THE IMPACT OF RESEARCH AND DEVELOPMENT EXPENDITURES ON INNOVATION PERFORMANCE AND ECONOMIC GROWTH OF THE COUNTRY—THE EMPIRICAL EVIDENCE

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Abstract: The main aim of this article is to empirically verify the relationship between research and development (R&D) expenditures, innovation, and economic growth. Based on the correlation analysis, we examine the interdependencies between selected indicators. We have found that countries with an increase in innovation performance over the past years mostly experienced a higher economic growth in the year 2012. Countries with higher research and development expenditures have not only more researchers, but as well more patents registration. Subsequently, the relationship between R&D expenditures and economic growth is examined based on econometric regression model of the panel data. Input data used in the regression covers EU countries between the years 1999 and 2011. Our results suggest the existence of positive effect of lagged R&D expenditures on economic growth in these countries. We have also identified positive impact of the flow of foreign direct investment (FDI) in this model, which could be related to mechanism of technology diffusion across the countries.

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Introduction

Economic growth is one of the most important areas of economic research at this time. An outward shift of the production possibility frontier of the economy is interestingly seen one of the causes of a long-term economic growth. Innovation is one of the key factors leading to such shifting in production possibility. The existence of R&D is a prerequisite for the development of innovative products and services; Uramová, Valach, & Paulik (2003) stated that R&D and investment policies are creating incentives for the new inventions (ideas, processes, etc.), which subsequently lead to its materialized form of "innovations." But, first, these must be transformed into economic processes through investment. Thus, without sufficient public and private expenditures on research and development, most of the innovations could not be implemented and economic productivity will not be viable.

The majority of the new economic growth concepts is based on a considerable extent of the Solow model (Solow, 1957). It is one of the first that considered the impact of technological change on economic growth. The functional relationship used in the Solow model can be written as

$$Y = f\,\{A(t), K(t), L(t)\} \tag{1}$$

Where,

t is the time;

K(t) is the capital input during time (t);

L(t) is the labor input during time (t);

A(t) is the total factor productivity (TFP), which captures the non-inclusive effects, among which technological progress is an especially significant factor.

According to the Solow model, capital accumulation cannot be the real cause of long-term economic growth because of diminishing marginal capital of the product. Technological progress, here, is only mentioned as an exogenous variable, which is the function of time. Other causes of technological progress are neither analyzed nor explained. As reported by Kuvíková, Mikušová-Meričková, Šebo, & Štrangfeldová (2011), technological progress may be the result of research and development that leads to improving production processes, or is the result of learning from experience and imitation.

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The relationship between the investment in research and development and economic growth is explained more in detail by endogenous models (Romer, 1986). Romer (1986) identified research and development as necessary conditions for the existence of technological progress. According to the endogenous model, technological progress is generated in research and development through the use of knowledge accumulation and human capital. An important element of endogenous growth models is also the assumption about increasing or constant returns to scale of knowledge, due to spill-over effects or so-called "learning by doing." By assuming increasing returns to scale of invention, we can get exponential economic growth even with constant R&D expenditures. On the other hand, when we assume constant returns to scale, it means that the increase in R&D expenditures should ensure a proportional increase in innovation as well. Therefore, this should lead to the proportional increase of productivity, and, thereby, enable a stable economic growth in the long-term.

Romer (1990) also subsequently confirmed the results of the model for most of the developed countries by empirical studies. He managed to show a positive effect of the number of researchers on the economic growth. Similar results were also achieved by Hall (1996), who examined the relationship between private investments in R&D, on the one hand; productivity and profitability of companies, on the other hand. He also found a significantly high, positive impact of the R&D expenditures. Wakelin (2001) also confirmed, on a sample of 170 companies from the UK, that expenditures on research and development had resulted in positive impact on productivity growth in these companies. The majority of authors also recommend further an increase in public R&D expenditures because knowledge arising from R&D produces a number of positive externalities regarding spill-over effects. Thus, social gains from private investments to R&D are substantially higher than the direct individual gains for the investor. Due to this fact, it is likely that private expenditures on R&D are suboptimal.

On the contrary, Jones (1995) showed different results by examining the effect of the number of researchers on economic growth in France, Germany, the U.S., and Japan. He did not detect any sufficiently significant positive effect on economic growth stemming from the increase in the number of R&D workers. As a result of these empirical findings, Jones (1995), Kortum (1997) and Segerstrom (1998) replaced the endogenous models by so-called "semi-endogenous models." These models assume the long-term decreasing returns to scale of the production of knowledge, due to the exogenous impact of population growth and other factors. This means that R&D expenditures could ensure long-term economic growth under the assumptions of semi-endogenous models. Aghion & Howitt (1998) explained the empirical findings of Jones (1995) and others slightly differently. They admitted that every new innovation makes previous technology outdated and also assumed that the effectiveness of R&D expenditure is gradually decreasing, because of an increasing variety of products. Innovation for each of the existing products requires widening the scope of research. In this case, an economic growth could only be achieved if that the volume of R&D expenditures, in relation to the expansion of product lines, will be preserved. Aghion & Howitt (1998) also found that the number of employees in R&D is an inappropriate indicator for empirical analysis and recommended using the ratio of R&D and GDP expenditures. Therefore, this article also deploys this variable in the econometric regression model. Several other empirical studies (e.g. Zachariadis, 2003) have confirmed the positive effect of this variable on GDP growth in developed countries. On the other hand, Samimi & Alerasoul (2009) examined this relationship in developing countries, but failed to provide valid proof.

The ability of each country to benefit from the knowledge spill-overs is also dependant on the so-called "innovation absorptive capacity." This is crucial, especially, for economic growth of developing countries. Dahlman & Nelson (1995) defined absorptive capacity as the ability of the country to learn and implement the technologies and associated practices of already developed countries. Absorptive capacity could be understood primarily by the educational level, but the value of the absorption capacity may also depend on the quality of human capital, infrastructure, and international trade (Castellacci & Natera, 2013). Sivák, Čaplánová, & Hudson (2011) confirmed the assumption that the quality of infrastructure is one of the factors determining the innovation performance of the country. They took into account, especially, the quality of the transport, IT, and financial infrastructure.

Data and methodology

To analyze the dependencies between the R&D expenditures, innovation, and economic growth, we used the data for the EU-27 member states. We measured innovation performance of the country by summary innovation index published by the European Commission (2013). Apart from the summary innovation index, we also used the index of innovation growth, also calculated by European Commission (2013), to capture the dynamic changes in the innovation performances of countries. Another important data source for our analysis is the World Bank database—World Development Indicators (WDI). To compare the economic performance and growth, we used GDP expressed in purchasing power parity and the change in GDP for each country in 2012. Research and development is represented by indicators of expenditure (% of GDP), the number of scientists and researchers, and the number of patents. Number of patents is an indicator, which could be used as a proxy for the level of research output in the form of innovation. For instance, Zachariadis (2003) stated that R&D expenditure is reflected in the number of patents; patents have a positive effect on the development of technologies, which raises economic growth. Similar effect of patents is also shown by Hudson & Minnea (2012). Potential interdependencies between these indicators are also present in this article, further examined by correlation analysis. earson correlation coefficients calculated between indicators pairs are shown in Table 2 in the following section. Subsequently, we estimated a panel data regression model for a more detailed examination of relationship between R&D expenditures and economic growth. R&D expenditures have been used as a key explanatory variable in accordance with the recommendations by Aghion & Howitt (1998). We have also integrated several control variables in the models, which are as often used by others to explore some other effects on GDP. One of the most interesting variables from our point of view, apart from R&D expenditures, is the flow of foreign direct investment (FDI). All variables used in the models are summarized in the Table 1.

By using panel data analysis, all variables included the cross-sectional components as well as time-series components. Panel dataset contains observation on selected variables for 26 EU Member States, except Estonia (due to the unavailability of certain data), for the period between the years 1999 and 2011. Due to the nature of the data, and based on the result of statistical testing (especially, the result of Hausman test), we chose to apply fixed effects panel data regression. Non-stationary variables where "stationarized" through the use of the first difference (or growth rate) of these variables. All variables shown in Table 1 were used in the first regression model. Second regression was conducted only with statistically significant variables. We also used lagged R&D expenditures in the second model because of an expected time-shift effect of this variable on GDP growth.

Table 1: Variables used in econometric regression model

Variable	Description	Source
Dependent variable		
ΔGDP	Annual GDP change in %	World bank. World development indicators database (WDI). Available at: <http://data.worldbank.org/>
Independent variables		
EATR	Effective average corporate	Spengel, Elschner, & Endres. (2012).

	tax rate	Effective tax levels at the industry level using the Devereux/Griffith methodology.
FDI	FDI inflows/GDP	World bank database (WDI). Available at: <http://data.worldbank.org/>
R&D_EXP	R&D expenditures (public and private)	World bank database. (WDI). Available at: <http://data.worldbank.org/>
UNEMPLOYMENT	Unemployment (in %)	World bank database. (WDI). Available at: <http://data.worldbank.org/>
PUBLIC_DEBT	Public debt (% GDP)	World bank database (WDI). Available at: <http://data.worldbank.org/>
STR_NEIGHBOUR	Average of statutory corporate tax rates in neighbouring countries	EK. 2012. Taxation trends in EU 2012. Available at: <http://epp.eurostat.ec.europa.eu/cache/ity_offpub/ks-du-11-001/en/ks-du-11-001-en.pdf>
GDP	GDP level per capita in PPP	World bank database (WDI). Available at: <http://data.worldbank.org/>
OPENNESS	Openness of economy (Export + Import)/HDP	World bank database (WDI). Available at: <http://data.worldbank.org/>
CORRUPTION	Corruption index (higher value means a lower level of corruption)	Transparency international. Available at: <http://archive.transparency.org/policy_research/surveys_indices/cpi/2007>

Source: Authors

Results and discussion

The calculated values of correlation coefficients shown in Table 2 indicate potential interdependencies between selected indicators. The values above 0.5 can be considered as indicators of relatively strong interdependence between the two variables.

A positive correlation was identified between the value of the summary innovation index and the level of GDP per capita across the countries. This may mean that higher innovation activity could cause intensive development of the economy and higher productivity. In other words, higher investments in innovation could also be the only result from a higher GDP level. Therefore, it is more appropriate to analyze the dependency between innovation performance growth and GDP growth over the years. Thus, in this case our results are similar. Moreover, we have identified the positive correlation between the index of innovation growth for the period of 2008 to 2012, and GDP growth in the year 2012. This indicated that those countries, which had been more intensively upgrading their innovation performance over the same period, reached a higher economic growth in 2012. A positive correlation was also discovered between R&D expenditure and the number of patents, as well as between R&D expenditures and the numbers of scientific researchers. We can say that higher R&D expenditures could directly add the number of researchers and patents for the country. However, based on the correlation analysis, we could not confirm the positive impact of R&D expenditure on GDP growth. Thus, a more appropriate method for the examination of this kind of dependency is the regression analysis, which we have also used in this study. The results of panel data regressions are shown in Table 3. Both models are based on the value of F-statics, statistically significant at all commonly used significance levels.

Table 2: Correlation coefficients between selected indicators

	Summary innovation index (2012)	**GDP per inhabitant – PPP (2012)**	**Index of innovation growth (2008-2012)**	**ΔGDP (2012)**	**R&D expenditures (% HDP)**	**Number of patents per 100k inhabitants**	**Number of R&D employees per 100k inhabitants**
Summary innovation index (2012)	1.000						
GDP per inhabitant - 2012 (PPP)	**0.680**	1.000					
Index of innovation growth (2008-2012)	-0.109	-0.228	1.000				
ΔGDP (2012)	-0.144	-0.073	**0.598**	1.000			
R&D expenditures (% HDP)	**0.855**	0.455	-0.086	-0.189	1.000		
Patents per 100k inhabitants	**0.689**	0.399	-0.280	-0.232	**0.744**	1.000	
Number of R&D employees per 100k inhabitants	**0.643**	0.470	-0.109	-0.111	**0.804**	**0.560**	1.000

Source: Authors

Table 3: Regressions results

Independent variables	**(1)**	**(2)**
C	0.1421 (0.03)	-5.8910 (-1.52)
D(R&D_EXP)	**-6.4302***** **(-3.37)**	
FDI	0.0293** (3.03)	0.0388*** (6.02)
EATR	0.7984*** (3.61)	0.8928** (2.44)
$EATR^2$	-0.0158*** (-3.54)	-0.0173** (-2.34)
STR_NEIGHBOUR	-0.0756 (-3.37)	
UNEMPLOYMENT	-0.3360*** (-4.48)	-0.3088* (-1.84)

D(PUBLIC_DEBT)	-0.3459*** (-8.64)	-0.3994*** (-3.48)
GDP	-0.0001* (-1.88)	
OPENNESS	0.0260* (1.79)	
CORRUPTION	-0.1875 (0.68)	
lagged D(R&D_EXP) (lag = -2)		**7.6922*** **(1.76)**
Observations	306	263
R–squared	0.543	0.561
F–statistic	9.17	9.53

Source: Authors

Notes: Regressions are estimated by fixed effects over the period of 1999-2011 across potentially 26 EU countries; due to missing observations, the number has reduced from 306 to 263 observations; (.) denotes t statistics and */**/*** indicates significance at the 10%/ 5%/ 1% levels. Standard errors have been corrected for heteroscedasticity.

The first difference in R&D expenditures has estimated parameter with a negative sign in the first regression. However, this is consistent with the theoretical assumption because the positive effect of R&D expenditure on GDP growth could be expected, especially, in the medium or long term. Therefore, we tried to lag the variable in the time. We can confirm the positive effect of this variable on GDP growth, after using a 2-year lag, but the variable is significant only at the 10% level or at every level above 6.7% (p-value = 0.067). Based on these results, we can conclude that it is very likely that the growth of R&D expenditures has a negative impact on economic growth in the same year (short term); however, it will have a positive impact in the medium or long run. The positive effect on productivity can be expected no earlier than two years since the increase in the level of R&D expenditures. Upon further investigation of other variables in the second model, we can see that all of them have the expected impact on GDP growth. We have found a non-linear relationship between effective corporate tax burden and GDP growth, as well as the negative impact of unemployment and changes in public debt. Based on the regression results, we can also say that foreign direct investment (FDI) inflows to the country have a positive effect on economic growth. This variable is significant at the 1% level. Thus, this could also be partially linked to technological diffusion because FDI is considered an important global source of technological diffusion between countries.

Conclusion

Technological progress is considered the most important determinant of economic growth since the development of the Solow model. The endogenous growth model later suggested that technological progress is dependent on the accumulation of knowledge, which should be directly related to R&D sector. Research and development creates inventions that could lead to innovation, which means increased productivity and economic growth. Thus, R&D expenditures are likely to be a key prerequisite for the existence of sustainable long-term economic growth.

However, there are still many semi-endogenous or modified endogenous growth models that predict a reduced or gradually declining impact of R&D expenditures on economic growth, mostly because of global population growth and growing variety of products. Based on the panel data regression, we can conclude that our results suggest a positive impact of R&D expenditures on economic growth when, considering a two-year lag. In addition, R&D expenditures in the EU member states are positively correlated with the number of employees in R&D sector, as well as with the number of patents. This could indicate that financial input into R&D has extensively resulted in the higher number of employees, thus leading to a larger number of outputs in the form of patents. We have also shown, by correlation analysis results, that EU countries, which had intensively improved innovation performance over the period of 2008 and 2012, in most cases reached a higher GDP growth rate in 2012. This fact only underlines the importance of innovation for economic growth of the country.

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