

# THE CONTRIBUTION OF INNOVATION ACTORS INTO BUSINESS R&D FUNDING – DOES THE SUBSTITUTION EFFECT OF PUBLIC SUPPORT WORK IN THE EU?

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**Abstract:** Innovation and R&D are becoming a prominent part of policies of countries and transnational unions such as the European Union. This is shown in strategy “Europe 2020” established by EU which prompts member states to invest 3% of their GDP in R&D. R&D expenditure is an important indicator of innovation performance of a country. However, it is not only important to look at R&D expenditure as one aggregate indicator, but to also consider the contributions of various innovation actors to R&D funding. Since firms are known to be the main innovation actor that creates the biggest amount of innovation in national innovation system, the paper is focused on financing of business R&D. The aim of the paper is to examine business R&D funding from resources of main innovation actors and to analyze the impact of public support of R&D on private R&D investment in EU member states. The research is based on descriptive statistics as well as panel regression and correlation analysis and cluster analysis of 28 EU member states. Our results suggest that the main source used to fund business R&D comes from business sector, followed by public support and resources from abroad. The cluster analysis resulted in four clusters based on the structure of business R&D financing in the EU countries. The analysis of substitution effect of public support of R&D suggests that public support has a positive effect on private investment in business R&D, with the raise of public support for business R&D of 0.1011% GDP resulting in 1% increase in business funded R&D expenditure.

**Keywords:** Innovation, R&D funding, substitution effect, public support.

**JEL Classification:** O31, O38.

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## Introduction

Many authors consider innovation to be the key element of economic growth and competitiveness of firms (Distanont & Khongmalai, 2018; Kuncoro & Suriani, 2018) and countries (Akis, 2015; Ciocanel & Pavalesce, 2015; Akcali & Sismanoglu, 2015; Krstić, Stanišić, & Radivojević, 2016; Şener & Saridoğan, 2011). Even though research and

development (furthermore just “R&D”) and innovation are not the same thing, R&D is a crucial part of innovation (Edquist, 2006). The importance of R&D is shown in the fact that one of the main priorities of the EU strategy “Europe 2020” is the increase of R&D expenditure in the EU member states (European Commission, 2010). However, we maintain that it is not only important to monitor R&D expenditure as

one aggregate indicator, but to also look at it incrementally from the point of involvement of various innovation actors in R&D funding. Since firms are considered to be the key innovation actor (Eggink, 2013), we decided to examine the financing of business R&D from various sources of funds (business, government, university, non-profit organization funds and funds from abroad). Many firms encounter the problem of lack of financial resources needed to launch innovation activities. Therefore, firms tend to try and obtain financial resources externally, e.g. through public support (Spielkamp & Rammer, 2009). However, public support of innovation does not always have a positive effect on private R&D investment and may crowd out private investments (Choi & Lee, 2017; Marino et al., 2016; David, Hall, & Toole, 2000). The aim of the paper is to examine funding of business R&D from resources of main innovation actors and to analyze the impact of public support on private R&D investment in the EU member states. The paper is focused on summarizing the theoretical findings of authors related to impact of various innovation actors on business innovation as well as the impact of public support on business R&D investment. EU countries are divided into clusters based on their structure of business R&D funding and occurrence of the substitution effect of public support is tested through panel regression and correlation analysis.

## 1. Literature Review

Despite the importance of innovation and R&D and its impact on growth and competitiveness, many firms are not involved in innovation activities (as suggested by the results of e.g. OECD survey from 2017). There are several barriers hindering a firm's decision to launch an innovation project. Spielkamp and Rammer (2009) divide factors that hamper the success of the innovation process into several categories – cost, economic risk and profit opportunities; lack of internal and external financial resources; knowledge and human capital; legal and bureaucratic burdens; and intercompany restrictions and constraints. D'Este et al. (2012) state that barriers firms encounter are often related to financial obstacles. These statements are in line with practice, since survey carried out by the European Commission in 2014 found that the main reasons firms decided not to undertake innovation activities included lack of internal

financial resources; lack of skilled employees in a firm; lack of motivation to innovate; low demand on market; previous innovation; lack of competition (European Commission, 2014). These studies lead us to believe that one of the key barriers of innovation activities within firms is the lack of financial resources needed to introduce innovation. Firms do not always have enough internal financial resources to launch in-house innovation projects and they therefore turn to providers of external funds (Wang et al., 2016).

Access of a firm to financial resources varies based on the size of a firm as well as its specialization (OECD, 2004). External financial resources used to fund innovation and R&D activities can be obtained from various economic subjects. Most often, firms receive these resources from other businesses (e.g. banks).

However, private investors often avoid investing in innovation projects for several reasons. Reasoning of these investors often includes:

- the fact that the innovation process is an uncertain activity, which means that it is difficult for an investor to evaluate potential of innovation projects;
- earnings from innovation process are extremely skewed, evidence suggests that earnings from innovation have the characteristics of Pareto's distribution, which leads to difficulties in applying standard methods of evaluation of innovation projects;
- the innovator has more information than the investor, therefore the investor cannot evaluate the necessary inputs and possible outputs of innovation projects;
- firms involved in innovation activities have high share of intangible assets – knowledge is represented in human capital (employees), which means that if an employee leaves his job, firm would lose an important source of innovation process (Kerr & Nanda, 2011).

Bekker (2013) partially agrees with this reasoning, while he adds that sunk cost, long time lags between cost and profit, adverse selection and moral hazard also discourage investors from funding innovation projects. These reasons often stop private investors from investing in innovative firms. Therefore, other actors step in to fill financial gap innovating firms

often encounter. Even though the public sector often fulfils the role of supporting innovative firms in need of funding, there are also other subjects that contribute to funding of business R&D. According to OECD (2015), business R&D can be funded by five main innovation actors – business enterprises, government, higher education institutions, private non-profit organizations and by institutions from abroad. These innovation actors help fund private innovation projects and overcome barriers hindering innovation. For example, universities mitigate the effect of sunk cost, since they endure the cost of “mistakes” instead of innovative firms. The collaboration with universities also helps reduce uncertainty stemming from innovation projects, since university employees can explore various options beforehand and guarantee that a firm gets good results. Time lags can also be shortened, since universities are capable of carrying out R&D in the initial stages of innovation, which shortens time lags of innovation activities in a firm (Bekker, 2013). The collaboration between innovation actors stems from Triple Helix model focused on interactions between these actors. Within the Triple Helix model, academy (higher education institutions, universities), government and business enterprises are three pillars that work together in order to create or discover new knowledge, technologies, products or services (Vaivode, 2015). Firms are forced to cooperate with universities and public research institutions in order to expand their innovation activities beyond their own potential. In this instance, we can consider these organizations to be a crucial source of business innovation (Moon, Mariadoss, & Johnson, 2017).

However, despite these benefits collaboration with other innovation actors brings to firms, it is questionable as to why these subjects cooperate with innovative firms and support them. The most important source of fund of innovative firms, outside of private investments, is public sector. Even though universities and private non-profit organizations also support innovative firms, their support is mainly non-financial, in a form of cooperation and joint research (Permann & Walsh, 2007; Rybnicek & Königsguber, 2018; Abidin et al., 2014).

The main reasoning behind the involvement of public sector (and other innovation actors) in business R&D funding is the fact that otherwise

market would invest less in innovation activities than is socially acceptable. There are microeconomic and macroeconomic reasons of public interventions in the area of R&D. Microeconomic justification of state interventions in R&D&I activities stems from the theory of market failures and characteristics of R&D that were introduced by neoclassical economists. According to this theory, innovation is affected by multiple market failures, of which some lead to insufficient and some to excessive R&D investment. However, economists mostly agree that in the absence of public support, market would engage in insufficient amount of innovation activities. Intellectual property rights and R&D subsidies funded by the state should therefore stimulate innovation (Leibowicz, 2018). Microeconomic reasoning for public support of R&D includes arguments such as:

- R&D has the characteristics of public goods, since it is non-rivalrous and non-excludable;
- R&D creates externalities in the form of knowledge spillovers, which leads to R&D creating positive external effects that cannot be internalized by firms, meaning that the social rate of return of knowledge creation is higher than the private rate of return of a firm;
- limited ability of reaping benefits of R&D related to knowledge spillovers;
- asymmetric information and problematic access to finance;
- coordination problems (Martin & Scott, 2000; Arrow, 1962; Hud & Hussiner, 2015; Jaumotte & Pain, 2005; Falk, 2007).

However, some authors say that market failures are not the only and not even the most significant reason of public interventions in innovation activities. While these authors do not question the existence of market failures, they state that market failures themselves do not provide evidence for adequate analysis and empirical basis of innovation policy. Public support of innovation is therefore not appropriate to be justified by market failures based on unrealistic assumptions of perfect competition and perfect information, but on the fact that turbulent world dominated by innovation is characterized by uncertainty (Dodgson et al., 2011). Chaminade and Edquist (2006) agree with this statement and add that the biggest advantage of neoclassical approach representing market failures is its

simplicity. However, they think that political implications stemming from the theory of market failures are not instrumental in policy creation. These implications do not suggest the size of subsidies or other interventions, or the areas in which the state should intervene. Market failure approach is therefore too abstract to provide a guide to create innovation policies. There are also cases when policy makers try to intervene and correct a market failure, which leads to creation of additional failures, e.g. by introducing intellectual property law to solve the problem of return on resources, policy makers create barriers to the flow of information, which leads to creation of additional market failures.

According to the macroeconomic approach, the main justification of public interventions in the area of R&D&I is potential impact of innovation on economic growth. Lundvall (2010) states that the main reason government contributes to innovation policy is the assumption that innovation is a key element of national economic growth. Government plays a key role in the support of innovation, helps sustain appropriate environment for development of innovation, invests in innovation activities, helps overcome certain innovation barriers and ensures that innovations contribute to accomplishing the main goals of public policy, such as economic growth, which in turn leads to other benefits, such as reduction of public debt (Knapková, Kiaba, & Hudec, 2019). Even though innovation policy is usually seen in a narrow view – policy supporting business R&D, venture capital funding, etc. – this policy is usually only a part of a set of policies that affect innovation performance. Thus, government needs to consider how innovation and innovation policies affect other public goals and complementary policies that need to be installed in order to accomplish all public goals.

From direct funding of education and R&D to various regulatory frameworks, public policy affects business innovation activities. However, effectiveness of public support and its impact on private R&D&I investment is the subject of many discussions. Despite many benefits of public support for innovation, there are also certain restrictions known as public failures. Guellec and van Pottelsberghe (2000) introduce three examples in which policies aimed at stimulation of R&D may have negative effects on private R&D investment:

- the crowding out effect through prices;

- the substitution effect;
- the allocation deformations.

Public R&D expenditure may crowd out private investments through increase of demand, which leads to an increase in the price of R&D. In cases where cost of R&D increases, firms will allocate their financial resources in other activities, which will lead to an increase of total volume of R&D even though “real volume” (measured by the number of researchers) will be lower and less economically effective. Another argument is that public funding of innovation directly replaces private investment in innovation. This phenomenon is known as substitution effect described as a situation when firms decide to replace investment in innovation from their own resources with programs provided by public support (e.g. from EU structural funds) (Némethová, Širaňová, & Šipikal, 2019). Public support for R&D&I can also be ineffective when the public support is allocated into projects less efficiently than if this allocation was made by the market, which leads to deformation in the area of allocation of resources between various research fields (Guellec & van Pottelsberghe, 2000).

The impact of the substitution and crowding out effect of public support for R&D&I is a center of attention of many authors. Guo, Guo and Jiang (2016) state that analyses of effects of governments programs for support of R&D do not show uniform results. It was proven that firms receiving government subsidies achieve higher productivity and profitability. It was also shown that these firms grow faster, have better access to external funding, invest a larger amount of financial resources into R&D and show higher social rate of return. However, many studies suggest that public programs to support R&D do not stimulate firms' performance or only have limited positive effect on business R&D expenditure with the exception of small businesses. Several studies show that government R&D subsidies crowd out private R&D investment, which leads to a decrease in social welfare and growth, e.g. Marino et al. (2016) found that substitution effect between public and private R&D expenditure occurs mostly within medium-size firms. Some authors concluded that although public subsidies do not crowd out private R&D investment, they do not stimulate it either (González & Pazó, 2008). Other authors state that the effect of additionality only occurs in

small firms (Löf & Hesmati, 2005). However, many other authors (Carboni, 2017; Choi & Lee, 2017; Liu, Li, & Li, 2016; Ali-Yrkkö, 2005; Sadraoui & Zina, 2009; Afcha & López, 2014) found that subsidy programs aimed at supporting R&D stimulate private investment in R&D in firms. The occurrence of substitution effect of public support of R&D therefore differs based on the region and industry in which a firm operates (Jin, Shang, & Xu, 2018; Capron & van Pottelsberghe, 1997).

## 2. Methodology and Data

The paper is aimed at the examination of business R&D expenditure from the point of view of sources of fund used to finance it and the analysis of occurrence of the substitution effect of public support for R&D in the EU. The main research questions of the paper are as follows:

**RQ1:** To what extent do innovation actors other than business enterprises invest in business R&D in the EU countries and contribute to structure of business R&D expenditure?

**RQ2:** Does government spending on business R&D lead to increase of business R&D investment in the EU countries?

The analysis uses secondary data obtained from Eurostat database as well as secondary data from OECD database “Innovation Indicators”. The key indicator examined in the paper is expenditure on R&D (GERD – Gross Domestic Expenditure on R&D) of the EU member states. OECD (2015) divides these expenditures based on two aspects:

- GERD by sector of performance – stemming from who spent the expenditure on R&D;
- GERD by source of fund – stemming from the financial resource that was used to fund R&D activity.

These two aspects are not always identical, seeing that a subject can fund its innovation activity from other funds, e.g. a firm can spend expenditure on R&D funded by public sector (e.g. by public support in a form of a subsidy or grant). The paper is focused on the second aspect of R&D expenditure – R&D expenditure based on the financial sources used to fund R&D activity. Eurostat differentiates five possible financial resources that can be used to fund R&D: resources of business enterprises, government, higher education institutions (further referred to as “universities”), private non-profit organizations and resources from

abroad. Since business enterprises are generally identified as the key innovation actor involved in most R&D activities in a country, we focus on the financial resources used to fund business R&D (BERD – Business Enterprise R&D Expenditure).

Analysis of secondary data is carried out using methods of descriptive statistics in addition to cluster analysis and panel regression and correlation analysis.

Descriptive statistics is carried out on the sample of all 28 EU member states. Descriptive statistics combines two different approaches:

- analysis of static data for one period (latest period with the available data – year 2015) used in order to compare contribution of innovation actors to business R&D funding in EU member states, and
- analysis of the longer time period on the sample of aggregate amount of business R&D expenditure of all EU member states (the aggregate value is used in order to achieve higher illustrative clarity of data) used to demonstrate development of sources used to fund business R&D over time.

Cluster analysis is also applied on the data of all EU member states for year 2015. We used hierarchic agglomerative algorithm in combination with the Ward method of linking. The results of cluster analysis are illustrated using dendrogram.

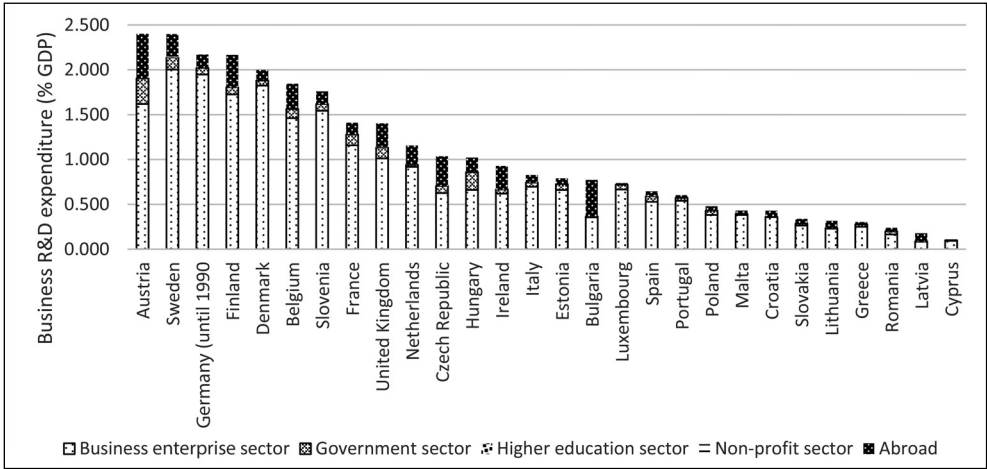
Regression and correlation analyses are applied on panel data, specifically on the sample of all 28 EU member states for the longer time period of 2008–2015. Regression analysis is based on the least squares method in the combination with fixed effects model of cross-sectional data. Logarithms of the data are used in the regression analysis in order to achieve normal distribution of the data. Granger causality hypothesis is used to test causality of chosen variables of regression analysis.

## 3. Results and Discussion

Growth of R&D expenditure of member states is currently one of the main priorities of the EU. Since a big part of R&D takes places in firms, which are considered to be the key innovation actor, we decided to focus on examination of R&D expenditure spent by firms. Even though many firms show interest in introducing innovation projects, one of the main barriers of innovation activities is lack of internal financial

Fig. 1:

**Business R&D funding from funds of innovation actors in the EU member states in 2015 (% of GDP)**



Source: authors, based on data from Eurostat

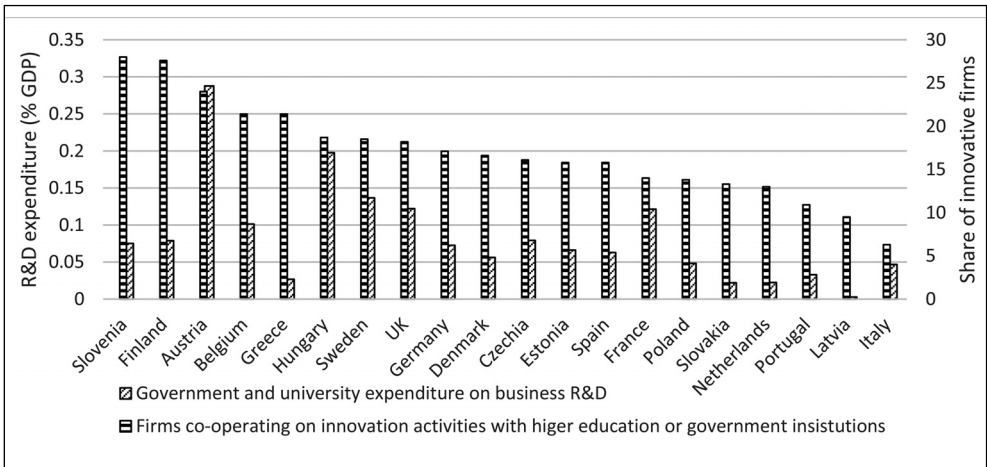
resources. Thus, other subjects get involved in funding of business R&D. The contribution of these subjects to business R&D funding in 2015 is illustrated in Fig. 1.

It is apparent that the level of business R&D expenditure spent in the EU member states varies considerably. While in some countries

(e.g. Austria, Sweden or Finland) firms spend over 2% of national GDP on R&D, in other countries (e.g. Cyprus, Latvia or Romania) this value is lower than 0.5%. However, difference in the business R&D expenditure is not only apparent in the total amount of expenditure spent, but also in its structure. In

Fig. 2:

**Share of innovative firms collaborating on innovation with universities and/ or government institutions compared to business R&D expenditure spent by universities and government in 2015**



Source: authors, based on data from Eurostat and OECD



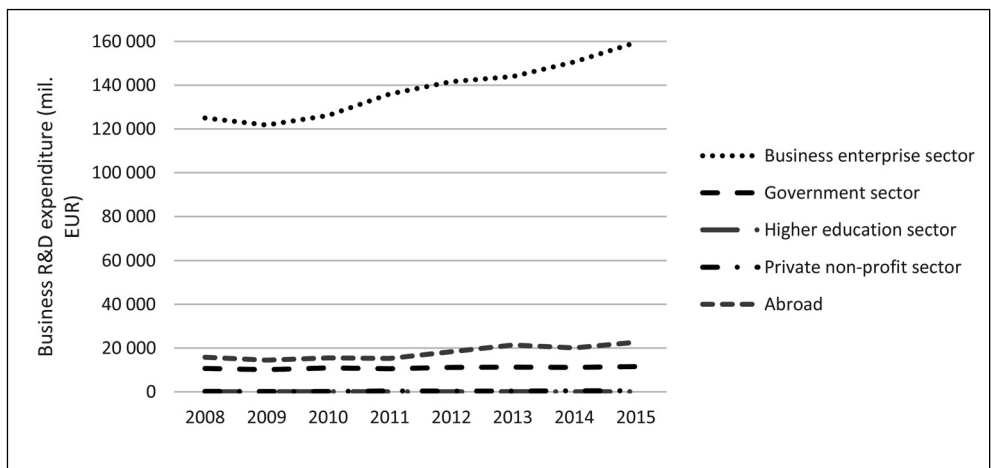
almost all countries under examination (with the exception of Bulgaria), firms mostly use private financial resources to fund their R&D activities, which means they mostly use their own profit or resources from other private enterprises (e.g. commercial banks).

The second most pronounced source of fund regarding business R&D is foreign funds. However, the level of funds from abroad varies across EU countries. It seems that foreign sources used to fund business R&D are mostly used in countries with open economies. The level of public funding also shows various results in monitored countries. Even though the public support of business R&D accounts for a significant part of business R&D expenditure in some countries (e.g. Hungary or Austria), in other countries, the use of public funding to support business R&D is very low. Business R&D funding from sources of universities and private non-profit organizations shows nearly negligible values in all EU member states, which means that these institutions do not significantly contribute to business R&D. These results are in line with economic theory as well as practice.

Considering the relation of the researched issue to Triple Helix model, we also decided to examine the share of innovative firms that used collaboration with universities and/

or government institutions in the innovation process. Since this data is provided by OECD, the data was not available for all EU countries. Thus, we had to remove eight countries (namely Romania, Bulgaria, Croatia, Lithuania, Malta, Cyprus, Ireland and Luxembourg) from this particular analysis. We also included the data regarding the expenditure spent on business R&D by universities and government in order to see if there is a link between these two variables. We can see that countries with the highest share of innovative firms using this form of collaboration included Slovenia, Finland or Greece. There are some parallels between the share of collaborations and the government and university spending on business R&D, but these parallels seem to be inconclusive. While some of the lowest government and university investments in business R&D happen to be in countries that also have very low intensity of collaboration (Slovakia, the Netherlands, Portugal, Latvia), we can also see that some of the countries in which we can find the highest share of collaboration, have quite a low government and university spending on business R&D (Slovenia, Finland). However, the collaboration between firms and other innovation actors within the Triple Helix model is not always financial in its nature, so we find these results plausible.

**Fig. 3: Development of business R&D funding from funds of innovation actors between 2008 and 2015 (as aggregate value of the EU member states, in mil. EUR)**

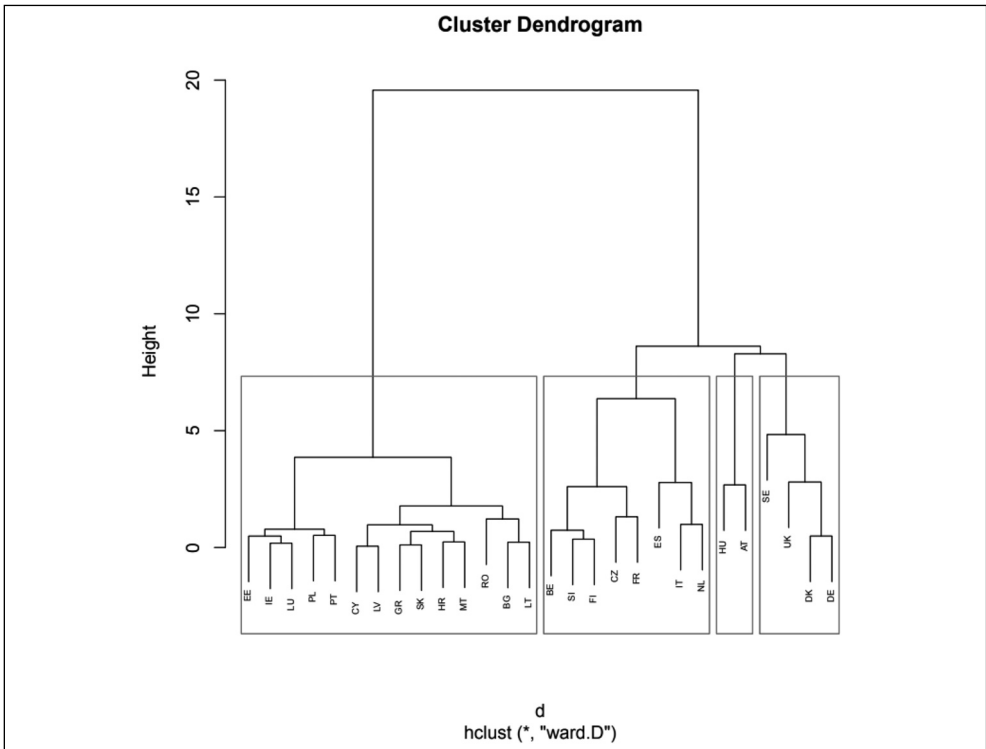


Source: authors, based on data from Eurostat

In order to illustrate development of business R&D funding in the EU over a longer period, contributions of various innovation actors to business R&D expenditure is also examined as an aggregate value of all EU member states. Development over time confirms our assumptions based on the static data from 2015. Long-term dominance of business-based funding can be seen (around 82% of total business R&D expenditure with growing tendency over time), with foreign funds being the second most pronounced source used to fund business R&D. Public funding accounted for 6–7% of total business R&D expenditure in the EU over period under review. Even though the share of external funding (from public sector or from abroad) has increasing tendency in absolute numbers, due to growth of business funds, the share of external funds to business R&D is constant on the same levels.

Based on the available data, we created dendrogram illustrating clusters of countries with similar structure of business R&D funding. Based on the Silhouette coefficient, average value of which is 0.4, we can state that algorithm of hierarchic clustering was chosen appropriately. Results suggest that it is appropriate to divide the EU member states into four clusters. The smallest cluster included two countries (Hungary and Austria), while the biggest cluster comprised of fourteen countries, including two V4 countries – Slovakia and Poland. These clusters suggest that structure of business R&D funding is similar in these countries. We can see some parallels between achieved results of cluster analysis and innovation performance of the EU member states according to Summary Innovation Index published by the European Commission (2019). Countries with higher scores of SII (especially

**Fig. 4:** Dendrogram showing clusters of the EU member states based on the structure of business R&D funding in 2015



Source: authors in statistical system R based on data from Eurostat



**Tab. 1: Average values and standard deviations of variables for each cluster of the EU member states based on the structure of business R&D funding in 2015**

Cluster/Source of fund	Business enterprises	Government	Universities	Private non-profit organizations	Abroad
<b>Cluster 1</b> (EE, IE, LU, PL, PT, CY, LV, GR, SK, HR, MT, RO, BG, LT)	0.351 (0.185)	0.026 (0.020)	0.087 (0.110)	2.86E-04 (0.001)	4.41E-04 (0.001)
<b>Cluster 2</b> (BE, SI, FI, CZ, FR, ES, IT, NL)	1.099 (0.437)	0.073 (0.031)	0.201 (0.114)	4.60E-04 (4.29E-04)	0.001 (0.001)
<b>Cluster 3</b> (HU, AT)	1.140 (0.677)	0.242 (0.063)	0.328 (0.236)	2.66E-04 (3.76E-04)	0.001 (0.000)
<b>Cluster 4</b> (SE, UK, DK, DE)	1.687 (0.463)	0.096 (0.038)	0.191 (0.075)	0.001 (0.001)	0.007 (0.001)

Source: authors based on data from Eurostat.

Note: Table contains average values with values of standard deviations being shown in parentheses (.).

some of the innovation leaders) according to the European Commission can be found in one cluster, which leads us to believe that business R&D affects innovation performance of a country to a certain extent.

Average values of business R&D funding of resulting clusters offer several conclusions. Public and university support of business R&D can mostly be seen in Cluster 2 (comprising of Hungary and Austria). It is also apparent that the highest average value of private business R&D funding can be found in Cluster 4, which includes countries belonging to the group of innovation leaders according to the European Commission. This cluster also shows the highest involvement of foreign funds. Since countries in this cluster belong to the EU member states with the highest innovation performance, we assume that these funds (business and from

abroad) are one of the factors of success of these countries in the area of innovation and R&D.

The occurrence of substitution effect of public R&D funding in the EU member states is examined based on the relationship between business and public funding of business R&D. Theory suggests that public support of business R&D may have positive or negative effect (so-called substitution effect) on private R&D investment. Thus, correlation and regression analysis of relationship between public and private business R&D expenditure is performed. Since many higher education institutions take a form of public universities, we decided to also examine the impact of university funding on business R&D.

Based on the correlation matrix, we can see that positive correlation can be found between

**Tab. 2: Correlation matrix of business R&D expenditure funded by business enterprises, government and universities in the EU member states between years 2008–2015**

	Business enterprise expenditure	Government expenditure	Higher education expenditure
Business enterprise expenditure	1.0000	0.5542	0.2458
Government expenditure	0.5542	1.0000	0.1899
Higher education expenditure	0.2458	0.1899	1.0000

Source: authors in econometric program EViews based on data from Eurostat

**Tab. 3: Results of Granger causality analysis between government and business funds and university and business funds based on 2 time lags in the EU member states in 2008–2015**

Null hypothesis	Observations	F-Statistic	Probability
GOV does not Granger Cause ENT	168	5.95178	0.0032
ENT does not Granger Cause GOV		0.80131	0.4505
UNI does not Granger Cause ENT	168	2.42721	0.0915
ENT does not Granger Cause UNI		0.48268	0.6180

Source: on data from Eurostat

**Tab. 4: Results of regression models examining the impact of university and government business funding R&D on private R&D investment with various time lags in the EU member states between 2008–2015**

	T	T-1	T-2
Constant	-0.3820** (-1.9135)	-0.3102 (-1.2538)	0.0817 (0.3120)
Government expenditure	0.1446* (3.3740)	0.1011** (2.0123)	0.0582 (1.0268)
Higher education expenditure	-0.0191 -1.3283	0.0009 0.0496	0.0526** 2.8526
R <sup>2</sup>	0.9554	0.9520	0.9590
R <sup>2</sup> adjusted	0.9487	0.9436	0.9504
Observations	224	196	168
Durbin Watson statistics	0.9978	1.0269	1.2184
Akaike info criterion	-0.0746	-0.0781	-0.0724

Source: authors in econometric program EViews based on data from Eurostat

Note: T-statistics are shown in parentheses (.) with pertaining significance level of p-values denoted as: \*\*\*/\*\*/\* on the significance levels of 10%/5%/1%.

variables. While the relationship between business and university funds shows negligible correlation, relationship between business and government funds suggests moderate positive correlation. Granger causality was furthermore used to determine if selected variables were appropriate for regression analysis, since correlation does not necessarily imply causation.

Based on the Granger causality tests, we can reject the hypothesis that government funding does not Grange cause business funding and that university funding does not Granger cause business funding. It therefore seems that Granger causality runs one-way in both cases from government and university (at 10 % significance level) funding to business funding. It is therefore appropriate to perform

regression analysis examining the impact of government and university funding on business R&D investment. In order to include possible time lags on this impact, we created several regression models including the impact of public and university funding invested in business R&D in 2013, 2014 and 2015 respectively on private funding of business R&D in 2015. This was done because the impact of public support for business R&D can show its impact not immediately, but after some time, when the provided financial resources are actually spent by firms.

Based on the Akaike information criterion, we decided to closely examine model with time lag of one year. Model examined the impact of public and university funding of business R&D provided in period  $n$  on business investment

in business R&D in period  $n+1$ . Based on the results of the model, changes in public and university funding explain 94.87 % of changes in private business R&D funding. The regression line of the impact of public and university funding on business funding is as follows:

$$\hat{y} = -0.3102 + 0.1011gov + 0.0009uni \quad (1)$$

where *gov* represents the coefficient of government funding and *uni* represents the coefficient of university funding. However, it is important to remark that p-value of T-statistics of university funding in the model suggests that coefficient is not statistically significant. Therefore, we can only interpret the impact of public funding on business R&D investment. Results suggest that government funding has a positive effect on business R&D investment. The model shows that increase of public funded business R&D expenditure of 0.1011 % GDP causes increase in business investment in R&D of 1 % of GDP. We can therefore state that in this case, the substitution effect of public support of R&D&I, which occurs when firms replace their own investment in R&D by public support, does not occur. Thus, we can say that in the EU member states, public support of R&D&I has a positive effect on private R&D investment. Our conclusions are in line with results of many authors examining the occurrence of substitution effect and impact of public support on private R&D investment, which confirm the positive effect of public support on private R&D investment (David, Hall, & Toole, 1999; Ali-Yrkkö, 2005; Choi & Lee, 2017) and are partially in line with other studies (Aristei, Sterlacchini, & Venturini, 2015). Therefore, we see public support of business R&D&I as an important part of innovation and R&D funding in the EU.

## Conclusions

Many studies show that innovation is one of the key elements of growth and competitiveness of firms. However, despite these benefits, some firms do not participate in innovation activities. One of the main reasons for this is the lack of financial resources needed to launch innovation projects. Therefore, other actors contribute to funding of business R&D&I activities.

The aim of the paper was to examine funding of business R&D from resources of main innovation actors and to analyze the impact of public support on private R&D investment in the

EU member states. Two research questions were set out at the beginning of research. First research question was answered by the analysis of structure of business R&D funding. It seems that business R&D is mostly funded from private resources followed by funds from abroad and public funds. Using cluster analysis, we created four clusters of EU member states with similar structure of business R&D funding. The results of cluster analysis were partially in line with the results of European Innovation Scoreboard, which suggests that business R&D funding is one of the factors of innovation performance of a country. Second research question was answered based on the correlation and regression panel analysis, where we found that in the EU member states, substitution effect of public support for R&D does not occur, since public funding of business R&D seems to have a positive effect on private R&D investment. The results suggest that increase in public funding of business R&D of 0.1011 % GDP causes 1 % of GDP growth of private R&D investment. These results are in line with results of many studies, as well as economic theory.

Achieved results provide several conclusions and political implications. We consider business R&D expenditure to be one of the key elements of innovation performance of a country, which is reflected in the EU strategy Europe 2020 which accentuates growth of R&D expenditure as one of its main goals. Even though structure of business R&D expenditure funding varies across the EU countries, we consider public support of R&D&I to be an important part of business R&D funding. Since our results confirm the positive effect of public support for R&D&I on private R&D investment, our suggestion is to intensify the public support of R&D&I in the EU member states and thus, through the leverage effect, increase private R&D investment. This may lead to growth of innovation performance and competitiveness of firms as well as countries.

Even though there are many papers focused on examination of the substitution and crowding-out effects of public support of R&D and innovation, not many of them take into account the structure of business R&D funding and contribution of other actors outside of public sector. We therefore think that one of the main contributions of our paper is international comparison of business R&D funding structure,

which provides interesting political implications at the EU level. However, we realize that our research is not without its restrictions. Since we only focused on business R&D funding, we did not take into account other factors that may impact private R&D investment. It could also be advisory to narrow the analysis of substitution effect of the public support to a certain cluster of the EU countries, which might provide more specific results that may result in recommendations beneficial to national policy makers.

As the study showed, one of the biggest obstacles to business innovation in Slovakia is the lack of resources. The recommendation for sustainable public policy-makers is to continue to increase the volume of public resources towards public and private sector. It is also crucial to support academic and business cooperation mechanisms in terms of the Triple Helix model. This way, the government would motivate enterprises to increase R&D expenditure in order to support the development of science and research base in the country as a source of its innovative development.

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