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The interdependence of R&D, innovations, and productivity: case of Polish manufacturing companies

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Abstract

Motivation: The structural model proposed by Crepon, Duguet, and Mairesse (the CDM model) in 1998 has been the workhorse of the empirical analysis of the relationship between firms' innovation input and output and performance. Most research applying the CDM methodology shows a positive relationship between firms' R&D, innovation, and productivity, primarily in highly developed countries. However, some studies do not confirm the universal nature of these relations, pointing to possible differences between countries, sectors, firm characteristics, sources of knowledge, types of innovation, or performance indicators.

Aim: The study aims to explore the relationship between R&D expenditures, patent applications, and labour productivity among Polish manufacturing firms. The study applies a four-stage analysis of the innovation-performance relationship based on the CDM model. The method enables us to track the transformation of innovation input into output and its impact on the performance of companies. The analysis is based on the survey conducted in 2018 on a random sample of 1049 Polish manufacturing firms.

Results: The results reveal interesting insights into the analysed relationship. Firstly, initial results confirm the vital role of cooperation, being an exporter, and functioning in specific markets for deciding to invest in R&D. Secondly, state aid, employees' education, and being part of the capital group are crucial for the R&D intensity. The analysis confirms a statistically significant positive relationship between Polish manufacturing firms' innovation input and output. However, the results of the last stage of the analysis indicate that the performance of manufacturing firms is unrelated to the innovation output.

Keywords: R&D; subsidy; patenting; innovation; firm-level analysis
JEL: O1; O3; O32

1. Introduction

The importance of innovation for economic growth and development, indicated by Schumpeterian and neoclassical growth theory (Aghion & Howitt, 1996, pp. 49–73; Fagerberg, 2005, pp. 1–40), has been the subject of many macroeconomic and industry-level empirical studies for several decades. The increasing availability of microdata made it possible to analyse this relationship also at the firm level. Initially, Cobb-Douglas production functions were the standard method of estimating the relationship between innovation and firms' productivity and efficiency (Griliches, 1998). Crepon et al. (1998) proposed an alternative approach to the analysis in the form of a structural model (known as the CDM model). Today, the CDM model is viewed as a workhorse in the empirical literature on innovation and productivity and has been frequently applied by researchers using survey data (Lööf et al., 2017, pp. 1–5). Most research applying the CDM methodology shows a positive relationship between firms' R&D, innovation, and productivity, mainly in economies operating close to the technological frontier. However, some studies concerning emerging economies do not confirm the universal nature of these relations. The results of some studies concerning non-European emerging markets indicate positive results of the relationship between R&D and innovation (Chudnovsky et al., 2006, pp. 266–288; Correa et al., 2005; De Negri et al., 2007, pp. 1–21). However, some other studies do not confirm this link (Benavente, 2006, pp. 301–315). Similar ambiguous results are obtained from the analysis of the relationship between innovation and productivity in this group of countries (Benavente, 2006, pp. 301–315; Chudnovsky et al., 2006, pp. 266–288; Correa et al., 2005; De Negri et al., 2007, pp. 1–21). Several existing studies on Central and Eastern Europe (CEE) economies differ from the studies mentioned above in that they usually concern not a single country but a group of countries (Disoska et al., 2020, pp. 280–295; Fedyunina & Radosevic, 2022; Hashi & Stojčić, 2013, pp. 353–366; Ramadani et al., 2019, pp. 271–280; Tevdovski et al., 2017, pp. 527–551; Toshevska-Trpchevska et al., 2019, pp. 543–562). The results of the studies revealed some regularities but also some differences between groups of countries, sectors, firm characteristics, sources of knowledge, types of innovation, or performance indicators.

Since data from Poland constituted only a tiny part of the sample used in just one known to us study on the relationship between the innovative activity of CEECs enterprises and their productivity (Ramadani et al., 2019, pp. 271–280), we have concluded to deepen the study of this relationship based on the data of a random sample of Polish manufacturing firms. Our study applies the modified CDM model to analyse the relationship between R&D, innovation, and productivity among Polish manufacturing companies. To our knowledge, such a study has yet to be carried out in Poland, as existing studies on the link between firms' innovation and productivity in Poland concern the service sector (Szczygielski & Grabowski, 2014, pp. 17–38; Szczygielski et al., 2017, pp. 249–262), and in the case of manufacturing, they are focused on the correlation between technological innovations and productivity (Kijek & Kijek, 2019, pp. 219–225).

The paper contributes to the empirical literature on the effect of patent applications on manufacturing firms' performance in Poland. We provide a four-stage analysis of the innovation-performance relationship built on an empirical framework proposed by Crepon et al. (1998, pp. 115–158). The multi-stage model enables the tracking and understanding of transforming innovation input into output and its impact on the performance of Polish manufacturing firms. Insight into this process and its determinants bring essential implications for the policy. The analysis was possible thanks to the access to a unique database based on a survey conducted 2018 on a random sample of 1049 manufacturing firms in Poland and supplemented with the firms' financial data from the Orbis database.

The structure of the paper is as follows. The next section briefly overviews the literature on firm innovation and performance relations. The third section presents and explains data sources, a description of variables, and the econometric model. The fourth section describes the results obtained from the analysis. Finally, we present conclusions.

2. Literature review

Since the beginning of the 1990s, an increasing number of innovation surveys conducted in many countries can be noticed. The survey data made it possible to extend the analysis of the relationship between innovation input and productivity with innovation output. The first structural model of this relation was proposed by Pakes and Griliches (1984, pp. 55–72). A few years later, Pakes and Griliches's model made the foundation for the CDM framework created by Crepon et al. (1998). The CDM model has been applied to analyse the relationship between innovation and productivity in dozens of countries (Lööf et al., 2017, pp. 1–5), primarily in highly developed ones (Baum et al., 2017, pp. 121–133; Griffith et al., 2006, pp. 483–498; Hall & Mairesse, 2006, pp. 289–299; Janz et al., 2004, pp. 184–204; Lööf & Heshmati, 2006, pp. 317–344; Lööf et al., 2001; Mairesse et al., 2005; pp. 489–529; Raymond et al., 2010, pp. 495–

504). Generally, these studies have confirmed the main findings of Crepon et al. (1998) on the link between R&D, innovation, and the firm's productivity.

The body of literature on the issue of transition economies and catching-up countries is limited. With a relatively small number of CDM model studies conducted for this group of countries, there is considerable variation in the analysis performed and, above all, in terms of results obtained (Raffo et al., 2008, pp. 219–239). Some studies confirm the ability of firms to transform knowledge efforts into innovation: Chudnovsky et al. (2006, pp. 266–288) for Argentina; Correa et al. (2005) and De Negri et al. (2007, pp. 1–21) for Brazil, and some do not prove this link, e.g. Benavente (2006, pp. 301–315) for Chile.

The heterogeneity of the results can also be observed in the case of the relationship between innovative output and firm performance. Some studies do find the link: Chudnovsky et al. (2006, pp. 266–288) for Argentina; Correa et al. (2005) and De Negri et al. (2007, pp. 1–21) for Brazil; Ramadani et al. (2019, pp. 271–280) for CEECs and others do not confirm it, e.g. Benavente (2006, pp. 301–315) for Chile. There are also studies on CEECs, which indicate a different result of the analysis on the relation between innovation output and firm performance depending on the adopted method of analysis and applied dependent variables (Fedyunina & Radosevic, 2022; Hashi & Stojčić, 2013, pp. 353–366), the analysed period (Masso & Vahter, 2008, pp. 240–261; Toshevska-Trpchevska et al., 2019, pp. 543–562) or relating to the different structure of the innovation systems and level of technological development (Disoska et al., 2020, pp. 280–295; Hashi & Stojčić, 2013, pp. 353–366). It should be noted that due to the data samples used in these analyses, the conclusions drawn from the research primarily concern the CEE countries as a whole. Thus, structural differences and the diverse role of R&D in the growth of individual countries, and the intensity of links with the global economy are rarely considered in these studies. However, research on individual countries indicates that the specificity of national economies in these issues can be essential factors in differentiating the relationship between R&D, innovation, and firms' performance.

3. Methods

In 2018, within the framework of the research project, *Intensity of competitive rivalry and innovative behavior of enterprises*, we surveyed 1049 manufacturing firms domiciled in Poland. Our sampling frame was the InfoCredit database (the source of the Orbis data on Polish enterprises), from which we initially drew a stratified random sample of 2750 manufacturing companies. The sample was representative of sectoral (2-digit industry sector) and regional (the location of the headquarters at NUTS 2 level of voivodships) levels. In the next stage, we managed to get answers to our survey questions from 1049 firms through contact with managers of enterprises and using various methods (due to the low effectiveness of the CAWI approach). The survey questionnaire was designed based on the CIS questionnaire. It contained detailed information on Polish manufacturing companies' R&D and innovation activity from 2015 to 2017. The survey data were supplemented with the firm's financial data from the InfoCredit database. The access to the InfoCredit database also enabled us to calculate sectoral concentration ratios (e.g. HHI).

We apply the CDM (Crepon–Duguet–Mairesse) model introduced by Crepon et al. (1998, pp. 115–158) (outlined earlier by Pakes & Griliches, 1984, pp. 55–72), modified by Griffith et al. (2006, pp. 483–498) and Hall et al. (2009; pp. 13–33). The CDM model is based on four equations producing a recursive system including relationships between:

- factors determining the decision to invest in R&D (selection equation);
- R&D investment equation as a function of its determinants;
- innovation output as a function of patent applications;
- productivity equation as a function of innovation output.

The classic CDM model successfully addressed a specific gap in the literature: the link between innovation efforts and firm performance, often treated as a 'black box' (Rosenberg, 1982) and offered an effective system to deal with selectivity and simultaneity biases (Lööf & Heshmati, 2006, pp. 317–344). Selection bias may arise because of not drawing firms randomly from a larger population when only the innovation sample of firms is used (Lööf & Heshmati, 2006, pp. 317–344) and addressing potential endogeneity of innovation input and output. The solution for the first problem is to add the selection equation, considering the non-innovative sample of firms. The answer for the latter is to use predicted values in innovation output and productivity equations (Griffith et al., 2006, pp. 483–498; Jefferson et al., 2006, pp. 345–366). Thus, we prepared an analysis in line with these studies, using a robust Heckman procedure with the first two equations, probit to estimate innovation output equations, and OLS to estimate the productivity equation.

The first equation represented the decision to invest in research and development and can be defined as follows:

$$D_{RDi} = \beta_0 + x_{1i}\beta_1 + \xi_{1i}, \tag{1}$$

where:

D_{RDi} expresses the decision to invest in R&D (dummy variable);

x_{1i} define explanatory variables;

β_1 are coefficients for specific explanatory variables; and

ξ_{1i} is the error term.

The independent variables of the equation include firm and sectoral characteristics affecting firms' innovative behaviour such as: firm size (the log of number of employees in 2017), cooperation (a dummy variable equal to 1, if a firm cooperated on innovation activities with other firms or organizations), a firm age (a log of firm age; *ln_age*), *foreign capital* (a dummy variable implies whether the firm has a foreign investor or not), exporter status (a dummy variable indicates whether the firm is an exporter or not; *exporter*), three dummy variables relating to firm market orientation (selling products in national, European or other markets), four dummy sector variables according to NACE Rev. 2 that implies whether the firm belongs to a low-tech (*nace_lt*), a medium-low-tech (*nace_mlt*), a medium-high-tech (*nace_mht*), or a high-tech manufacturing sector (*nace_ht*), and a HHI concentration index (a continuous variable measured at a two-digit industry level corresponding to the NACE classification).

The second equation represented the decision to amount of R&D expenditures (intensity; the "innovation input"), and can be defined as follows:

$$Innov_{input} = \varnothing_0 + x_{2i} \; {}_2 + \; {}_{2i}, \qquad (2)$$

where:

Innov$_{input}$ expresses the intensity of the investment in R&D (continuous variable in logs), which we define as expenditures on five different innovation activities comprising:

- in-house R&D;
- external R&D;
- acquisition of machinery, equipment, software & buildings;
- acquisition of existing knowledge from other enterprises or organisations (licenses, patents, other tech transfer agreements);
- all other innovation activities, including design, training, marketing, and other relevant activities;

β_2 are coefficients for specific explanatory variables; and

ξ_{2i} is the error term.

The independent variables in this equation comprise some of the variables from the first stage (foreign capital, exporter status, firm market orientation, dummy sector variables) plus some additional variables such as *capital_group* (a dummy variable specifying whether the firm is part of a larger capital group or not), personnel qualification (the log of percent of enterprise's employees in 2017 with a tertiary degree of education), state aid (a dummy variable equal to 1, if a firm any public financial support for innovation activities during the three years 2015–2017), and the categorical variable CEO_age_group aims to control for a managerial experience.

As a result of the second equation, we obtained the "innovation input" (predicted value as a post-estimation result of the second stage) for the next step. Moreover, the Heckman procedure enabled us to check for potential selection bias while calculating the Inverse Mills Ratio and including it in the "innovation output" equation. If we discover the Inverse Mills Ratio (MR or IMR) as a statistically significant factor during our analysis (e.g., the coefficient for lambda), it would assume that selection bias is present in the model.

The third stage covered the probit estimation of the innovation output equation (enclosing the "innovation input" from the second stage).

$$Innov_{output} = \beta_0 + \beta_1 Innov_{input_{pred}} + \beta_3 x_{3i} + \beta_{MR} MR + \xi_{3i}, \tag{3}$$

where:

$Innov_{output}$ expresses the patent application (a binary variable *ip_patent_app*, which is equal to 1 if a firm applied for a patent during the three years from 2015 to 2017);

$Innov_{input_{pred}}$ express the predicted value of the innovation input from the second stage;

x_{3i} define the vector of explanatory variables;

β_i are coefficients for specific explanatory variables;

MR accounts for the potential selection bias; and

ξ_i is the error term.

The vector of independent variables of the stage includes many of the variables used in previous steps (*ln_empl_2017*, *ln_age*, *exporter*, *foreign_capital*, *ln_hcgraduates*, *cooperation*, *state_aid_agg*, and four dummy sector variables) as well as such variables as three binary variables indicating types of innovations (*process_innovation*, *org_innovation*, *marketing_innovation*).

The productivity equation was estimated with OLS, in line with Crepon et al. (1998; pp. 115–158) and Jefferson et al. (2006, pp. 345–366). The fourth stage equation could be defined as follows:

$$Productivity = \beta_0 + \beta_1 Innov_{output_{pred}} + \beta_4 x_{4i} + \xi_{4i}, \tag{4}$$

where:

Productivity expresses the firm's labor productivity (the log of sales per worker in 2017 at the level from the InfoCredit database);

$Innov_{output_{pred}}$ express the predicted value of the innovation output from the third stage;

x_{4i} define the vector of explanatory variables;

β_i are coefficients for specific explanatory variables; and

ξ_i is the error term.

The labour productivity is specified as a function of the predicted value of innovation output (*patent_app*), age (*ln_age*), exporter status (*exporter*), ownership variable (*foreign_capital*), dummy sector variables, capital intensity (*fixa_emp*), establishment's capital (*ln_capital*), firm location in the capital Warsaw (*citywaw*). All variables' descriptive statistics are indicated in Tables 1 and 2.

4. Results

Table 3 presents the estimation results of the first stage of our analysis in which the decision to invest in R&D and R&D intensity equations were estimated jointly in the Heckman two-step sample selection model. The estimation results imply that the likelihood of investing in R&D by Polish manufacturing firms is positively affected by the cooperation on innovation activities, the status of the exporter, and the orientation of sales to national and other than European foreign markets. In turn, the orientation of sales to the European foreign markets is the only factor limiting the propensity of enterprises to invest in R&D.

The outcomes of the second equation indicate that the orientation of sales to foreign markets (both European and non-European), state aid, and the older age group of CEOs have a significant and positive impact on the intensity of R&D. On the other hand, the factors limiting the amount of a firm expenditure on R&D include the percentage of employees with higher education, belonging to the capital group, and to the low-tech sector.

The results of the patent application equation (Table 4) indicate a significant and positive impact of state aid, organizational innovations, cooperation, and the percentage of skilled workers on the innovation outcome. On the other hand, marketing innovations and belonging to the medium-low-tech sectors (compared to high-tech sectors) decrease the propensity to patent applications. It should also be noted that R&D expenditures and foreign ownership only weakly increase the propensity of firms to patent applications.

The results of the last stage of our model indicate that the impact of innovation output on labor productivity is insignificant. The significant and positive effect on the firm's performance has the following variables: capital intensity (fixa_emp), establishment's capital (ln_capital), a firm located in the capital Warsaw (citywaw) and belonging to medium-low-tech and medium-high-tech sectors (compared to belonging to the low-tech sectors). Thus, the results may signal the minor importance of innovation activity for manufacturing firm performance in Poland or a disruption effect (a production disruption resulting from introducing innovation, resulting in a reduction in productivity), as indicated by Roper et al. (2008; pp. 961–977).

5. Conclusion

A relatively limited number of studies on the relationship between firms' innovation activities and productivity conducted for transition economies and catching-up countries prompted us to conduct such a study on Polish manufacturing enterprises. We used a structural CDM model to estimate this relationship and made several contributions to the literature.

We find that firms' cooperation on innovation activities and market orientation has a significant impact on the probability of a firm's decision to invest in R&D. As in the case of Hashi and Stojčić (2013, pp. 353–366) for firms from CEECs, our results indicate that firms that are oriented towards national and non-European markets are more likely to innovate. However, a somewhat unexpected finding is the negative and significant coefficient of the firm's European market orientation, while being an exporter increases the probability of the firm's decision to invest in R&D. This result contrasts somewhat with statistical data, which indicates that the European market is the important market for Polish exporters. The result requires in-depth research, covering not only the direction of the firm's sales but also the level of development and degree of competition in these geographic areas and their impact on the decision to invest in R&D.

However, It should be noted that the results of the second equation indicate a significant positive impact of firms' foreign market orientation on R&D intensity. The outcome is in line with empirical findings (Disoska et al., 2020, pp. 280–295; Hashi & Stojčić, 2013, pp. 353–366; Masso & Vahter, 2008, pp. 240–261) and theoretical prediction, which state that greater competition in foreign markets forces firms to be more innovative and efficient. Another factor having a significant positive impact on the amount of expenditure on R&D incurred by Polish manufacturing firms is public support for these activities. The results of many studies have confirmed that state aid aimed at innovation helps firms to undertake activities that they would not otherwise undertake due to the high level of uncertainty and information asymmetry (Czarnitzki & Licht, 2006, pp. 101–131; Petelski et al., 2020, pp. 66–88; Radas et al., 2015, pp. 15–30). Therefore, numerous studies applying the CDM model indicate a significant positive impact of public support on R&D intensity (Disoska et al., 2020, pp. 280–295; Masso & Vahter, 2008, pp. 240–261; Raffo et al., 2008, pp. 219–239). The outcomes of our study also imply that the age of the CEO over 61 (compared to the youngest group of CEOs — up to 40) positively impacts the number of R&D expenditures. The result points to one of the two conflicting views existing in the literature, according to which older CEOs tend to undertake more risky actions (e.g., innovation) compared to young CEOs because short-term goals do not drive their decisions (Anderou et al., 2017, pp. 1287–1325; Holmstrom, 1999, pp. 169–182). The results of our study also indicate a significant negative impact on the R&D intensity by the company belonging to the capital group and skilled workers.

In line with expectations based on the literature review, the variable representing the level of employees' education and the cooperation variable, the state aid obtained by the company and the introduction of organisational innovations, significantly increase the propensity of Polish manufacturing companies to patent applications. Although with minor significance, the predicted value of R&D expenditures and foreign ownership also positively impacts the innovation output. The results of our analysis also show that the factors limiting the propensity of Polish manufacturing firms to apply for patents are marketing innovation and the firm's belonging to the medium-low-technology sectors, compared to the high-tech sectors. One likely explanation for the negative relationship between marketing innovation and patent applications can be that these activities involve a considerable amount of financial means limiting each other (Disoska et al., 2020, pp. 280–295). Moreover, marketing innovations may be more related to forms of IPRs other than patents, such as trademarks (Millot, 2009, pp. 1–47).

Finally, our estimates of the outcome equation show the statistically insignificant relationship between the predicted value of the firm's patent applications and productivity. The source of the result might be a timing problem of survey data indicated by Mohnen (2019, pp. 97–122). The problem is related to the fact that innovation data refers to three years (in our case, 2015–2017), whereas quantitative variables refer just to the last year of three year period (in our case, to the year 2017). Therefore, the patent applications filed in 2015–2017 may not impact labor productivity in 2017. Moreover, patent applications do not reflect the commercial aspect of innovation, as many have yet to find practical applications, and thus may not affect firms' productivity. In addition, the obtained results of the productivity equation can be associated with the level of development of transition-driven economies, such as Poland, where innovation is not the most important source of productivity growth.

Overall the results of our study revealed some interesting insight into the analysed innovation-performance relationship. Polish manufacturing firms have specific regularities in their innovative behaviour. One that stands out, particularly, is the insignificant impact of patent applications on labour productivity. Such a result may be related to the specific structure of the innovation systems and the level of technological development. Although our study allowed us only partially confirm the relationship indicated by the original CDM model, it enabled us to identify several interesting relationships, the analysis of which may be deepened in subsequent studies, e.g., the role of market orientation to innovation input, the relation between CEOs characteristics and innovation, or the impact of different forms/indicators of innovations on firms' productivity. The emerging policy implications from our study confirm what Radosevic et al. (2019) pointed out. The EU R&D-based policy should give more importance to support of innovation implementation and production capabilities in CEECs.

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Appendix

Table 1.
Descriptive statistics of continuous and count variables

Variables	N	Mean	SD	Min	Max
cash_flowtotal_assets	932	0.112	0.179	–1.265	1.757
hhi	1049	165.6	160.2	0	3024
ln_expend_rd	383	11.87	1.674	7.601	14.73
new_product_market_share	472	21.57	25.35	0	100
new_product_firm_share	472	24.38	22.40	0	100
sum_new_product_market_andnew_pr	472	45.95	31.92	0	100
ln_inn_sales	442	3.614	0.856	0	4.605
ln_hcgraduates	623	3.026	1.062	0.693	4.605
age	1049	17.28	14.98	0	199
ln_age	1049	2.601	0.893	0	5.298
employment_2017	1049	2.290	0.844	1	4
ceo_group	1049	3.189	1.173	1	5
employ_2017_o	725	109.2	262.4	0	5.691
fixa_emp	687	279.6	1.813	0	44 698
sales_o_17	983	48627	127.860	2	2.428e+06
prod_O_2017	721	594.9	1.436	5	30755
ln_prod_O_2017	721	5.814	0.965	1.609	10.33
ln_empl_2017	724	3.767	1.447	0	8.647
innovation_input_new	429	12.39	0.835	9.985	14.47
imr_new	429	0	0	0	0
ln_capital	1004	6.109	2.346	0	12.81
process_innovation_n	387	–0.376	1.217	–2.674	3.506
product_innovation_n	387	0.287	1.175	–2.409	4.532

Source: Own preparation.

Table 2.
Descriptive statistics of dichotomous variables

Variable	N	0 — no	1 — yes	% 0	% 1
product innovation	1049	519	530	49.48	50.52
process innovation	1049	689	360	65.68	34.32
organisational innovation	1049	841	208	80.17	19.83
marketing innovation	1049	759	290	72.35	27.65
patent applications	1049	994	55	94.76	5.24
R&D cooperation	1049	857	192	81.70	18.30
exporter	1049	591	458	56.34	43.66
capital group	1049	883	166	84.18	15.82
foreign capital	1049	946	103	90.18	9.82
national market	1049	46	1003	4.39	95.61
European market	1049	361	688	34.41	65.59
other countries	1049	798	251	76.07	23.93
state aid R&D	1049	941	108	89.70	10.30
city WAW	1049	954	95	90.94	9.06

Source: Own preparation.

Table 3.
Results of Heckman two-step procedure: factors determining the decision to invest in R&D (Step 1) and the amount of R&D expenditures (Step 2)

Variables	Decision to invest in R&D (Step 1)		The amount of R&D expenditure (Step 2)	
ln_empl_2017	−0.044	(0.039)		
cooperation	0.645***	(0.138)		
ln_age	0.004	(0.064)		
foreign_capital	−0.014	(0.173)	−0.345	(0.390)
exporter	0.709***	(0.132)	0.205	(0.424)
national_market	0.844***	(0.305)	−0.299	(0.784)
market_european	−0.556***	(0.133)	0.980***	(0.339)
other countries	0.304**	(0.132)	0.614**	(0.263)
nace_lt	−0.089	(0.364)	−0.923*	(0.550)
nace_mlt	0.019	(0.383)	−0.399	(0.538)
nace_mht	−0.262	(0.370)	−0.373	(0.587)
hhi	0.0002	(0.0004)		
capital_group			−1.406***	(0.401)
ln_hcgraduates			−0.188**	(0.092)
state_aid_agg			0.683**	(0.302)
ceo_group 2			0.345	(0.399)
ceo_group 3			0.005	(0.426)
ceo_group 4			0.140	(0.395)
ceo_group 5			0.768**	(0.387)
lambda	−1.224**	(0.524)		
constant	−1.331**	(0.554)	13.501***	(1.395)
Wald chi2(15)		88.31		
prob>chi2		0.000		
observations		683		

Note:
*** p<0.01, ** p<0.05, * p<0.1.

Source: Own preparation based on STATA 15.

Table 4.
The innovation output equation estimated under the assumption that labour productivity is measured in level (Step 3 and Step 4)

Variables	Innovation output *ip_patent_app* (Step 3)		Productivity *ln_prod_O_2017* (Step 4)	
innovation_input	0.957*	(0.510)		
patent_app			−0.241	(0.314)
ln_empl_2017	0.029	(0.166)		
ln_age	0.202	(0.370)	−0.120	(0.065)
exporter	2.533	(1.609)	−0.163*	(0.098)
foreign_capital	1.578*	(0.892)	−0.170*	(0.101)
ln_hcgraduates	1.472***	(0.477)		
cooperation	2.307**	(1.115)		
process_innovation	−1.762*	(1.001)		
org_innovation	3.864***	(0.913)		
marketing_innovation	−2.480***	(0.825)		
state_aid_agg	1.686***	(0.517)		
nace_lt	−0.624	(0.725)	0	(omitted)
nace_mlt	−1.325**	(0.585)	0.240**	(0.100)
nace_mht	–		0.282**	(0.130)
nace_ht	0	(omitted)		
fixa_emp			0.0004***	(0.000)
ln_capital			0.086***	(0.018)
citywaw			0.426**	(0.196)
constant	−24.354**	(10.229)	5.455***	(0.264)
observations	417		391	
R-squared	0.401		0.183	

Note:
*** p<0.01, ** p<0.05, * p<0.1.
Source: Own preparation based on STATA 15.