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Does public R&D expenditure matter for economic growth? GMM approach

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Abstract. The aim of the paper is to quantify the impact of public research and development (R&D) expenditure on economic growth. The empirical evidence focuses on the 20 selected EU member states in the period of 1995-2013. The research is based on a dynamic panel regression model (Generalized Method of Moments). The results confirm positive and statistically significant impact of government R&D expenditure, which is the main driver for economic growth during the analysed period. Contrary, business expenditure on the same is found to be insignificant. Traditional growth variables (higher share of qualified human resources and higher intensity of investments) report the positive effects, although in the case of investments – only partial one. The significance for R&D coefficient remains robust to different sub-periods.

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1. INTRODUCTION

Research and development (R&D) is of crucial importance in creation of knowledge, products and technologies as has been recognised in (Solow, 1956; Köhler et al., 2012; OECD, 2012; Szarowská 2013, 2016; Halásková & Halásková 2015, Freimane & Bāliņa 2016; Marcelino-Jesus et al. 2017). Generally, governments have three main instruments for financing R&D (own R&D, direct and indirect funding), each having advantages and disadvantages from the perspective of economic theory (David et al., 2000). Direct support is more focused on long-term research, while indirect channnels primarily support short-term applied research and increase incremental innovations (Westmore, 2013). The European Commission (2003) reports that most OECD/EU member countries apply a mix of direct and indirect measures to support R&D. Several countries have introduced or extended fiscal instruments to support R&D. Indirect fiscal R&D incentives reduce the costs of R&D for a wide variety of firms, including SMEs. Fiscal incentives are recommended to be used to support private R&D because these schemes have the potential to address a wide range of firms, including SMEs, and leave the decision as to the contents of the research to their discretion. If well designed, fiscal schemes can contribute to raising the overall level of in-vestment in business R&D.

The financial crisis obliged many governments to introduce tough fiscal consolidation measures, prioritizing other issues over R&D. In 2012 the share of public R&D expenditure in the total government expenditure was lower than in 2007 for half of the EU member states (OECD, 2012). On the other hand, Hud and Hussinger (2015) pointed out that in order to prevent firms from reducing their R&D expenses and maintain the national R&D capacities, policymakers in many countries reacted immediately to the crisis and increased the public R&D budgets. Anyway, limited financial resources and pressure to balance expenditure on innovation against expenditure on other policies force the governments to look for newer instruments.

The aim of the paper is to examine and quantify the impact of public R&D expenditure on economic growth in the selected European Union (EU) member states in the period of 1995–2013. The paper summarizes direct and indirect public funding instruments for R&D used in the EU countries and analyzes the impact of R&D expenditure and tax incentives on GDP growth. Basic source of data here is the Eurostat database, which is complemented by information from the OECD. The article is organized as follows. The next section presents theoretical background and the literature review. The following chapter introduces methodology and data. The empirical part is focused on basic forms of funding R&D as well as testing and quantifying impact of R&D expenditure on economic growth. Conclusion summarizes main findings.

2. THEORETICAL BACKGROUND

The neoclassical growth model known as Solow-Swan model (1956) considers the long-run economic growth. This model explains the economic growth with the capital accumulation, productivity, population growth and technological progress as the dominant drivers of economic growth. The model recognized the significance of the positive impact of technology on growth, but it is considered as exogenous. Next, the development of endogenous growth theory has provided many new visions into the sources of economic growth. Dzambaska (2013) points out, the essence of the new theory is that growth is an effect of rational economic decisions.

Barro and Sala-i-Martin (2003) modelled technological progress as an expansion of the variety of intermediate goods used by producers. The rate of growth depends on various characteristics of preferences and technology, including the willingness to save, the level of the production function, the cost of R&D, and the scale of the economy (measured by the quantity of a fixed factor, such as raw labor or human capital). Some alternative specifications of the R&D technology can preserve most of the growth implications while eliminating the apparently counterfactual scale effects. Barro and Sala-i-Martin´s equilibrium growth rate in the model corresponds to the exogenous rate of technological change in the Solow–Swan (1956) models. They note that if the diffusion of ideas from one country to an-other is rapid, the model explains why the technology in all countries would improve over time. Therefore, the model can explain why the long-term growth rate of the world' s real per capita GDP would be positive.

Steger (2005) writes that growth models which focus on R&D are used for explaining sustained economic growth in industrialized countries. The first generation of R&D-based growth models suffered from the scale effect, according to which the long-run growth rate increases with the size of the economy. A second generation of R&D-based growth models have been developed, which are not spurred by the scale effect – so called non-scale growth models. The second generation of R&D-based growth models implies a strong ineffective-ness proposition, according to which public policy is powerless to affect the long-run growth rate. Perez-Sebastian (2007) notes that even policy in Jones-type non-scale models (1995) has no long-run growth effects and level effects can be substantial.

Svennson (2008) presents an overview of the economic literature on the relationships between R&D investments and economic growth. He discusses positives and negatives of different types of public funding of R&D and analyses what differentiates R&D from other forms of input and why spillover effects occur. Becker's study (2015) offers the most systematic review and critical discussion focused on R&D literature (more than 120 papers). She gives attention especially to mutual comparision between conclusions of published studies.

The empirical evidence is often focus on studies that econometrically analyse the impact of R&D tax incentives on key policy goals of the instrument. Since a primary goal of R&D tax incentives is to raise R&D spending by enterprises, most studies look at input additionality, i.e. the change in private R&D expenditure that can be attributed to the tax incentive (Castellacci & Lie, 2015; Ientile & Mairesse, 2009). Some of studies were official evaluations commissioned by governments and conducted as part of policy implementation (Faria et al., 2011). The studies are typically based on firm-level panel data and either cover periods before and after the introduction of a tax incentive, or they analyse the effects of changes in the generosity of R&D tax incentives. E.g. Hall and Van Reenen (2000) study the econometric evidence on the effectiveness of fiscal incentives for R&D. In imperfect state of knowledge, they conclude that a dollar in tax credit for R&D stimulates a dollar of additional R&D.

Guellec and de la Potterie (2004) introduce factors important for the growth. These factors are the absorptive capability, the origin of funding, the socioeconomic objectives of government support, and the type of public institutions that perform R&D. Garland and Allen (1995) analyze the relative importance of public and private R&D in the economic growth of different countries. They confirm that private R&D has a greater impact on growth than public R&D, which is to a large degree devoted to basic research. Bilbao-Osorio and Rodriguez-Pose (2004) present results which indicate that R&D investment, as a whole, and higher education R&D investment in peripheral regions of the EU, in particular, are positively associated with innovation. The existence and strength of this association are, however, contingent upon region-specific socio-economic characteristics, which affect the capacity of each region to transform R&D investment into innovation and, eventually, innovation into economic growth.

Berliant and Fujita (2011) state that long-run economic growth is positively related to the effectiveness of pairwise R&D worker interaction and to the effectiveness of public knowledge transmission. Kim (2011) investigates the effect of R&D stock for economic growth during the years 1976–2009. Guadalupi et al. (2013) also confirm the hypothesis that the technological change stimulates the economic growth. Especially the less advanced EU regions, in which the public expenditure in R&D is higher, report the higher GDP growth rate.

Silaghi et al. (2014) empirically estimate the role of private and public R&D for growth of Central and Eastern European Countries during 1998–2008 and public R&D is found to be statistically insignificant. Brautzsch et al. (2015) analyze the macroeconomic effects of R&D subsidies in the business cycle. Their findings suggest that the R&D program counter-acts the decline of GDP by 0.5%. Compared to the strongly discussed alternative uses of subsidies for private consumption, R&D spending is more effective.

Köhler et al. (2012) summarize results of 18 published papers and note that regardless of a growing number of studies on the effect of R&D expenditure and tax incentives, the knowledge about the effectiveness of R&D expenditure and how a scheme should be de-signed to maximise its impact, remains limited.

Bilas et al. (2016) note the issues of economic growth and development are constantly re-evaluated, especially after occurrence and severe consequences of the economic and financial crisis of 2008-2009. They use dynamic panel data and panel generalized method of moments as an estimator and find out that Gross domestic expenditure on R&D on average depends on gross domestic expenditure on R&D previous year with coefficient 0.77 and on annual GDP per capita growth rate with coefficient -0.0073.

Recently, Afonso and Sarabanda (2017) extend the existing R&D growth literature by focusing on the short-medium-long run effects of the informal sector on R&D intensity, wage inequality and economic growth by considering 18 OECD countries between 1990 and 2008 and they show that the steady state is unique and stable; the share of informal economy in production affects negatively R&D intensity and wage equality.

In accordance with presented papers and empirical studies, it can be concluded that literature offers support for all ideas about importance and impact of R&D on economic growth – positive, negative and zero. The variety of findings is generated due to differences used in econometric models, country samples, observation period and considered variables. Therefore, the aim of the article is to quantify impact of public R&D expenditure on economic growth in selected EU member states.

3. RESEARCH METHODOLOGY AND DATA

The empirical analysis is based on the methodology of Barro and Sala-i-Martin (2003), which is adapted to the framework of this study. Empirical evidence is based on unbalanced annual panel data of the EU member states in a period 1995–2013 (the longest available time series). The sample selection is limited by the availability of data. That's why, the empirical evidence is performed for 20 EU countries, namely Belgium (BE), Bulgaria (BG), Czech Republic (CZ), Denmark (DK), Germany (DE), Ireland (IE), Spain (ES), Finland (FI), France (FR), Hungary (HU), Italy (IT), Latvia (LV), Netherlands (NL), Poland (PO), Portugal (PT), Romania (RO), Slovak Republic (SK), Slovenia (SI), Sweden (SE) and United Kingdom (UK).

In order to test whether R&D expenditure matters for economic performance, there are estimated econometric models. The basic dynamic panel model is defined in (1):

$$GDP_{it} = \beta_0 + \beta_1\, GDP_{it-1} + \beta_2\, GERD_{it} + \beta_3\, INV_{it} + \beta_4\, HRST_{it} + \varepsilon_{it}, \tag{1}$$

where β_1 to β_4 contain the coefficients assigned to the independent variables, and β_0 is a constant, the subscript t indexes the year, i country. GDP means GDP growth per capita expressed by the amount of GDP per capita in purchasing power parity (EU28), the series for GDP are converted into logs. GERD means Gross domestic expenditure on R&D, INV is expressing investment ratio on the GDP, HRST as a share of the active population classified as HRST (i.e. having successfully completed an education at the third level or being employed in science and technology) as a percentage of total active population aged 15–74, and ε is the error term. R&D expenditure are expressed not only as GERD, but also split its main components: business R&D (BUSINESS), and government (GOV) as well as higher education (EDU) R&D expenditure which make up public R&D. In this way it is possible to assess which types of activities has an effect on economic growth.

From a methodological perspective, the research is based on a dynamic panel regression model. Compared to the cross-sectional analyses, the panel regression has a very important option of including individual effects (i.e. the existence of heterogeneity across cross-sectional units). This makes presented evidence more credible, given the relatively small number of countries and short time series. Estimations are based on dynamic panel data estimators using the differenced Generalized Method of Moments (GMM) with Arellano-Bond type instruments (Arellano & Bond, 1991):

$$lnGDP_{it} = \beta_1\, lnGDP_{it-1} + \beta_2\, dGERD_{it} + \beta_3\, dINV_{it} + \beta_4 dHRST_{it} + \varepsilon_{it} \quad (2)$$

where *d* denotes first difference of a variable. Correlation of the residuals and endogeneity problem is corrected by instrumenting $dGDP_{it-1}$ with various dependent variable lags, different lag combinations were used to test robustness of results, and outcomes were mainly quite similar. Hence, the below models include a lag of one period and fixed effects as is usual in this type of studies (Perez-Sebastian, 2007; Silaghi et al., 2014). The software E-Views (9) is used for estimations.

The GMM is a generic method for estimating parameters in statistical models. Usually it is applied in the context of semi parametric models, where the parameter of interest is finite-dimensional, whereas the full shape of the distribution function of the data may not be known. GMM is popular in estimating structural economic models, as it requires much less conditions on model disturbances than Maximum Likelihood. Another important advantage is that it is easy to obtain parameter estimates that are robust to heteroscedasticity of un-known form (Hansen, 1982). For a model specification, Dynamic Panel Data Model Wizard is applied. The wizard aids in specifying members of the class of dynamic panel data models with fixed effects. Arellano and Bond (1991) designed models for panels with a large number of cross-sections and a shorter time series.

Many studies point out that using non-stationary macroeconomic variable in time series analysis causes superiority problems in regression. Thus, a unit root test should precede any empirical study employing such variables. Recent literature suggests that panel-based unit root tests have higher power than unit root tests based on individual time series. Panel unit root tests are similar, but not identical, to unit root tests carried out on a single series (Verbeek, 2000). Used panel unit root tests (Levin, Lin, & Chu, 2002; Breitung, 2000; Im, Pesaran, & Shin, 2003; Fisher-type tests using ADF and Fisher PP tests) confirm the stationary of all time series on the first difference (except GDP, which is stationary on level data), results are available on request.

4. RESULTS AND DISCUSSION

Financial support of R&D

It is known that R&D is fundamental for the knowledge-based economies' competitiveness and support of R&D and innovation is also a political measure. In line with Lisbon strategy and Europe 2020 targets, investment in European R&D should be raised to 3% of GDP but this target was not reached yet. Gross domestic expenditure on R&D (GERD) is total intra-mural expenditure on R&D performed on the national territory during a given period. GERD includes R&D performed within a country and funded from abroad but excludes payments for R&D performed abroad. GERD is usually reported for sectors of performance: business enterprise, higher education, government and private not-for-profit institutions serving households. Average EU-28's R&D expenditure was 2.02% GDP (Eurostat database and OECD, 2014). The importance of the source of funding has been recognized in one of the Barcelona targets of the Lisbon agenda where it is said that the appropriate split for R&D is 1/3 financed by public funds and 2/3 by private (European Commission, 2013). Figure 1 shows total R&D expenditure (GERD) divided into performing sectors in 2013 (the latest available time serie).

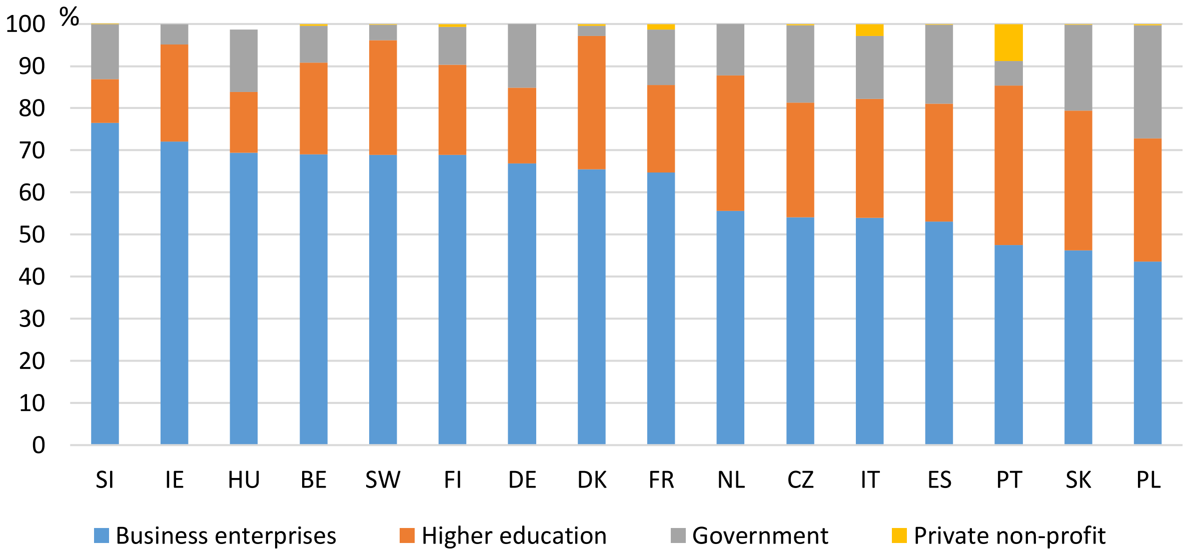

Figure 1. R&D expenditure by performing sectors
Source: author's compilation based on OECD data

Business enterprise expenditure on R&D (BERD) records gross expenditures on R&D performed by all firms, organisations and institutions whose primary activity is the production of goods and services for sale to the general public, and the private non-profit institutions mainly serving them. Government-funded business R&D is the component of R&D performed by business enterprises attributed to direct government funding. It includes grants and payments for R&D contracts for procurement, but not R&D tax incentives, repayable loans or equity investments. Figure 2 presents a share of direct and indirect public funding of business R&D expenditure in 2013.

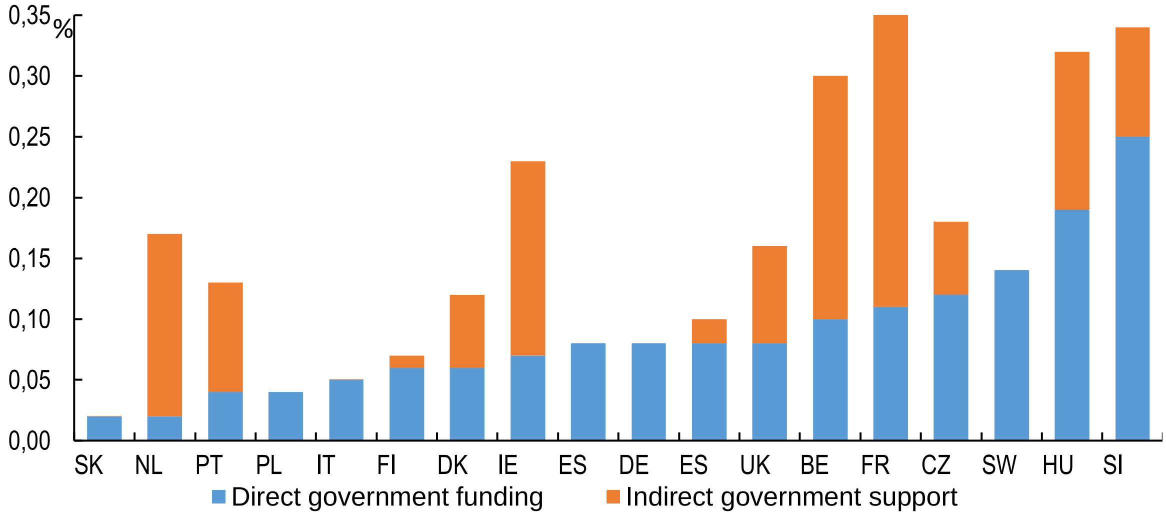

Figure 2. Direct and indirect government funding of BERD in % GDP
Source: author's compilation based on OECD data

As OECD (2015) reports, the business sector accounts for the largest share of R&D per-formed in most economies and more than 60% of expenditure on R&D (GERD). This share has remained fairly stable over the past decade. Higher education R&D accounts for almost 20% of total GERD. The government sector plays a relatively minor role as a performer of R&D but it is a major funder of R&D performed in the higher education and business sec-tors. R&D is typically concentrated among a limited number of firms in which large ones are typically over-represented. In some countries, however, small and medium-sized firms (SMEs) account for a significant share of total business R&D. SMEs receive a relatively large share of government funding in several countries including Estonia, Slovakia and Fin-land. The distribution of business R&D by economic activity reveals a pattern of specialisation influenced by a country's economic structure. In most countries, a limited number of activities account for a large share of total business R&D.

OECD (2010) notes that indirect public funding is mostly realized as tax incentives and it is usually more neutral than direct support in terms of industry, region and firm characteristics, although this does not exclude some differentiation, most often by firm size. Tax incentives reduce the marginal cost of R&D and innovation spending. While direct subsidies are more targeted towards long-term research, R&D tax schemes are more likely to encourage short term applied research and boost incremental innovation rather than radical break-throughs.

Guellec and van Pottelsberghe (2003) mention that tax incentives applicable to different tax arrangements, including corporate and personal income taxes, are also widely used to encourage private investments in R&D and the exploitation of IP assets, to attract business angels and leverage early-stage finance, and to attract foreign talent or foreign multinationals.

Indirect support in recent years become more important to encourage investment in R&D and as write Garnier et al. (2014) at least one form of stimulus R&D currently exists in 26 EU countries. Within the EU, only Germany and Estonia currently do not have a tax policy aimed directly at stimulating innovation. Although tax incentives are usual, they are far from homogeneous and differ noticeably across countries, with most countries offering more than one type of instrument. R&D tax credits are the most popular type of incentive, followed by enhanced allowances and accelerated depreciation. Tools also include reduction of social security contributions, exemption from customs duties, preferential loans, venture capital support, and advantageous lease of regional and central infrastructure (OECD, 2014). R&D tax incentives aim to encourage firms to perform R&D by reducing its costs. Compared with direct subsidies, R&D tax incentives allow firms to decide the nature and orientation of their R&D activities, on the assumption that the business sector is best placed to identify research areas that lead to business outcomes. A detailed description of financial instrument variety can be found in Szarowská (2015).

Table 1

Tax incentives for R&D and innovation

Tax arrangements	***Expenditure-based***	***Income-based***
Corporate income tax	Austria, Belgium, Czech Rep., Denmark, Finland, France, Greece, Hungary, Italy, Latvia, Poland, Portugal, Slovakia, Slovenia, Spain, United Kingdom	Belgium, Greece, Hungary, Italy, Luxembourg, Netherlands, Poland, Spain, United Kingdom
Payroll withholding and soc. sec. taxes	Belgium, France, Hungary, Netherlands, Spain, Sweden	
Personal income tax	Denmark, Hungary	Denmark
Value-added tax	Poland	
Other taxes (e.g. land taxes)	France, Italy, Portugal	
No tax arrangements	Estonia, Germany	

Source: compilation based on OECD (2012, 2014)

Table 1 summarises expenditure-based and income-based tax arragements in the EU countries. Table is based on tax incentives applied in 2014 and repots that corporate income tax arragements are the most commonly used. In this way, governments can affect the effective tax burden, generosity of tax subsidy and competitiveness of the country.

5. TESTING IMPACT OF R&D EXPENDITURE ON ECONOMIC GROWTH

In order to test whether R&D expenditure affects economic growth, there are estimated econometric models based on Arellan-Bond estimator (1991).

As it is already noted, for models specification, Dynamic Panel Data Model (DPDM) Wizard is applied. The DPDM Wizard is a special tool included in the software E-Views (9) which aids in specifying members of the class of dynamic panel data models with fixed effects. All models include cross-section fixed effects (orthogonal deviations) and constant added to instrument list. Information criteria identified as the optimal time lag 1 year. Firstly, series for R&D expenditure are expressed as GERD and the basic dynamic panel model (Model 1) is defined in (3).

$$lnGDP_{it} = \beta_1\, lnGDP_{it-1} + \beta_2\, dGERD_{it} + \beta_3 dINV_{it} + \beta_4 dHRST_{it} + \varepsilon_{it}\,. \tag{3}$$

β_1 to β_4 contain the coefficients assigned to the independent variables, the subscript t indexes the year, *i* country, *d* first difference of variable, *lnGDP* means GDP growth per capita expressed by the amount of GDP per capita in PPP (EU28) converted into logs. GERD means Gross domestic expenditure on R&D, INV is expressing investment ratio on the GDP, HRST as a share of the active population classified as HRST as a percentage of total active population, and ε is the error term. Period is analysed not only as s whole but it is also divided by the year 2008. Split of time span into two periods allows deeper analysis of structural changes related to the influence of crises. Models 1 and 4 are focused on a whole period (1995, resp. 1997–2013), models 2 and 5 on pre-crisis period (1995, resp. 1997–2007) and models 3 and 6 on post-crisis period (2008-2013). Models 4–6 contain period fixed effects as dummy variables for a better capture the impact of the crisis (there are labeled as "year"). Their adding increased a statistical quality of models. The reported J-statistic is the Sargan statistic (value of the GMM objective function at estimated parameters).

Table 2 presents the most appropriate specifications of models resulting from GMM.

The main results concerning the effect of R&D expenditure on economic growth indicate that findings are very dependent on applied time span and model specification. For a whole analyzed period, GERD affects economic growth positively, but after adding time dummies decreased and impact of "traditional" growth variables (investment and human resources) is stronger. GERD influence on growth is negative and insignificant in the precisis period and vary in post-crisis period. That´s why, no general conclusion can be drawn about GERD as the results differs across periods.

Next GERD is substituded by its main components (BUSINESS, GOV and EDU). It is possible to analyse R&D impact of each sector and Table 3 presents results of the most appropriate specifications of estimations.

Model 7 reports results for a whole period, Model 8 the pre-crisis findings and Model 9 the post-crisis results. Model 10 relates also period dummy variables included (it does not transform period dummy variables) into Model 9. Model 11 presents the results when using the same estimates over the pre-crisis period, Model 12 during the post-crisis period. As BUSINESS expenditure is found to be insignificant in Models 7 and 11 (1995–2013), it was excluded as Model 13 shows. This way, a statistical quality of estimations was increased.

Table 2

Panel regression estimations (GMM) for GERD

Variable	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6
Ln $GDP_{(-1)}$	**0.609*** **	**0.569*** **	**0.501*** **	**0.615*** **	**0.583*** **	**0.595*** **
dGERD	**0.069*** **	–0.018	**0.029* **	**0.002* **	–0.010	–0.013
dINV	**0.003*** **	0.015	–0.001	**0.009*** **	**0.016*** **	0.001
dHRST	**0.008*** **	**0.008** **	**0.003** **	**0.006*** **	**0.007* **	0.002
"1997"				0.071	**–0.113** **	
"1998"				0.036	0.030	
"1999"				0.036	**–0.035** **	
"2000"				0.028	**–0.030** **	
"2001"				**0.054* **	**–0.039*** **	
"2002"				**0.056* **	–0.013	
"2003"				**0.072** **	–0.003	
"2004"				0.056	**0.013* **	
"2005"				0.058	–0.005	
"2006"				**0.063* **	–0.008	
"2007"				**0.068* **	–0.005	
"2008"				**0.102*** **		**–0.015** **
"2009"				**0.126*** **		**0.015** **
"2010"				**0.082** **		**0.023*** **
"2011"				**0.079** **		**–0.009** **
"2012"				**0.074* **		0.003
"2013"				**0.093** **		**–0.012*** **
S.E. of reg.	0.101	0.118	0.022	0.096	0.113	0.019
S.D.dep. var.	0.254	0.269	0.031	0.254	0.269	0.031
Instrumental rank	156	69	90	173	80	96
J–statistics	152.6	58.1	91.8	148.8	56.7	92
Observations	335	215	120	335	215	120

Note: Symbols ***, ** and * denote statistical significance at the 1%, 5% and 10% level.
Source: author's calculations

Table 3 shows that the estimated coefficients of GOV expenditure are positive and statistically significant (except Model 12, in which is negative and statistically insignificant). This finding confirms that increase of government R&D expenditure contributes to the economic growth. It is necessary to point out that its influence is the main driver for economic growth with stronger effect that traditional growth variables (investment and human capital approximated by HRST). Contrary, business R&D expenditure seems to have negative influence on economic growth, as coefficients are negative and moreover often statistically in-significant during the reported periods. Hence, business R&D expenditure is excluded in Model 13 and it improves the quality of the estimation. EDU affects economic performance diversely – in pre-crisis period mostly negatively, in post-crisis period positively. It supports assumption about increasing importance of higher education expenditure, generally. Results also confirm positive impact of a higher share of the active population having successfully completed an education at the third level or being employed in science and technology. Positive influence of higher intensity of investment on economic growth is confirm only partly, exception is post-crisis period without period dummy variable.

Table 3

Panel Regression Estimations (GMM) for R&D expenditure by sectors

Variable	Model 7	Model 8	Model 9	Model 10	Model 11	Model 12	Model 13
Ln $GDP_{(-1)}$	**0.643*** **	**0.557*** **	**0.532*** **	**0.645*** **	**0.588*** **	**0.561*** **	**0.647*** **
dBUSINESS	–0.004	**–0.123***	–0.012	–0.040	–0.058	**–0.037** **	
dGOV	**1.022*** **	**0.942*** **	0.110	**0.956*** **	**1.016*** **	–0.040	**0.969*** **
dEDU	**–0.124** **	–0.234	**0.152*** **	**–0.301*** **	**–0.414***	**0.117***	**–0.306*** **
dINV	–0.001	**0.013*** **	**–0.001** **	**0.005*** **	**0.014*** **	0.001	**0.005*** **
dHRST	**0.006*** **	**0.008***	**0.004** **	**0.004** **	**0.008***	**0.002***	**0.004** **
"1997"				**–0.101** **	**–0.122** **		**–0.099** **
"1998"				0.041	0.032		0.041
"1999"				**–0.047*** **	**–0.047** **		**–0.046*** **
"2000"				**–0.042*** **	**–0.032** **		**–0.041*** **
"2001"				**–0.035*** **	**–0.029*** **		**–0.036*** **
"2002"				**–0.020***	–0.009		**–0.020***
"2003"				**–0.028** **	–0.006		**–0.027** **
"2004"				–0.010	0.009		–0.008
"2005"				**–0.022** **	–0.006		**–0.021** **
"2006"				–0.028	**–0.016** **		**–0.027*** **
"2007"				**–0.023*** **	–0.010		**–0.023*** **
"2008"				**–0.013***		**–0.013** **	**–0.012***
"2009"				0.013		**0.014*** **	0.012
"2010"				**0.032*** **		**0.018*** **	**0.032*** **
"2011"				–0.003		–0.011	–0.002
"2012"				0.002		0.003	0.001
"2013"				–0.011		**–0.013*** **	**–0.012** **
S.E. of reg.	0.092	0.114	0.022	0.087	0.107	0.018	0.087
S.D. depend. var	0.254	0.269	0.031	0.254	0.269	0.031	0.254
Instr. rank	158	71	90	175	82	98	174
J–statistics	125.5	57.9	91.8	121.5	60.5	91.7	123.4
Observations	335	215	120	335	215	120	335

Note: Symbols ***, ** and * denote statistical significance at the 1%, 5% and 10% level.
Source: author's calculations

The findings are in line with conclusion of many studies, e.g. Bilbao-Osorio and Rodriguez-Pose (2004) who indicate importance of public R&D investment and higher educated worked labour. Positive influence of government R&D expenditure is confirmed also by Castellacci and Lie (2015), Ientile and Mairesse (2009), Hall and Van Reenen (2000) or Kim (2011). Becker (2015) supports especially conclusions about importance of high-skilled human capital and investment. Perez-Sebastian's conclusion (2007) supports the findings about R&D as a whole as states that R&D models have no definite long-run growth effects and level effects can be substantial. Also Freimane and Bāliņa (2016) report statistically significant impact of R&D expenditures on the economic growth in the EU countries based on panel data regressions in the period of 2000–2013. The significance for R&D coefficient remains robust to different sub-periods, but the level of significance decreases as a sub-sample of new EU countries was considered.

In terms of a business R&D expenditure, the results are not in line with the findings of earlier empirical studies focused on impact of private expenditure and economic growth, such as Becker (2015), Garland and Allen (1995), Silaghi et al. (2014) or Brautzsch et al. (2015). The variety of findings is generated due to differences used in econometric models, country samples, observation periods and considered variables.

Arnold et al. (2011) were able to theoretically derive an error correction form to be estimated for both a neoclassical augmented Solow model, respectively for constant returns to a scale endogenous growth model. In order to empirically discriminate between these setups, they exploit different non-linear restrictions implied by the models regarding the relation-ship between factor shares and speed of convergence. While acknowledging that there are theoretical derivations of error correction forms under both neoclassical and endogenous growth setups, it is not considered restrictions on the production function, since the article has no interest in discriminating between the two frameworks. In this context the long-run estimated coefficients can be viewed as the standard concept of long-run propensities, i.e. the long-run change in the dependent variable given a ceteris paribus permanent increase in the explanatory variable of interest.

6. CONCLUSIONS

The article focuses on R&D expenditure, its funding and the aim of the paper was to quantify influence of R&D expenditure on economic growth in selected EU member states in the period 1995–2013. The presented empirical evidence is based on unbalanced annual panel data of 20 EU countries.

Review of theoretical literature and empirical studies shows that importance and impact of R&D on economic growth is not unequivocal and published studies present positive as well as negative effects.

This research confirms that there is a trend to combine direct public funding from both national and EU sources and indirect public funding instruments. Governments offer direct support through public procurement for R&D and a variety of grants, subsidies, loans or equity funding. While direct subsidies are more targeted towards long-term research and growth, indirect funding and R&D tax schemes are more likely to encourage short-term applied research and boost incremental innovation. Due to limited financial resources, indirect support has become more important in recent years.

The direct empirical evidence tested whether R&D expenditure matters for economic performance. R&D expenditure were investigated not only as a whole GERD, but also as its components: business R&D, and government as well as higher education R&D expenditure which make up public R&D. Moreover, time span was divided into a pre-crisis and a post-crisis period. Explanatory variables were not examined in individual regressions, but the study used GMM applied on dynamic panel data and estimations are based on Arellan-Bond estimator (1991). An important finding resulting from this research is that the dynamic pan-el analysis confirms positive and statistically significant impact of government R&D on economic growth conclusively. Its effect is the main driver for economic growth with stronger effect that traditional growth variables (investment and human capital approximated by HRST). Surprisingly, business R&D

expenditure was found to be negative and statistically insignificant in most cases. Possible reason can be found in development of business and public R&D expenditure when the financial and economic crisis hit the EU in 2008. R&D expenditure of the business sector distinctly fell in 2008 and 2009 (and also in next years, see OECD 2012). As Cincera et al. (2012) note, businesses usually decrease the amount they spend on R&D during economic crisis as a cost-reduction strategy in time of economic pressure and tight credit constraints, the similar development was reported also in some countries in the sample. Based on the presented data it can be concluded that higher education R&D expenditure influences economic growth diversely – in the pre-crisis period negatively, in the post-crisis period positively. It supports assumption about increasing importance of higher education expenditure, generally.

All reported models were estimated for unbalanced annual panel data using first difference GMM procedure of Arellano, Bond (1991) with robust standard error, consistent with panel-specific autocorrelation and heteroscedasticity. That allowed removing the individual effects. Some variables like GERD and INV might suffer endogeneity problems with respect to the GDP growth; therefore the lagged values of variables were used. Instrumental variables were tested with the Sargan J test. Respective null hypothesis is that there are no correlations between instruments and residuals. Autocorrelation problem was tested with the Arellano-Bond test for 1 and 2 lags. For all reported models Arellano-Bond test could not reject the null hypothesis of absence of autocorrelation in the residuals.

Future research will be focused on smaller and more homogenous groups of countries and more accurate specification of a short-term and a long-term impact of R&D variables on economic growth.

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