Business Spending on Research and Development and its Relationship to Invention and Innovation

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Abstract

The paper deals with the problem of business spending on research and development and their relation to innovation activities. It is focused on R&D in the business sector as a crucial part of the innovation system. R&D expenditure can be seen as the main precondition of successful innovation. However, the successful transformation of R&D investment into invention or innovation cannot be guaranteed. Our main aim is to examine the relationship between business R&D expenditure, invention and innovation in the long-run. We also examine the level of business R&D expenditure in EU countries. The long-run causalities have been tested by using panel cointegration approach on the macro-level panel data for EU countries. The scope of inventions is proxied by the share of firms introducing product or service innovation as well as the number of patents registered. Based on our results, there appears to be a positive causal effect of business R&D expenditure on patenting in the long-run.

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Introduction

Research and development (R&D) expenditure are often considered as the crucial prerequisite of innovation activities in the business sector. Firms with the intention to bring new innovative goods or services to the market often need to apply state-of-the-art technologies or new knowledge which are both mostly the results of R&D activities. There are two potential ways of how these results can be achieved. Firstly, research and development can be performed in house by their research capacities. In the second case, they can acquire them from other institutions such for example public and private research institutions. Despite the fact, that part of the knowledge is freely available to the public, most firms have invested some financial resources to obtain useful information. Thus, it seems to be straightforward that R&D expenditure can be considered as one of the determinants of business innovation. R&D expenditure should be spent by firms to get some outputs that should be further useful for innovation itself. However, several factors are affecting the effectiveness of this process. In line with this fact, our research is primarily focused on the relationship between a firm's commitment to research and development and its innovative outcomes. Hence, our main scientific aim is to examine the potential long-run relationship between business R&D expenditure, invention and innovation. Furthermore, we analyse the extent and structure of business R&D expenditure in the EU countries as well. In the following text, we provide an overview of literature dealing with the problem of R&D expenditures as well as their potential consequences for the business. Further, we briefly describe the data and methodology used in our research and present and discussed our results. Finally, we make some conclusions.

R&D expenditure is the key input into the innovation process. In line with the triple helix model, the innovation itself can be seen as the results of activities and cooperation between business, universities and government is crucial (Etzkowitz and Leydesdorff, 2000). Hence, there are at least three different types of subjects which are funding or providing R&D activities. R&D expenditure can be therefore classified according to the source of funds or based on the subject of performance. In our case, we take into account the second type of classification.

The main goal of spending money on R&D in business is mostly to enhance innovation performance and finally improve the competitiveness of the firm at the market which can be reflected in firms' economic situation. Several studies found a positive effect of R&D spending on the growth of the firm (e.g. Pieri et al., 2018). It is likely that business R&D expenditure also positively affects business economic and financial performance, such for example profitability (Freihat & Kanakriyah, 2017; Shen et al., 2017; VanderPal, 2015;), apparent labour productivity (Hunady et al., 2019); turnover (Park et al., 2018) or value-added (Hunady et al., 2019). R&D investment is crucial especially for the development of high-tech products (Sandu & Ciocanel, 2014). Therefore, they are also considered as the main growth drivers of high-tech industries (Karahan, 2015; Wang et al., 2013), which include for example aerospace, computers, pharmaceutical or electronics and telecommunications industries (Sandu & Ciocanel, 2014). High technology companies are more dependent upon the intellectual property and except own sources, they are often using external sources (Stankevice & Jucevicius, 2013). These external sources can be provided to the business by universities, research institution or government. Scientific knowledge provided by public researchers has a significantly positive effect on both inputs and outputs of the firms' innovation process (Herrera et al., 2010). However, this is only true in the case when firms have enough research capabilities to absorb and use this knowledge. Hence, funding of in-house research capacities also enables a firm use, and understand acquired knowledge (Penner-Hahn & Shaver, 2005).

While business and government R&D expenditure can be measured directly, their effect on innovation performance is more difficult to capture. The effect of R&D expenditure on technology development and also innovation can be reflected by the number of patents. Zachariadis (2003) argues that R&D expenditure is mostly reflected in the number of patents, and patents have a positive effect on the development of technologies, which raises economic growth. Hasan and Tucci, (2010) based on a sample of 58 countries for the period 1980–2003 indicate the positive effect of quality and quantity of patents on economic growth. Furthermore, Orviska et al. (2019) also found a positive effect of patents on the development of new technologies in the economy. However, in economic literature patents are often considered more as invention rather than innovation itself. Grant (2016) characterise an invention as the creation of new products and processes through the development of new knowledge or the combination of existing knowledge. Innovation is defined as commercialization of invention by producing and marketing a good or service or by using a new method production. Hence, invention is more about the new ideas, while innovations are more focused on new commercial products or services. As mentioned by Artz et al. (2010) patents are often used as a proxy for inventions and they can then be seen as the first step towards innovation. Compared to academic publication or most of the other research outputs patents are closer to innovation and technological development (Breschi et al., 2005). Despite mentioned potential differences, there are many recent studies, which are considering the number of patents as a direct indicator of innovation performance (such for example Bronzini & Piselli, 2016; Löfsten, 2014).

The effect of R&D expenditure on patents can be expected to be positive because the internal research capabilities, particularly those focused on basic research are crucial for the firm to generate creative outputs (Artz et al., 2010). For example, Cardinal and Hatfield (2000) examined firms with different intensity of R&D expenditures and observed that firms with higher R&D spending experienced significantly more inventions proxied by the number of patents. Similarly, Peeters and van de la Potterie (2006) found that firms with more focus on research activities produce significantly more patenting output. On the other hand, Acs and Audretsch (1990) argue that the relationship between R&D expenditure and intensity of patenting a is more complex and firms can often experience decreasing returns to their R&D investment. Some empirical papers have also shown that increasing levels of R&D spending over a certain threshold is ineffective or even counterproductive for innovation outputs (Graves & Langowitz, 1996). The role of patenting in the innovation process was also emphasised by Demirel and Mazzucato (2012). They found the positive impact of R&D on firm growth is conditional upon the firms' activity in patenting and persistence in patenting. For small firms, R&D increase their growth for only a subset of firms who patent persistently for a minimum of five years. The effect of R&D subsidy program on innovation has been examined by Bronzini and Piselli (2016). Innovation has been in this study proxied by the number of patents. Authors conclude that the R&D subsidy program in Northern Italy has a positive and significant effect on the number of patent applications. The benefits of the program have been especially evident for smaller firms.

Methodology

As we mentioned in the introduction the main aim of the paper is to examine the potential relationship between business R&D expenditure, invention and innovation.

We have been focused on the business sector as one of the main innovation producers in the economy. In the first part of the analysis, we examine the extent and structure of R&D expenditure in EU countries. The cross-sectional data for the latest available year have been used for this comparison. Data have been retrieved from the Eurostat database. Firstly, we compare intramural R&D expenditure (GERD) in the business enterprise sector of EU member states. Cointegration analysis, as well as the panel, cointegrated regression, have been applied on data with the longer time frame (from the year 2007 to 2017).

All main variables used in the analysis are described in more detail in Table 1.

Table 1

Description of variables used in the analysis

Variable	Description
Patents (dependent variables in regression)	The number of patent applications to the EPO per 10 million inhabitants.
Business R&D exp.	Intramural R&D expenditure (GERD) in Business enterprise sector as % of GDP)
	Intramural R&D expenditure (GERD) in Business enterprise sector (of GDP) in PPS per inhabitant
GDP per capita	Real GDP per capita in PPS
Apparent labour productivity	Value-added at factor costs divided by the number of persons employed (in thousands of euros per person employed).
SMEs introducing product or process innovations	The share of SMEs who introduced a new product or a new process to one of their markets on a total number of SMEs (in %).
SMEs innovating in-house	Share of SMEs with in-house innovation activities on all SMEs (both innovators and non-innovators). This indicator does not include new products or processes developed by other firms.
Employment in High technology and medium-tech.	Employment in High technology and medium technology firms as % of total employment. The definition of high- and medium-high technology manufacturing sectors and knowledge-intensive services is based on a selection of relevant items of NACE Rev. 2 on the 2-digit level and is oriented on the ratio of highly qualified working in these areas.

Note: Intramural R&D expenditures are all expenditures for R&D performed within a statistical unit or sector of the economy during a specific period, whatever the source of funds

Source: Authors, based on the data from the Eurostat database

Our dataset consists of panel data. Thus, variables include a cross-sectional (country) dimension as well as a time dimension. It includes data for EU28 countries.

In line with our main aim, we tested the potential relationship between business R&D spending and patenting in the economy. To fulfil the goal, we decided to use the cointegration approach as the main method. The transformation of R&D expenditure into invention (proxied by the number of patents) or innovation usually takes a rather long time. The effect will be probably not visible in the same period and using longer lags will significantly decrease the number of available observations. Moreover, there is likely a long-run causal relationship arising from R&D spending to patenting activity.

Firstly, we also test variables for weak stationary and the order of integration for all variables, which we want to use in the cointegrated regression model. We use the Levin et al. (2002), Im et al. (2003) and Breitung (2000) tests as well as the Fisher ADF and PP tests defined by Choi (2001) and Maddala and Wu (1999).

To test long-run causalities, we apply panel cointegration analysis. GDP per capita was used mainly as the control variable.

The long-run equations will be further estimated as:

$$\text{Patents}_{it} = \text{f}(\text{Business R\&D expenditure}_{it}, \text{GDP per capita}_{it}) \quad (1)$$

After we have managed to satisfactorily demonstrate the same level of integration for selected variables by unit root tests, we test for the existence of cointegration by panel cointegration tests. Cointegration between the dependent and independent variables has been tested for using panel cointegration tests developed by Pedroni (2004) and Kao (1999), which are both widely used in the empirical literature. Both are testing the null hypothesis of no cointegration between selected variables. The Pedroni (2004) cointegration tests use seven different statistics. Four of them are panel cointegration statistics based on the within the approach and three of them are group-mean panel cointegration statistics which are based on the between approach. Kao (1999) tests the null hypothesis that the residuals from the estimation are non-stationary.

The panel cointegration tests allow us to identify the presence of cointegration but cannot estimate any long-run causalities. For this purpose, we use panel cointegrating regression models. The long-run parameters are estimated by the fully modified OLS (FMOLS) panel cointegration estimator.

We used especially the pooled FMOLS estimators which based on the "within dimension" of the panel. The pooled FMOLS estimator is proposed in Phillips and Moon (1999). The estimator is robust concerning the potential problems of serial-correlation and endogeneity, which are potential problems with common OLS panel data estimators (Pedroni, 2000). It solves this problem by nonparametric corrections.

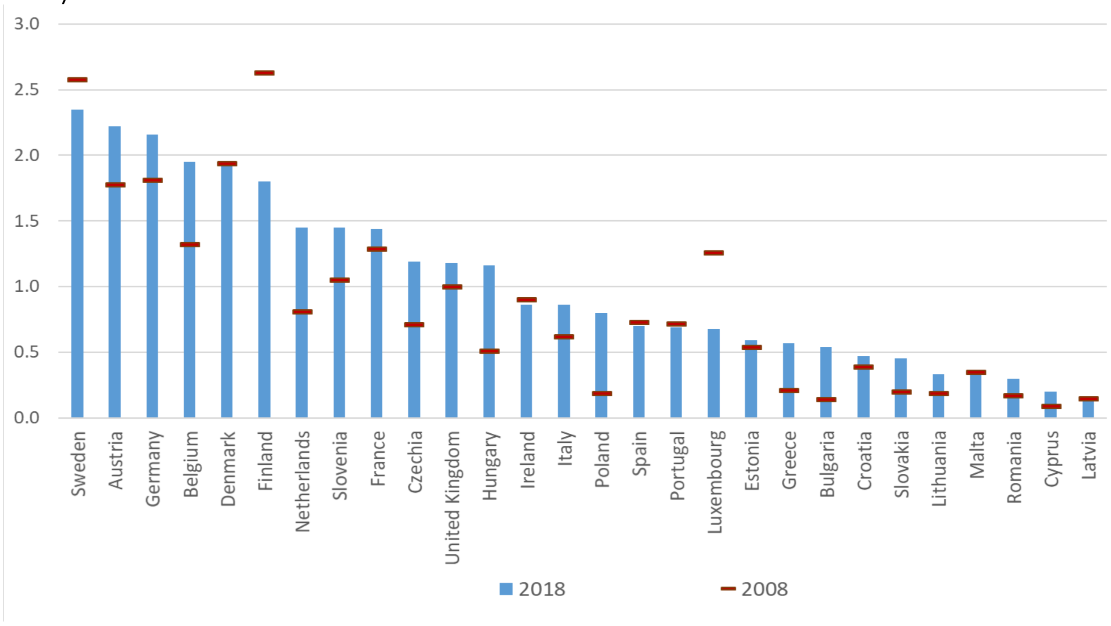
Results and Discussion

As mentioned in our analysis we focused on business R&D expenditure, which in some countries represent a major share of total R&D expenditure. The share of business intramural R&D expenditure on GDP in the years 2018 and 2008 are shown in Figure 1. The differences among countries appear to be evident. Leading countries are Sweden, Austria and Germany. They are followed by Belgium, Denmark and Finland. Most of the countries experienced slight growth in business R&D expenditure during the ten years since 2018. However, there are also many countries such for example Denmark, France, Ireland, Spain or Portugal, which are stagnating over this period. Moreover, business R&D expenditure drops significantly during this period in three EU countries namely Finland, Luxembourg and Sweden.

In the next part of our analysis, we in more detail examine potential relationships between selected variables (Table 2). Our main focus is on the relationship between R&D expenditure, invention and innovation.

To proceed further in our analysis we test potential long-run causalities we used the number of patents as the dependent variable and business R&D expenditure as a percentage of GDP as the main independent variable in our analysis. Patents are considered to be a measure of the invention (Artz et al., 2010) or sometimes they are also used as a proxy for innovation (Bronzini and Piselli, 2016; Löfsten, 2014). We lean more to the first approach and therefore we perceive them in the text more as invention or the first stage of innovation.

Figure 1
Intramural R&D expenditure (GERD) in the business enterprise sector as % of GDP in the years 2018 and 2008



Source: Authors

We assume that there can be a long-run relationship between business R&D funding and inventions measured by the number of patents per capita. The number of patents can be also into certain degree affected by the economic development in the country. Therefore, we also used GDP per capita as a control variable. The cointegrated regression approach allows us to determine long-run causalities. It is robust for both non-stationarity problems and most of the endogeneity problems. However, the number of control variables is limited in this case, because all variables used in the mode must be cointegrated. To test the same level of integration or the cointegration of selected variable we firstly need to use panel unit-root test. We applied five different panel unit-root test. The results mostly suggest that all three variables are very likely non-stationary at their levels but they are stationary when using the first difference. This means that the first necessary condition for the cointegration of these variables has been met.

Table 2
The results of panel unit root tests – variables calculated as % of GDP

	Null Hypothesis: non-stationarity				
	LLC test	**Breitung**	**IPS test**	**ADF test**	**PP test**
Patents - intercept & trend	-6.17***	-0.77	-0.39	64.03	89.89***
ΔPatents - intercept & trend	-23.25***	-5.92***	-5.04***	162.5***	234.5***
Business R&D exp. (% GDP) – intercept & trend	-4.44***	-2.22	-0.244	64.8	88.2***
ΔBusiness R&D exp. (% GDP) – intercept & trend	-10.6***	0.115	-2.25**	109.2***	183.9***
GDP_per_capita – intercept & trend	-29.95***	4.29	-7.53***	133.2***	69.58
ΔGDP_per_capita – intercept & trend	-28.38***	-4.7***	-6.52***	212.8***	266.3***

Notes: **/*** means significance at the 5% / 1% levels
Source: Authors´ own computation

The existence of cointegration between these three variables has been further tested by Pedroni and Kao panel cointegration tests. All results are shown in Table 3 and Table 4. In the first part showed in Table 3 we test cointegration among all three variables. Despite slightly mixed results, the majority of tests confirm the existence of statistically significant cointegration at least at 5% level of significance. Thus, based on the results we can proceed further to cointegrated regression analysis.

Table 3
Results of panel cointegration tests among all three variables

Cointegration: Patents, Business R&D expenditure (% GDP) , GDP per capita / Intercept			
Null Hypothesis: no cointegration		**Statistic**	**Weighted Stat.**
Pedroni test (Engle-Granger based) tests – individual intercept, lag length selection based on SBC	Panel v-Statistic (within dimension)	1.21	-0.73
	Panel rho-Statistic (within dimension)	0.67	0.33
	Panel PP-Statistic (within dimension)	0.001***	-6.70***
	Panel ADF-Statistic (within dimension)	-4.42***	-6.78***
	Group rho-Statistic (between dimension)	2.54	
	Group PP-Statistic (between dimension)	-9.77***	
	Group ADF-Statistic (between dimension)	-7.83***	
Kao coint. test	ADF-Statistic	-2.30**	
Cointegration: Patents, Business R&D expenditure (% GDP), GDP per capita/Intercept & trend			
Pedroni tests (Engle-Granger based) – individual intercept & trend, lag length selection based on SBC	Panel v-Statistic (within dimension)	-2.58	-3.27
	Panel rho-Statistic (within dimension)	3.83	3.57
	Panel PP-Statistic (within dimension)	-0.01	-7.71***
	Panel ADF-Statistic (within dimension)	-1.94**	-6.84***
	Group rho-Statistic (between dimension)	5.32	
	Group PP-Statistic (between dimension)	-13.6***	
	Group ADF-Statistic (between dimension)	-9.11***	

Note: **/*** means significance at the 5% / 10% levels
Source: Authors´ own computation

In Table 4 we tested cointegration only between number fo patents per capita and share of business R&D expenditures on GDP. This time the results are even more convincing. Based on the majority of tests we can conclude that there is cointegration between these two variables.

After the cointegration tests, we can finally proceed to panel cointegrated regression models. To check the robustness of the results we applied FMOLS estimator with different specifications as shown in Table 5.

The long-run positive effect of business R&D expenditure on the number of patents is statistically significant at least at 10% level of significance in all five models. Moreover, this effect is also significant at 5% level in four out of five models. Hence, we can conclude that our results strongly suggest that there is a positive long-run effect of business R&D expenditure on inventions which could likely also further lead to innovation in the business sector. Higher R&D expenditure in business enterprises sector will likely increase also innovation performance. The long-run effect of GDP per capita on patenting was in our case insignificant in almost all models except one. The effect of GDP can likely be more evident in short-run rather than in long-run.

Table 4
Results of panel cointegration tests between Patents and R&D expenditure

Cointegration: Patents, Business R&D expenditure (% GDP) / Intercept			
Null Hypothesis: no cointegration		**Statistic**	**Weighted Statistic**
Pedroni test (Engle-Granger based) tests – individual intercept, lag length selection based on SBC	Panel v-Statistic (within dimension)	2.18**	0.016
	Panel rho-Statistic (within dimension)	-0.82	-1.33*
	Panel PP-Statistic (within dimension)	-2.88***	-5.36***
	Panel ADF-Statistic (within dimension)	-4.06***	-6.28***
	Group rho-Statistic (between dimension)	0.76	
	Group PP-Statistic (between dimension)	-6.90***	
	Group ADF-Statistic (between dimension)	-6.98***	
Kao coint. test	ADF-Statistic	-2.56***	
Cointegration: Patents, Business R&D expenditure (% GDP) , GDP per capita / Intercept & trend			
Pedroni tests (Engle-Granger based) – individual intercept & trend, lag length selection based on SBC	Panel v-Statistic (within dimension)	-1.96	-3.02
	Panel rho-Statistic (within dimension)	2.28	1.85
	Panel PP-Statistic (within dimension)	-0.68	-6.40***
	Panel ADF-Statistic (within dimension)	-2.40***	-7.54***
	Group rho-Statistic (between dimension)	3.53	
	Group PP-Statistic (between dimension)	-6.96***	
	Group ADF-Statistic (between dimension)	-6.72***	

Note: */**/*** means significance at the 1%/ 5% / 10% levels
Source: Authors´ own computation

Table 5
Results of panel cointegrated regression models

Dependent variable: Patents					
Pooled estimator (within dimension)					
	(1) A	(2) B	(3) C	(4) D	(5) E
Business R&D exp. (% of GDP)	11.29* (1.84)	8.33** (2.21)	7.09*** (232.34)	12.38** (2.01)	8.82*** (2.34)
Log(GDP per capita)	3.88 (0.25)	0.53 (0.06)	5.41*** (219.4)	5.65 (0.42)	1.07*** (0.13)
R^2	0.99	0.99	0.99	0.99	0.99
Adj. R^2	0.98	0.98	0.99	0.99	0.99
Long-run variance	203.1	76.44	11.81	11.83	11.81
Observations	280	280	280	280	280

Notes: */**/*** means significance at the 10%/ 5%/ 1% levels; long-run variances calculated based on Bartlett kernel and Newey-West bandwidth have been used for coefficient covariances
A - FMOLS (pooled estimator), constant included, coefficient covariance matrix with homogenous variances;
B - FMOLS (pooled estimator), constant included, coefficient covariance matrix with heterogenous first-stage coefficients;
C - FMOLS (pooled weighted estimator), coefficient covariance matrix with homogenous variances;
D - FMOLS (pooled estimator), constant &linear trend, coefficient covariance matrix with homogenous variances;
E - FMOLS (pooled estimator), constant and linear trend as an additional regressor, coefficient covariance matrix with homogenous variances.
Source: Authors´ own computation

Conclusion

Based on our results we can conclude that investments in research and development appear to be important for the creation of invention and innovation. Business R&D expenditure on GDP has a positive long-run effect on the invention expressed by patents. Hence, increased business investment into research and development activities is mostly leading to more invention and innovation in the future.

We also found that countries with higher business R&D expenditure on GDP also mostly experienced a higher share of innovative firms as well as higher patenting activity. Countries such as Sweden, Austria and Germany experienced the highest R&D expenditure in the business enterprise sector in the EU. Turning to the dynamics of business R&D expenditure we can conclude that not all EU countries were able to increase this indicator during selected ten years. There were significant drops in Finland, Sweden and Luxembourg. However, in most of the EU countries, we noted a slight increase.

Despite our effort to achieve the most relevant results, our approach has also certain limitations. First, the patenting used in the analysis can be seen only as a proxy for invention or innovation. Secondly, we assumed that the effect of business R&D expenditure is largely localised in the same country where these funds have been used. Thus, we do not account for potential cross-border spill-overs or indirect effect. The scope of the data has been limited by data availability. Moreover, FMOLS estimator can be also used only on cointegrated variables. These two facts limited the number of control variables. Even though the problem of endogeneity has been to a large extent solved by using panel FMOLS estimator, more control variables might further improve the robustness of our results. Our approach does not allow us to capture differences between countries. Moreover, based on our data we are not able to distinguish between the different business sectors or research areas. Hence, potential further research can be aimed at the differences between different sectors or countries. In the paper, we used macro-level data and sectoral approach. Further analysis of this problem based on the level of firms could be complementary to our results.

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