of selected variables connected with external linkages and intellectual assets on innovation activities of Czech and Polish firms. With regard to Czech firms, the results reveal, surprisingly, a negative impact of such a variable of external linkages as private co-funding of public R&D ex-

penditures on firms' innovation activities. These findings are not in line with, among others, Ankrah and AL-Tabbaa (2015, pp. 387–408). Considering intellectual assets, the study implies a diverse impact of trademark applications on innovation activities of Czech firms. This situation may reduce the abilities of Czech firms to increase competitiveness, and as a consequence, their abilities to foster economic growth of regions and the country.

With respect to Poland, the results show that in 2008–2015, firms' innovation activities were significantly influenced only by the variable of intellectual assets such as trademark applications. This indicates that Polish firms may improve innovation and competitiveness by the enhancement of knowledge flow. Here, the findings provide evidence about a surprisingly negative impact of trademark applications on firms' innovation activities in Poland. These results stand in contrast to, among others, Mendonça *et al*. (2004, pp. 1385–1404) and suggest limited abilities of Polish firms to stimulate innovation activities.

In line with the obtained results, the findings emphasise the importance of linkages between firms and public research institutions and between firms and other firms. Here, the flow of knowledge is essential in fostering innovation and competitiveness of firms and, as a consequence, of regions and countries.

Conclusions

This study analysed external linkages and intellectual assets as indicators of innovation activities of Czech and Polish firms in 2008–2015. On the basis of the Cobb-Douglas function, the results indicate that innovation activities of firms in both the Czech Republic and Poland were affected by such a variable of intellectual assets as trademark applications. Considering external linkages, the study reveals a significant impact only for Czech firms' innovation activities. In this respect, the obtained results highlight the influence of such a variable of external linkages as private co-funding of public R&D expenditures on firms' innovation activities.

In policy and practical terms, the findings call for strengthened variables of firms' innovation activities regarding external linkages and intellectual assets. In this respect, regional and country policies should further intensify, among others, linkages between firms and other firms, universities, research organisations and institutional environment. Here, it is also important that firms create conditions for innovation and competitive advantage.

This study has some limitations. This paper uses indicators of firms' innovation activities and data from the European Innovation Scoreboard 2018. This paper draws also on innovation activities measured as: (1) percentage of SMEs introducing product or process innovations, (2) percentage of SMEs introducing marketing or organisational innovations, (3) percentage of SMEs innovating in-house. It would be interesting to investigate whether the results also hold in other measurements of firms' innovation activities.

In terms of future research, it is important to study the impact of other innovation activities indicators on firms from the Czech Republic and Poland. It would also be interesting to undertake studies to understand the reasons for a negative impact of selected variables describing external linkages and intellectual assets on Polish and Czech firms' innovation activities.

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Annex

Table 1. Description of diagnostic variables

Variables			Description
External linkages	Innovative SMEs collaborating with others	X_1	percentage of SMEs
	Public-private co-publications	X_2	per million population
	Private co-funding of public R&D expenditures	X_3	percentage of GDP
Intellectual assets	PCT patent applications	X_4	per billion GDP
	Trademark applications	X_5	per billion GDP
	Design applications	X_6	per billion GDP

Source: The European Innovation Scoreboard 2018 (European Commission, 2018a).

Table 2. Descriptive statistics of diagnostic variables for the Czech Republic

Variables		Mean	St. Dev.	Min.	Max.
Innovative SMEs collaborating with others	X_1	10.80	0.67	10.03	11.63
Public-private co-publications	X_2	22.52	2.87	19.99	28.32
Private co-funding of public R&D expenditures	X_3	0.02	0.01	0.01	0.03
PCT patent applications	X_4	0.91	0.11	0.69	1.07
Trademark applications	X_5	5.07	0.42	4.24	5.74
Design applications	X_6	3.13	0.56	2.34	4.07

Source: own calculations based on data for the period 2008–2015 from the European Innovation Scoreboard 2018 (European Commission, 2018a).

Table 3. Descriptive statistics of diagnostic variables for Poland

Variables		Mean	St. Dev.	Min.	Max.
Innovative SMEs collaborating with others	X_1	4.48	1.13	3.50	6.40
Public-private co-publications	X_2	5.19	0.56	4.36	6.06
Private co-funding of public R&D expenditures	X_3	0.02	0.01	0.02	0.02
PCT patent applications	X_4	0.51	0.10	0.35	0.69
Trademark applications	X_5	4.41	0.78	3.45	5.33
Design applications	X_6	5.08	0.70	4.20	5.99

Source: own calculations based on data for the period 2008–2015 from the European Innovation Scoreboard 2018 (European Commission, 2018a).

Table 4. Regression results of the Cobb-Douglas function for the Czech Republic: model 1

Variable	Coefficients	Standard error	t-Stat	p-value	Significance F	R^2
const	-3.0392	0.2531	-12.0085	0.0003	0.0001	0.9979
$ln(X_3)$	-0.0496	0.0549	-0.9043	0.4170		
$ln(X_4)$	-0.0230	0.0908	-0.2529	0.8128		
$ln(X_5)$	4.8847	0.1238	39.4653	0.0001		

$ln(y)=-3.0392+(-0.0496)ln(X_3)+(-0.0230)ln(X_4)+4.8847ln(X_5)$

$Y=0.05X_3^{-0.50}X_4^{-0.02}X_5^{4.88}$

Autocorrelation consistent. Level of statistical significance: $p \leq 0.05$.

Source: own calculations based on data from the European Innovation Scoreboard 2018 (European Commission, 2018a).

Table 5. Regression results of the Cobb-Douglas function for the Czech Republic: model 2

Variable	Coefficients	Standard error	t-Stat	p-value	Significance F	R^2
const	3.6151	1.0011	3.6111	0.0225		
$ln(X_3)$	-0.6592	0.2171	-3.0371	0.0385	0.0217	0.8903
$ln(X_4)$	-0.8652	0.3592	-2.4088	0.0736		
$ln(X_5)$	-1.6939	0.4896	-3.4598	0.0258		
$ln(y)=-3.6151+(-0.6592)ln(X_3)+(-0.8652)ln(X_4)+(-1.6939)ln(X_5)$						
$Y=37.15X_3^{-0.66}X_4^{-0.86}X_5^{-1.69}$						

Autocorrelation consistent. Level of statistical significance: $p \leq 0.05$.

Source: own calculations based on data from the European Innovation Scoreboard 2018 (European Commission, 2018a).

Table 6. Regression results of the Cobb-Douglas function for the Czech Republic: model 3

Variable	Coefficients	Standard error	t-Stat	p-value	Significance F	R^2
const	3.9155	0.2173	18.0177	0.00005		
$ln(X_3)$	0.0046	0.0471	0.0974	0.9270	0.1085	0.7481
$ln(X_4)$	-0.0755	0.0780	-0.9687	0.3875		
$ln(X_5)$	-0.3538	0.1063	-3.3292	0.0291		
$ln(y)=3.9155+0.0046ln(X_3)+(-0.0755)ln(X_4)+(-0.3537)ln(X_5)$						
$Y=50.18X_3^{0.005}X_4^{-0.08}X_5^{-0.35}$						

Level of statistical significance: $p \leq 0.05$.

Source: own calculations based on data from the European Innovation Scoreboard 2018 (European Commission, 2018a).

Table 7. Regression results of the Cobb-Douglas function for Poland: model 1

Variable	Coefficients	Standard error	t-Stat	p-value	Significance F	R^2
const	1.5214	0.2764	5.5033	0.0027		
$ln(X_1)$	0.6138	0.0857	7.1611	0.0008	0.0001	0.9617
$ln(X_5)$	0.1584	0.1099	1.4413	0.2090		

$ln(y)=1.5214+0.6138ln(X_1)+0.1584ln(X_5)$

$Y=4.58X_1^{0.61}X_5^{0.16}$

Autocorrelation non-consistent. Level of statistical significance: p≤0.05.

Source: own calculations based on data from the European Innovation Scoreboard 2018 (European Commission, 2018a).

Table 8. Regression results of the Cobb-Douglas function for Poland: model 3

Variable	Coefficients	Standard error	t-Stat	p-value	Significance F	R^2
const	1.5488	0.5108	3.0322	0.0290		
$ln(X_1)$	0.6669	0.1584	4.2114	0.0084	0.0009	0.9401
$ln(X_5)$	-0.1232	0.2031	-0.6068	0.5705		

$ln(y)=1.5488+0.6669ln(X_1)+(-0.1232)ln(X_5)$

$Y=4.71X_1^{0.70}X_5^{-0.12}$

Autocorrelation non-consistent. Level of statistical significance: p≤0.05.

Source: own calculations based on data from the European Innovation Scoreboard 2018 (European Commission, 2018a).

Table 9. Regression results of the Cobb-Douglas function for Poland: model 2

Variable	Coefficients	Standard error	t-Stat	p-value	Significance F	R^2
const	5.4813	0.9578	5.7226	0.0023		
$ln(X_1)$	-0.3495	0.2970	-1.1767	0.2922	0.0066	0.8656
$ln(X_5)$	-1.5093	0.3809	-3.9630	0.0107		

$ln(y)=5.4813+(-0.3495)ln(X_1)+(-1.5093)ln(X_5)$

$Y=240.17X_1^{-0.35}X_5^{-1.51}$

Autocorrelation consistent. Level of statistical significance: p≤0.05.

Source: own calculations based on data from the European Innovation Scoreboard 2018 (European Commission, 2018a).