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How Public R&D Support Affects Research Activity of Enterprises: Evidence from the Czech Republic

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Abstract

Public support for research and development (R&D) in business sector is usually justified by the argument about market failure. New knowledge produced by research and development has some features of public good, which causes underinvestment in private R&D activities. From the social development point of view, it is desirable to produce and diffuse new knowledge. The article seeks to answer the question what impact a change in the amount of public support for R&D has on research activities of private enterprises. This paper tries to bridge a gap in the literature dealing with impact of R&D policy in emerging innovation systems in Central Europe. Our research is carried out on the example of the Czech Republic and its regions. We evaluate direct and indirect R&D support in the period 2007–2015, and we pay attention to three variables representing R&D in businesses: business expenditures on R&D, number of R&D employees in businesses and number of R&D workplaces in businesses. We calculate year-on-year changes in all the observed variables, and the relation between the public support and research activities of enterprises is assessed through descriptive statistics, measures of association and regression models. Our analyses proved a positive impact of R&D support on companies' own expenditures on R&D and the number of employees. The relation between R&D support and number of workplaces seems to be quite weak. The paper also discusses limitations of the research and implications for public policy.

Keywords Research and development · Innovation · Public support · Expenditures on R&D · Region · Czech Republic

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Introduction

Innovations are perceived as an important factor for economic and social development of regions and countries. They represent a mean for economic growth, productivity increase, new jobs and wealth creation. They can also serve for solving of various social and environmental problems. With respect to the level of novelty, they are classified into incremental and radical innovations (Beck et al. 2016). Research and development (R&D) is one of the most important sources for innovations (Kraftová and Miháliková 2011; Barge-Gil and López 2014). As an example of other sources of innovation, we can name inspiration from business partners and customers, industry and market structure change, process needs and chance (Drucker 2015). However, R&D is essential for launching of the radical innovations. R&D creates new knowledge and enables companies to create radical innovations with high value added and a more significant socio-economic impact. Innovations are commonly attributed to entrepreneurs and enterprises (Schumpeter 1939; OECD 2005; Dodgson 2017), but they can arise in non-business sphere as well. In this context, the terms usually used are social innovations (Agostini et al. 2017) or public sector innovations (Potts and Kastelle 2010).

The most developed countries (innovation leaders) invest more than 3% of gross domestic product (GDP) in R&D, and a significant part of it is financed by business. It is generally accepted that private sector finances a large proportion of R&D expenditures in top-performing countries (Crespi et al. 2016). On the other hand, the role of public sector in support for research, development and innovations (R&D&I) is of crucial importance and we can observe strong emphasis on innovation and research policy in the countries that are considered to be the innovation leaders (Gál 2014; Mynarzová and Štverková 2015; Prokop and Stejskal 2017). Besides their economic and social importance, the basic interest of public authorities in this field comes from the fact that innovative firms and industries are generally regarded as being not only at the forefront of the technological frontier but also responsible for advancing it (Faggian and McCann 2009). Public policy should use various policy tools to create an environment that stimulates companies to introduce new innovations. Importance of innovations for economic and social development was also confirmed by the Europe 2020 Strategy (European Commission 2010), and increase in expenditures on R&D is the main way to improve the innovation performance of the European Union.

The scientific literature on innovation emphasizes that market failures and imperfections discourage companies from investing in R&D (Beck et al. 2016; Bronzini and Piselli 2016). Results of R&D have a character of a public good, because knowledge is regarded as non-rival and non-excludable goods (Arrow 1962). New knowledge cannot be fully appropriated, and due to knowledge spillovers, the firm's rivals may be able to free ride on its investment (Aerts and Schmidt 2008; Crespi et al. 2016). On the other hand, creation and diffusion of new knowledge is vital for the development of society. The above-mentioned imperfect appropriability causes underinvestment in R&D activities, which means that the level of R&D expenditures is below the socially desirable optimum (Weber and Rohracher 2012; Brown et al. 2017). In other words, knowledge spillovers (Fischer et al. 2009) cause a tension between social and private rate of returns of R&D. Furthermore, results of research projects are uncertain and come in long-term perspective, which means that profits from innovations are uncertain and long term too. Public funding reduces the R&D costs for companies to a level at which the research projects become profitable for investors (Aerts and Schmidt 2008). The willingness of firms to cooperate with others is also limited (Arvanitis and Bolli 2013; Soukopová et al. 2017). This market imperfection is perceived as a rationale for policy interventions (McCann and Ortega-Argilés 2013). It was proved that participation in supported collaborative projects increases the willingness of research entities to cooperate in other projects (Schiavone and A Simoni 2016).

We would like to emphasize that research activity is spatially uneven, which is also proved by a large strand of literature (Klímová and Žítek 2012; Hudec and Procházková 2015; Hlaváček and Sivíček 2017). Individual regions have different prerequisites for conducting R&D, and we can find both regions with very high level of research activity and regions with very low level of the activity (Klímová and Žítek 2017). These disparities are often connected with the problem of organizational thinness, which is the case when a region lacks sufficient agents to form a functioning innovation system (Isaksen 2001). They are also related to other local factors such as economic diversity and specialization (Ženka et al. 2017). The role of place in development of R&D and innovations is broadly discussed especially in the framework of the regional innovation systems concept (Autio 1998; Boschma 2005; Asheim et al. 2011).

The paper seeks to answer the question how public support for R&D affects business expenditures on R&D, R&D employment in businesses and number of R&D workplaces in businesses. Our attention is focused on both direct and indirect public support for R&D, which is provided to stimulate research activities in the Czech Republic. The aim of the paper is to assess what impact a change in the amount of public support for R&D has on Czech enterprises' research activities represented by expenditures, number of employees and number of workplaces. We have set three hypotheses that should be examined through our research:

H1: With an increasing amount of public support for R&D, the business expenditures on R&D increase.
H2: With an increasing amount of public support for R&D, the number of R&D employees in business sector increases.
H3: With an increasing amount of public support for R&D, the number of R&D workplaces increases.

There is a large strand of literature dealing with the relationship between public support for R&D and research activities of companies. As the following section shows, these studies are usually focused on big and developed countries with long history of market economy. Analyses aiming at small and transitive economics with emerging innovation systems are published rarely as they are slightly neglected in research. We would like to brige this gap in the existing literature. We intended to examine public support impact on an economy with special features that has to solve similar problems as other countries in Central Europe. The Czech Republic started transforming its economy 30 years ago, but its economic performance is still worser than in countries with long market tradition. It is small open economy, which is dependent on international trade. Research, development and innovations became the policy priority after accession to the European Union, and they are perceived as the main source of the competitive advantage nowadays. Nevertheless, the history of innovation policy is too short and this country, together with other countries in Central Europe, belongs to the group of moderate innovators in accordance with the European Innovation Scoreboard (European Commission 2018). We also believe that our study will contribute to the discussion about efficient research policy in this geographical area and provide an inspiration for future research.

The paper is organized as follows: The next section gives an overview of scientific literature dealing with the impact of R&D support. The third section describes statitistical data and variables, explains the methodology used for our study and informs about support for R&D in the Czech Republic. The fourth section presents results and is divided into two parts, one focused on descriptive statistics and measures of association and the other focused on regression models. The fifth section discusses the results with respect to policy implications, research limitations and possibilities for future research. Finally, the "Conclusions" summarizes the main findings.

Literature Review

Research projects in businesses can be supported in a direct or an indirect way. The direct way is based on providing subsidies to companies in public tenders. The indirect support of research and development usually lies in some type of tax incentives. In general, the following main kinds of indirect support can be used: tax deduction (allowance) and discount (credit), discounts (or benefits) for social insurance, progressive financial depreciation for long-term assets and customs regulations (e.g. Janeček et al. 2012; OECD 2016). Direct subsidies raise the private marginal rate of return on investment in R&D, whereas tax incentives reduce the cost of R&D (David et al. 2000). In recent years, a wide range of scientific articles evaluating public support for R&D all over the world have been published. In this section, we analyse the literature dealing with effects of both direct and indirect forms of public R&D support in businesses and discussing their advantages and disadvantages for governments as well as companies. We agree with the statement that the currently available analyses are characterized by heterogeneity of methodologies (Gershman and Kitova 2017). Authors of these research studies use various types of data, data sources and methods. Their studies are usually based on micro-data from secondary statistical resources, and they mostly use some type of regression estimates of the public support effects on business research activities. However, significat part of them confirmed a positive impact of public aid on research and innovation activities.

Czarnitzki et al. (2011) recommended providing the indirect support rather than the direct type. They pointed out the government failure that is usually connected with direct support, whereas this risk is minimized in the case of indirect support. They also stressed that indirect support is considered to be a neutral form of encouragement to R&D as all companies, irrespective of the industry, size and innovation activity, can claim it. In other words, this type of support is not selective and is compatible with economic competition. Tax incentives are market-based, and thus, they are considered more neutral than direct support. On the other hand, it means that government cannot influence the structure of research and choice of R&D projects (Elschner et al. 2011). Some authors argue that private companies use indirect support to implement projects with high private returns inducing investments with a short-term horizon that would have been implemented in any case, i.e. without public aid (Crespi et al. 2016).

Berube and Mohnen (2009) argued that companies should combine both types of support. They found out that companies using both instruments introduce more new products than their counterparts that only received the indirect support. Busom et al. (2014) connected the type of public support with the character of companies. They stated that direct and indirect funding are not perfect substitutes with respect to their ability to reach firms facing barriers associated to market failures. Subsidies may be better suited than tax reliefs to encourage companies to start doing R&D, which is valid especially for young knowledge-based companies. Brown et al. (2017) tested the relation between indirect support and the character of industry. They argue that private R&D investment is below the socially optimal level, particularly in high-tech industries, and that the indirect support is more effective at promoting low-tech R&D, but it is not sufficient for promoting high-tech R&D.

Many researchers discuss the issue of crowding-out effect (e.g. David et al. 2000; González and Pazó 2008; Crespi et al. 2016), i.e. if public subsidies replace private investments or not. Most of these studies state that the crowding-out effect was not confirmed (or it is lower in the case of indirect support). Aerts and Schmidt (2008) investigated whether public R&D subsidies crowd out private R&D investment in Flanders (Belgium) and Germany. They rejected the crowding-out effect, because, on average, the R&D intensity of German and Flemisch granted companies was significantly higher than the R&D intensity of non-granted companies. Huergo and Moreno (2017) compared the effect of different types of public direct support (subsidies and loans) in Spain. They rejected the crowding-out effect for all types of direct support and stated that any type of direct aid clearly increases the probability of conducting R&D activities. González and Pazó (2008) paid attention to subsidies for Spanish manufacturing firms and confirmed the absence of crowding-out effect between public and private investments in R&D. They argued that some firms, mainly small firms operating in low technology sectors, might not have engaged in R&D activities in the absence of subsidies. Similar conclusions have been confirmed by Choi and Lee (2017) on the example of Korean small, but high-tech (biotechnology), firms. Hud and Hussinger (2015) analysed the impact of direct public funding on R&D investment of small- and medium-sized enterprises in Germany during the recent economic crisis. They proved an overall positive effects of subsidies on firms' research activity, but some crowding-out effect during 2009 was observed. This temporary crowding-out effect was caused by reluctant investment behaviour of granted companies rather than by government countercyclical innovation policy (expansion of the grant programme) during the crisis. Montmartin and Herrera (2015) empirically proved a small crowding-out effect for both direct and indirect support in selected OECD countries, and they consider the two types of support to be substitutes for stimulating business expenditures on R&D. At the same time, they argue that the leverage effect on private investment can be achieved, if the policy represents a sufficient level of subsidization for companies, and that the crowding-out effect is likely to arise, if the policies represent a low level of subsidization for them.

Some authors also deal with the impact of public support on employment in R&D (Thomson and Jensen 2013; Dortet-Bernadet and Sicsic 2017). Both mentioned studies analysed impact of direct and indirect support on R&D employment (in OECD countries and France) and proved that both instruments have a positive effect. Ali-Yrkkö (2005) confirmed a positive and economically significant impact of public R&D

funding on R&D employment in Finland; nevertheless, the impact can be different in economic crisis and economic boom. Afcha and García-Quevedo (2016) analysed the effects of public R&D subsidies on the level of qualification of R&D employees in Spanish businesses. They proved that R&D subsidies increase the number of R&D employees and that companies recruit more qualified human resources (e.g. PhD holders) in the subsequent years after support reception.

At the end of the literature review, we would like to mention that the public support for R&D has another relation to market failure. It was argued that public support is justified by the existence of market imperfections lying in free knowledge spillovers. Nevertheless, at the same time, firms not receiving support may be also affected by the public aid, because the granted research produces knowledge spillover effect too (Klette et al. 2000).

Data and Methodology

The paper tries to answer the question what impact a change in the amount of public support for R&D has on research activities of Czech enterprises. The attention is paid to three variables representing R&D in businesses: business expenditures on R&D (BERD), number of R&D employees in businesses (FTE) and number of R&D workplaces in businesses (WP). The last variable de facto expresses the number of enterprises with their own research activity. Public support for R&D (SUPPORT) consists of direct and indirect support. Despite the fact that some foreign studies evaluate both types of support separately, we do not think that this way is suitable and possible for our research. With regard to the available statistical data, it is not possible to distinguish effects of direct support from effects of indirect support. Therefore, it is necessary to evaluate both types of support together. Figure 1 indicates the relation among the examined variables.

Table 1 shows the list of variables used in our analysis. The input data were gained from several databases published by the Czech Statistical Office (CSO). The Czech Statistical Office is a central body of the state administration of the Czech Republic which is responsible for retrieval of statistical data, their processing and publishing. Therefore, its data represent the most comprehensive and reliable information source

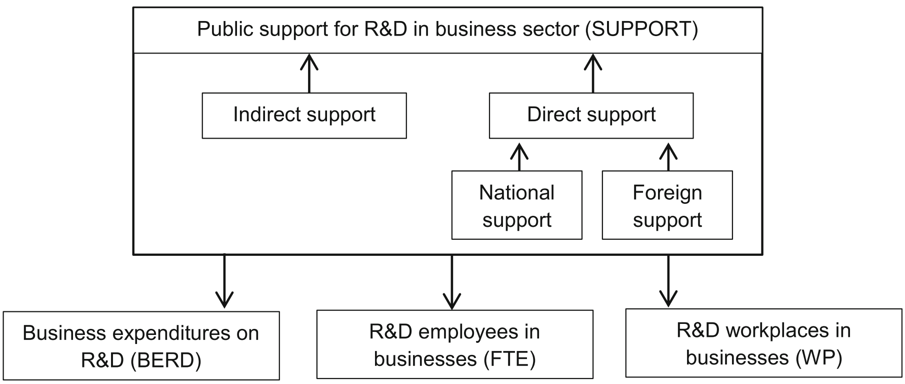

Fig. 1 Scheme of research rationality. Source: authors' own processing

that can be achieved. The data on research activity (BERD, FTE, WP) and direct support are collected by CSO in the framework of the Annual Survey on Research and Development. By law, this questionnaire must be filled out by all entities that carry out research and development. Statistics about indirect support are published annually by the Czech Statistical Office and their calculation is based on the data from income tax returns provided by the Financial Administration of the Czech Republic. The methodical principles for collection of all statistical data are based on the Frascati manual (OECD 2015).

From the territorial point of view, the analysis is carried out at the level of 14 Czech regions (NUTS3 regions), which is the lowest territorial unit for which the statistical data are monitored (see Fig. 2). The Czech Republic lies in the Central Europe, and it can be described as a quite young market economy. The transformation from the central planned to the market economy started in 1989 after the Velvet revolution. Whereas some regions managed to adapt to changes in the economy better, others (particularly, old industrial regions) were not so successful. In 2004, the Czech Republic became a member state of the European Union. Since entering the EU, national as well regional governments have paid more attention to research and innovation policy.

A methodical limitation that has been consulted with the Czech Statistical Office lies in the impossibility to clearly distinguish an important amount of support between Prague and the Central Bohemian Region. For this reason, data values for these two regions are consolidated. This procedure can be justified by a wide range of economic arguments that are all grounded in the close links between these regions and the position of Prague representing a natural centre of the Central Bohemian Region.

In our paper, we evaluate the period 2007–2015. Considering that year-on-year changes of variables are evaluated, all results refer formally to the period 2008–2015. We evaluate the utmost length of time, which is determined by the data availability, particularly availability of data about indirect support at the regional level that have been monitored since 2007. Analyses are based on a dataset where cases are represented by 13 NUTS3 Czech regions, and variables of the interest (SUPPORT, BERD, FTE and WP) are calculated as year-on-year average changes of R&D variables across the years 2008–2015. As the year-on-year changes in variables are subject to irregular fluctuations

Table 1 List of variables

Variable	Description	Data source
BERD	Business expenditures on R&D (financial unit)	Czech Statistical Office (CSO 2016)
FTE	Number of R&D employees in businesses expressed as full-time equivalent (non--financial unit)	Czech Statistical Office (CSO 2016)
WP	Number of R&D workplaces in businesses (non-financial unit)	Czech Statistical Office (CSO 2016)
SUPPORT	Sum of direct and indirect public support for R&D (financial unit)	Czech Statistical Office (CSO 2017) + internal database on financial flows among sectors in R&D provided by CSO + authors' own calculation

Source: authors' own processing

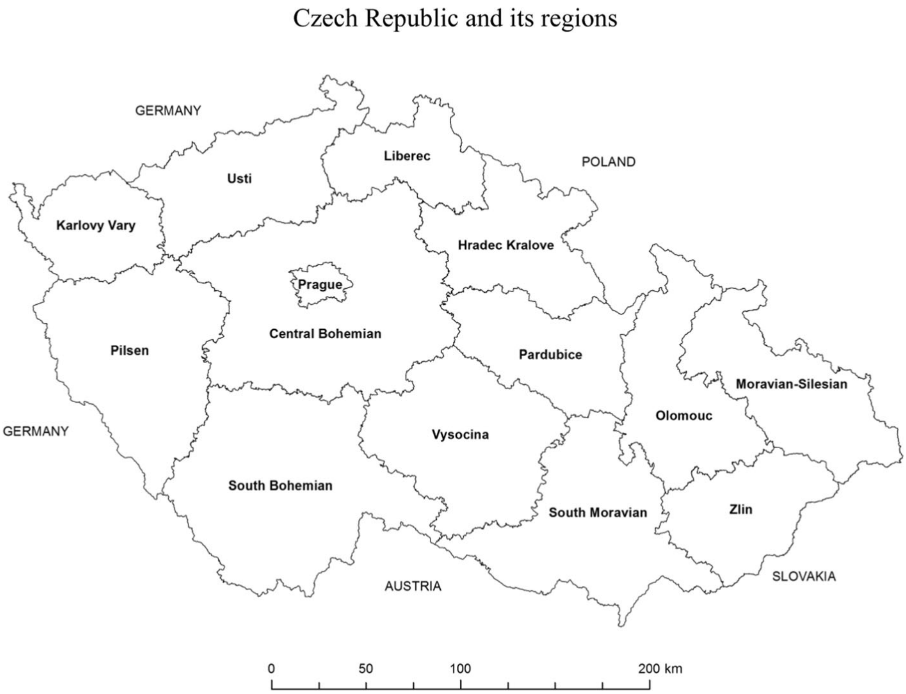

Fig. 2 Czech Republic and its regions. Source: authors' own processing

and reach both negative and positive values, it is necessary to operate with average values of changes in the reference period. Because the sample of 13 region units is the population itself (in a sense of all Czech units at level NUTS3 with adjustment to a merge of Prague and the Central Bohemian Region), there is no need to perform inferential statistics. Thus, all sample statistics are equal to population statistics.

Analyses were conducted in the following steps. First, elementary descriptive statistics of public R&D support and individual variables representing R&D in businesses were performed. Further, measures of association (Pearson correlation coefficient and Spearman correlation coefficient) between public R&D support and individual R&D variables in businesses were calculated. Finally, regression models interpreting variance of individual R&D variables in businesses by the means of public R&D support were developed. Parameters of linear regression models were estimated by the standard ordinary least square method (OLS), and the quality of the models was examined.

For the sake of completeness, we should explain what support for R&D can be obtained by enterprises in the Czech Republic and what the presented statistics include. Direct support for research and development is provided in the form of subsidy (grant), and it is financed from public national resources (state budget, in particular) and public foreign resources. The direct public aid to enterprises is usually designed for conducting applied research, because carrying out basic research is less frequent in the private sector. Czech direct support for R&D is administered mainly by the Technology Agency of the Czech Republic (programmes such as Alpha, Gamma and Epsilon). Furthermore, various types of applied research are also sponsored by individual ministries in compliance with their competences (e.g. Ministry of Industry and

Trade, Ministry of Defence, Ministry of Health). Public foreign resources are financed by the European Union (structural funds and community programmes) and other international organizations and foreign national government institutions. The main foreign sources for Czech companies are represented by operational programmes, in particular OP Enterprise and Innovation (2007–2013) and OP Enterprise and Innovation for Competitiveness (2014–2020) and EU framework programmes (7th Framework Programme and Horizon 2020).

Indirect support for research and development has been provided in the Czech Republic since 2005 in the form of expenses as deductible items from the tax base of income tax. It means that the taxpayer can deduct the expenditures on research and development from the tax base, and in reality, these expenses are deducted twice. They are first deducted within the tax base calculation and for the second time they are deducted from the calculated tax base. The basic condition for using this type of support is that the same research project (and the same expenses) cannot be subsidized by any type of direct public aid. The innovative company has to decide whether it prefers direct or indirect form of support.

Results

Results are split into two sections. The first section ("Descriptive Statistics and Measures of Association") focuses on descriptive statistics of all regional units under research. Further, the measures of associations are performed. The second section ("Regression Models of R&D Variables in Businesses") presents regression models and their estimates. Both parts aim to examine the relationship between the change in the amount of public R&D support (SUPPORT) on one hand and the change in R&D variables in businesses such as business expenditures on R&D (BERD), number of R&D employees in businesses (FTE) and number of R&D workplaces in businesses (WP) on the other hand. The business expenditures on R&D represent a financial output (in millions of Czech crowns), whereas the number of R&D employees in businesses and the number of R&D workplaces in businesses represent non-financial outputs (numbers).

Descriptive Statistics and Measures of Association

Descriptive statistics such as average, standard deviation, minimum value and maximum value were calculated for all variables under research on the basis of year-on-year changes across 2008–2015. They are presented in Table 2. The highest average annual increase in public R&D support is achieved by Prague and the Central Bohemian Region followed by the South Moravian Region. The same order is true for BERD, whereas the highest average annual increase in number of R&D employees and number of R&D workplaces is achieved by the South Moravian Region followed by Prague. These two regions are considered to be outliers as their average values of all examined variables are much higher than for the rest of the sample. All the mentioned regions are generally perceived as innovation leaders among Czech regions; therefore, it is possible to expect that more developed regions have a higher absorptive capacity for drawing public support.

The worst regions with respect to the average annual increase in public R&D support are the Pardubice and the Olomouc Regions as their averages across time are negative. The benefit of across time aggregated variables instead of evaluating individual years themselves is evidenced by the Liberec Region. This region achieved both the highest negative (decrease) and the highest positive change (increase) in public R&D support.

Except public R&D support, all the other average variables across all units achieved positive values. This can be interpreted as average growth of considered variables in all

Table 2 Year-on-year changes in public R&D support and R&D variables across the years 2008–2015

Region	Average	Min	Max	St. Dev	Average	Min	Max	St. Dev
	SUPPORT				BERD			
Prague + Central Bohemian	161.57	− 168.11	595.33	262.07	714.38	− 1601.32	3048.17	1573.21
South Bohemian	9.86	− 50.35	42.38	33.75	79.99	− 0.60	171.58	73.68
Pilsen	30.4	− 63.69	126.78	74.34	233.40	− 174.81	620.66	321.80
Karlovy Vary	3.78	− 4.00	18.96	7.14	13.98	− 76.39	66.00	43.43
Usti	16.56	− 54.05	115.00	63.56	33.00	− 149.04	205.70	108.16
Liberec	10.17	− 589.51	740.20	370.35	99.39	− 251.05	295.21	176.71
Hradec Kralove	23.51	− 238.25	266.66	135.51	67.22	− 116.95	180.49	96.22
Pardubice	− 1.65	− 70.06	73.45	57.61	50.94	− 165.33	231.65	159.80
Vysocina	22.13	− 39.98	104.29	42.78	115.15	1.36	302.61	117.94
South Moravian	63.57	− 172.20	344.37	166.48	674.85	193.34	1897.31	574.72
Olomouc	− 3.27	− 64.03	57.77	43.45	79.71	− 90.35	267.39	116.41
Zlin	0.74	− 147.93	162.24	92.04	77.24	− 128.86	255.58	138.03
Moravian-Silesian	17.22	− 111.71	182.73	91.50	174.24	− 361.52	938.48	409.18
	FTE				WP			
Prague + Central Bohemian	323.60	− 575.29	1086.26	544.77	14.88	− 11.00	44.00	20.50
South Bohemian	44.83	− 49.40	119.72	50.46	2.88	− 2.00	11.00	4.16
Pilsen	132.98	− 315.49	521.77	237.09	3.50	− 13.00	16.00	8.60
Karlovy Vary	17.76	− 8.30	48.02	19.3	0.38	− 4.00	4.00	2.56
Usti	18.67	− 58.72	111.63	66.06	3.75	− 5.00	14.00	7.63
Liberec	73.25	− 62.01	244.96	108.35	5.13	1.00	12.00	3.91
Hradec Kralove	42.21	− 147.33	128.32	98.50	3.88	− 3.00	20.00	7.20
Pardubice	12.84	− 145.12	180.17	116.53	4.25	− 4.00	15.00	6.84
Vysocina	54.37	− 21.85	128.22	55.17	5.00	− 1.00	13.00	5.18
South Moravian	512.19	82.03	1312.82	360.27	17.88	− 9.00	56.00	18.54
Olomouc	50.58	− 61.27	166.71	85.68	4.63	− 11.00	11.00	7.91
Zlin	25.47	− 138.59	154.22	106.40	6.25	− 2.00	24.00	9.18
Moravian-Silesian	161.63	− 24.31	428.42	155.72	9.00	− 11.00	27.00	12.4

Source: authors' own calculation based on CSO (2016, 2017). Note: SUPPORT and BERD are expressed in mil. CZK, current prices; FTE and WP are expressed as numbers regions in the Czech Republic. Particularly noticeable is the fact that growth of BERD has been a higher than the growth of public R&D support in all regions. Further, in the Vysocina and the South Moravian Regions, the values of maximum and minimum changes in BERD are positive, which means that in these regions, BERD increased across all the observed years and regardless of economic crisis.

Considering employment in R&D in enterprises, besides Prague with the Central Bohemian Region and the South Moravian Region, also the Moravian-Silesian and the Pilsen Regions achieved average values above 100 of measurement units. Further, the South Moravian Region is the only region where employment increased every year. This is evidenced by the minimum and the maximum values of this variable.

The low increase in the number of R&D workplaces in enterprises has only been observed in the Karlovy Vary Region. However, this is not a surprise as the Karlovy Vary Region reaches very low values of this variable each year (from 15 to 23).

The main purpose of this article is to examine the impact of the amount of the public R&D support on variables representing R&D in businesses. As a part of explanatory data analysis, the measures of association were calculated first. The average values of year-on-year changes of all considered variables were treated as input data for the calculation of both Pearson and Spearman correlation coefficients. These values are demonstrated in Table 3.

All the observed correlation coefficients are positive which can be interpreted as a positive association between public support for R&D and each individual R&D variable in businesses. However, Pearson correlation coefficient is not robust to outliers and, as we have mentioned above, mainly Prague with the Central Bohemian Region and the South Moravian Region are outliers with respect to all considered variables. For this reason, Spearman correlation coefficient is more appropriate for these data. Further, the discrepancies between Pearson and Spearman correlation coefficients in the case of BERD–SUPPORT association and WP–SUPPORT association suggest a different than linear trend in regression models performed in "Regression Models of R&D Variables in Businesses". On the other hand, the accordance between FTE–SUPPORT Pearson and Spearman coefficients suggests a linear trend.

However, based on these coefficients, the positive impact of public R&D support on each individual R&D variable in businesses is plausible.

Regression Models of R&D Variables in Businesses

In this section, there are three final models of R&D variables in businesses. The only explanatory variable in all three models is the public support for R&D variable. In the

Table 3 Pearson and Spearman correlation coefficients

	Pearson correlation coefficient	Spearman correlation coefficient
BERD and SUPPORT	0.8835	0.6923
FTE and SUPPORT	0.7085	0.7088
WP and SUPPORT	0.7336	0.3461

Source: authors

process of model development, Prague with the Central Bohemian Region showed to be such an influential unit that we decided to exclude it from the sample to avoid its heavy effect on parameter estimates. Thus, all the results in this section are related to all Czech NUTS3 regions except Prague and the Central Bohemian Region.

Further, models have a predictive nature. Thus, causal interpretations of SUPPORT on other variables based on parameter estimates are correct only under this causal assumption. The presented p values of parameter estimates are irrelevant in the context of our observed data, which represent the entire population. However, we perform them just to show how significant the estimates would have been if we had the regular sample (different from population).

Modelling Business Expenditures on R&D

The final regression model for BERD variable has the following form:

$$BERD = \beta_0 + \beta_1 \exp\left(\sqrt{SUPPORT + 3.28}\right) + \varepsilon \tag{1}$$

where ε follows normal distribution.

The parameter estimates of this model are presented in Table 4.

The multiple R^2 value is equal to 0.9215. This means that 92% of variance of BERD variable is explained by the SUPPORT variable. As the estimate $b_1 = 0.1701$ is a positive number and function $\exp\left(\sqrt{\text{SUPPORT} + 3.28}\right)$ is an increasing function across the entire domain, we may interpret the effect of SUPPORT on BERD as positive. Evaluations of model residuals were also accomplished and the p value = 0.2257 of Shapiro–Wilks normality test does not reject the hypothesis of normal distribution of residuals at a 5% significance level.

The support has a positive impact on companies' own expenditures on R&D, which is a key prerequisite for their long-term position in a globally competitive environment. However, it should be noted that there are significant regional differences in the achieved results. These disparities are difficult to interpret at the regional level. The evaluation is also accompanied by other limitations, which are discussed in "Result Limitations and Inspiration for Future Research".

Modelling the Number of R&D Employees in Businesses

The final regression model for FTE variable has a form:

$$FTE = \beta_0 + \beta_1 SUPPORT + \varepsilon \tag{2}$$

Table 4 Estimates of Model 1

	Estimate	Std. error	t value	p value
Intercept	77.9306	16.2274	4.80	0.0007
$\exp\left(\sqrt{\text{SUPPORT} + 3.28}\right)$	0.1701	0.0157	10.84	0.0000

Source: authors

where ε follows normal distribution.

The parameter estimates of this model are presented in Table 5.

The multiple R^2 value is equal to 0.7653. This means that 76.5% of variance of FTE variable is explained by the SUPPORT variable. Quality of this linear model was anticipated as the Pearson and Spearman correlation coefficients for FTE and SUPPORT were almost the same. As the estimate $b_1 = 6.64$ is a positive number and the trend function is linear, we may interpret the effect of SUPPORT on FTE as positive. Evaluations of model residuals were also accomplished and the p value = 0.611 of Shapiro–Wilks normality test does not reject the hypothesis of normal distribution of residuals at a 5% significance level.

Our research confirmed that with increasing public support for R&D, the number of research job positions in enterprises increases. However, as in the previous model, we are aware of the fact that our results have some limitations, which are discussed in "Result Limitations and Inspiration for Future Research".

Modelling the Number of R&D Workplaces in Businesses

The final regression model for WP variable has a form:

$$WP = \beta_0 + \beta_1 SUPPORT + \beta_2 SUPPORT^2 + \varepsilon \quad (3)$$

where ε follows normal distribution.

The parameter estimates of this model are presented in Table 6.

The multiple R^2 value is equal to 0.7625. This means that 76.2% of variance of WP variable is explained by the SUPPORT variable. However, here the interpretation of model parameter estimates is not straightforward. Though the explained variance is high, parameter estimates $b_1 = -0.088773$ and $b_2 = 0.004677$ are very small in absolute values compared to the scale of the dependent WP variable. Further, the quadratic function is not monotonous. The convex graph of the quadratic function has its minimum for SUPPORT = 9.49. Thus, a small positive impact of SUPPORT on WP can be observed only for the SUPPORT greater than 9.5 measurement units. Evaluations of model residuals were also accomplished, and the p value = 0.6339 of Shapiro–Wilks normality test does not reject the hypothesis of normal distribution of residuals at a 5% significance level.

This weak result is not a surprise as the Spearman correlation coefficient between SUPPORT and WP was only 0.3461 (and on top of that Prague + the Central Bohemian

Table 5 Estimates of Model 2

	Estimate	Std. error	t value	p value
Intercept	− 11.037	27.648	− 0.399	0.698147
SUPPORT	6.640	1.163	5.711	0.000195

Source: authors

Table 6 Estimates of Model 3

	Estimate	Std. error	t value	p value
Intercept	4.322319	1.091592	3.960	0.00331
SUPPORT	− 0.088773	0.102237	− 0.868	0.40778
SUPPORT^2	0.004677	0.001658	2.820	0.02003

Source: authors

Region was excluded in its calculation). It seems necessary to conduct other research for more provable verification of the relation between SUPPORT and WP.

Discussion

As already indicated in the previous sections of the paper, there is a wide range of issues that need to be discussed. This concerns both factual issues and methodical foundations and findings. Therefore, the discussion is divided into two parts: the first one is devoted to the limitations of the presented results and possibilities of further research; the second one is devoted to the general matters of public support and policy implications.

Result Limitations and Inspiration for Future Research

All measures of the association between public R&D support on the one hand and each of the three R&D variables representing R&D in businesses on the other hand were positive. The strongest relationship was observed between public support and business expenditures on R&D. At the same time, the descriptive statistics demonstrated that the growth of BERD was higher than the growth of public R&D support in all observed regions. These statistics also proved that the highest average annual increase in public R&D support was achieved in the regions that are considered innovation leaders. It is in accordance with some theoretical assumptions that more developed regions are able to take full advantage of offered public resources. The regression models we performed in the previous chapter fully confirmed our hypotheses H1 and H2 that an increasing amount of support leads to increased BERD and FTE. A higher impact can be observed in expenditures on R&D. Hypothesis H3 was confirmed to some extent only. A positive impact of support on the number of workplaces is only relevant for public support greater than 9.5 measurement units, and the results are weaker. The impact of public support on the number of R&D workplaces is only of marginal importance. The results reached by our analysis are valid for the Czech Republic and cannot be easily generalized. We suppose that similar effects would be observed in countries with similar features, particularly in transitive economics with emerging innovation systems in Central Europe.

We consider it correct to point out some limitations of our research. These limitations are of general nature and can be encountered in other similar analyses. We do not think that these limitations diminish the significance of our results; furthermore, we have taken them into account in the methods used. On the contrary, we perceive them as inspiration and space for further research.

One of the basic limitations of our research is the fact that the beneficiaries of public R&D support are not the regions themselves but individual enterprises in the regions. However, a representative evaluation of the public aid impact at the enterprise level is practically impossible due to the unavailability of suitable statistical data. If we wanted to assess the direct impact of public support (to quantify the financial effect on the region), data for the control group of regions that are unsupported and comparable would have to be available. However, such data do not exist and cannot exist.

Another limitation of our research is the period for which the research was carried out, although we evaluate the utmost length of time. Part of this period was under the economic crisis, which influenced investment optimism and investment behaviour of businesses. This may have led to a decrease in R&D expenditures in some years (especially around 2009). On the other hand, the impacts of the economic crises in the Czech Republis was not so enormous as in other countries in Europe. Furthermore, in two Czech regions, no decrease in the BERD over the whole period was confirmed. The first of them is the South Moravian Region, which reaches the highest BERD as percentage of gross domestic product. The second one is the Vysocina Region, whose BERD is significantly lower. Prague and the Central Bohemian Region showed a decrease in BERD only at the beginning of the reference period; however, their BERD has grown continuously since 2010. The period was also affected by the guidelines of public aid. This is connected with the turn of the EU programming period when the old programmes were terminated, but the project calls relating to the new period were still limited. Therefore, the future research should focus on a longer period in order to eliminate the effects of the economic crisis and changes in support programmes.

Our research has proved that the leveraging effect of public support differs among regions. It was observed that some regions are able to use public support better than others and to increase business R&D expenditures more. Future research should pay attention to explaining the causes of these regional disparities and the possible ways of their elimination. It can be assumed that these disparities are related to the level of research activity of the regions and their ability to exploit the offered public support.

Future research should focus on the R&D characteristics of the granted firms and alternatively on their comparison with the R&D characteristics of the firms that did not apply for the public aid or did not receive any. Ideally, this could be investigated in the form of question survey among enterprises. The second option would be to analyse firm-level statistical data (micro data), but this would not allow the comparison with any control group. These methods make it possible to really confirm or disprove the existence of crowding-out effect, which is partly assumed by the theory. Firm-level data would also allow us to assess and differentiate between the effects of the direct and the indirect support.

Public Policy Implications

On the basis of our analyses and the literature review, we would like to discuss some policy implications. When presenting any conclusions, we have to keep in mind that the analyses have been carried out for the Czech environment, and therefore, the conclusions can be valid for similar countries. We think that our results can be useful especially for small and open economics that are undergoing transformation towards well-developed market economy.

Government interventions in the field of business R&D activities are justified by the argument of market imperfections and market failures. However, it is also necessary to point out the fact that public R&D support can distort economic competition. Public support creates an imbalance between businesses that received it and the others. In the optimum case, public support should be necessary and adequate. The necessity means that public support responds to the market failure. The adequacy concerns the extent of public support and says that the aid should be so high as to eliminate the market failure. Ideally, the government should allocate public funds to the projects that are socially beneficial and would not be implemented without the public aid. If some businesses receive the support repeatedly, distortion of the market environment can become a permanent phenomenon. Some enterprises can become dependent on regular public aid, which can lead to a permanent decrease in their own resources invested in R&D. It is therefore necessary to search for such mechanisms of R&D public policy that minimize these negative phenomena. This has also to do with the need to regulate the amount of public funds allocated to public R&D support so that these resources can be used in the most efficient way.

When designing public support, policy makers have to be well acquainted with the risks of innovation enterprise. Implementation of innovation is connected with high costs, such as expenditures on research and development. Furthermore, the return on these investments is quite long, as there is a long time between the innovation idea and the innovation introduction to the market. This is, in particular, valid for some high-tech industries, such as biotechnology. Moreover, the return on these investments is not certain. It is not certain that research will be successful and that the new products will be successful in the market. For these reasons, it is essential for policy makers to carefully consider who will receive the public support. The impact of public interventions varies depending on the size and age of supported companies, the sector in which they operate and the level of company innovativeness.

Our analyses showed that public support for R&D is a suitable policy tool to increase business expenditures on R&D and it can be quite a good instrument to boost employment in R&D. Although models both of BERD and number of employees showed positive impact of public support, we consider the impact on employment to be more relevant in terms of long-term perspective. We suppose that an increase in business expenditures can only last for a short time, whereas hiring new employees means that companies' research intentions are long term. In other words, if the policy objective is to increase business expenditures on R&D, the public support in the form of subsidies and tax incentives can be an efficient tool, but if the policy objective is to increase employment in R&D, we recommend combining this support with other policy tools. For example, this type of public support can influence the demand for human resources only, but it cannot influence the supply of research workers.

The interpretation of the last model is not straightforward and is ambiguous as the positive impact of public support on the number of workplaces was only showed for pulic support greater than 9.5 units and was small. We expected this weak result as the establishment of a new workplace represents a strategic decision of management, which is hard to influence from outside. Therefore, subsidies and tax incentives do not seem a suitable policy tool for creation of new workplaces. We believe that other policy instrument, such as support for research infrastructure, can be more useful with respect to the establishment of new workplaces. The government should also distinguish if the new workplaces should be created in small young companies or in companies with a longer history.

The efficient of public support is also linked to the form of the support. In the Czech Republic, R&D is supported only through subsidies and tax reliefs. Some countries support research through loans as well. However, if the government wants to support R&D through loans, it would be necessary to carry out a detailed analysis of the Czech environment and consider all the advantages and disadvantages of this form. In the area of indirect support, we would like to recommend defining the tax rules on deduction of eligible costs in a more precise manner. Some businesses do not use this form of support because they are afraid of sanctioning if they unintentionally claim incorrect costs.

The statistical data show that a large part of the public aid flows to a few regions in the Czech Republic. Public policy should strive for increase in the absorption capacity of the remaining regions. However, we would also like to point out that public support should be directed to the regions that need to stimulate investments in R&D but, at the same time, these regions have to be able to use the offered resources efficiently. Taking into account our familiarity with the situation in the Czech regions, we can state that the less developed regions are not sufficiently able to exploit the offered public resources, because they are specialized in low technology sectors that are not engaged in R&D so strongly. The government should take into consideration these differences among regions and design policy interventions reflecting the real conditions of such regions.

Conclusions

Innovation is an important factor for the economic, social and environmental developments of regions and states. Radical technological innovations, which have the largest impact on society, usually stem from the results of research and development. New knowledge resulting from R&D has some features of public goods because it is non-rivalry and difficult to exclude from the consumption of those who do not pay for it. This is caused by the knowledge-spillover effect. This effect causes that enterprises are willing to invest in R&D less than would be socially desirable. This is the main argument used to justify the public support for research and development in enterprises. However,the amount of public funds is limited; moreover, public support may distort the economic competition. Therefore, public support rules have to be set in a way that minimizes these negative phenomena, generates the maximum effect and stimulates business expenditures on research and development.

The article dealt with the relationship between public support for research and development in enterprises (subsidies and tax reliefs) and the research activity of enterprises and sought answer to the question what impact a change in the amount of public support has on business expenditures on R&D (BERD), increase in R&D personnel in business sector (FTE) and increase in the number of R&D workplaces in business (WP). Our hypotheses supposed that an increase in public support is associated with an increase in the three observed variables. The analysis has been carried out at the level of 14 Czech regions for the period 2007–15, which is the maximum period for which necessary statistical data are available. Year-on-year changes in individual variables have been examined and their average values have been assessed. The regression models modelling the change in R&D variables in businesses by the means of the change in amount of public R&D support were developed. All three models well predicted the R&D variables in businesses (the multiple R^2 values were 0.9215; 0.7653; 0.7625). In other words, we can say that our hypotheses have been confirmed. However, only the results of models for BERD and FTE allowed a straightforward interpretation. Particularly, public support encourages enterprises to increase their own R&D expenditures and has a positive impact on the increase in the number of R&D employees in businesses. The impact of public support on the number of R&D workplaces is quite weak. Nevertheless, the effects of public support are not the same in all Czech regions. In some of them, public aid can bring higher effects than in the others.

The main limitation of our research is the unavailability of more detailed statistical data. In order to assess the amount of leveraging and crowding-out effect, it would be necessary to analyse the firm-level data. The best results would be achieved if the control groups of supported and unsupported businesses and regions were compared. Our analysis also provides some implications for public policy. In an ideal case, the government should allocate public funds to the projects that are socially beneficial and would not be implemented if the support was absent. When designing policy measures, policy actors have to be well acquainted with the risks of innovation enterprise and have to carefully consider who will obtain the public support and in what form.

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