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R&D expenditure and economic growth: EU28 evidence for the period 2002–2012

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ABSTRACT
In this paper, we investigate the influence of R&D expenditure on economic growth in the EU28 during the period of 2002–2012. For this purpose, we constructed a multiple regression model, which showed that, *ceteris paribus*, an increase in R&D expenditure as a percentage of GDP by 1% would cause an increase of real GDP growth rate by 2.2%. This model takes into consideration actual financial crises and emphasises the negative influence of fertility rate in the EU28 on economic growth. We believe that the achieved research results can be beneficial to the economic policy makers in the innovation and demographic areas.

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1. Introduction

At the present time, developed countries largely base their economic growth on the creation and use of knowledge. Knowledge, objectified in technological changes, has become a fundamental creator of competitive advantage of companies and countries on the world market (Lucas, 1988, 1993).

The study of knowledge as a key determinant of economic growth is especially present in so-called new growth theory. The two most important directions of new growth theory are endogenous growth models and evolutionary approach to presenting the complex of technological change as a source of economic growth. The common thread is their attempt to arrive at a proper answer to the question of what are the key drivers of complex technological changes.

Endogenous growth models, based on research and development, in some way follow Schumpeter's idea of the importance of organised knowledge creation in generating economic growth (Schumpeter, 1942). The basis of these approaches rests on the idea of creative destruction (Ayres & Warr, 2009). What drives individuals to engage in research and development activities is their perception that such activity will ensure extra profit (Ruttan, 2004).

The economic recession of the 1970s has contributed to the emergence and spread of evolutionary and institutional trends in economic theory. This fact has, among other things,

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given rise to the claim that research and development activities are a necessary, but not sufficient condition for generating technological change. This implicitly shifted the interests of economic growth analysts from science to technological innovation, as objectified knowledge that can be commercialised. Pointing out the importance of efficient organisation of research activities aimed at creating innovation can be found in the affirmation of the concept of a national innovation system of the 1980s and 1990s in Europe (Freeman, 1985) and the USA (Dosi, Freeman, Nelson, Silverberg, & Soete, 1988). The key message of this view is that economic growth is far more dependent on the quality of the functioning of educational and research and development capacities of countries in relation to their potentially available physical capacity (OECD/TEP, 1992).

In light of the above-mentioned attitudes, importance is given to the question of whether the link between the activities that drive the complex of technological changes and economic growth of individual countries in previous years can be empirically confirmed. In this regard, it is quite clear that the overall activities of the country that trigger technological changes are represented by a large number of indicators. One of the indisputable indicators of such efforts is the GERD indicator. The GERD (Gross domestic expenditure on R&D) as a percentage of GDP presents research and experimental development (R&D), comprising creative work undertaken on a systematic basis in order to increase the stock of knowledge, including knowledge of man, culture and society and the use of this stock of knowledge to devise new applications.

The research in this paper covered 28 EU countries, observed in the timeframe 2002–2012. Using the multiple regression method, except for the GERD indicator, the following have been used as control variables, relevant to the generation of economic growth: gross capital formation, government final consumption expenditure, fertility rate, and the financial crisis.

The paper will first present theoretical views about the importance of the complex of research and development for the economic growth of individual countries, and then provide an overview of significant empirical research regarding this topic. The final part will present the results obtained by the multiple regression method, based on a sample of 28 EU countries in the period from 2002 to 2012.

2. Literature review

The view that the complex of technological changes represents the most important source of economic growth first entered economic science when precisely promoted by the representatives of neoclassical economic thought. The neoclassical growth theory predominantly rests on Robert Solow's model, developed in the mid-1950s (Solow, 1956). Solow came to the conclusion that approximately 50% of historical growth in industrialised countries cannot be attributed to the growing use of physical capital and labour, but to the third factor, the so-called residual (Solow, 1957). Residual includes all growth factors of an intangible nature, such as the development of existing, and the creation of principally new, means of production, changes in education and expertise of employees, research and development, changes in organisation and methods of production.

Therefore, neoclassical theory has introduced the complex of technological changes in the economic analysis as the key factor of economic growth. In this way, in a methodological context, it made a significant step forward in the study of the most important drivers of economic growth. However, the neoclassical theory of economic growth fully neglected the issue of the sources of technological changes, which is considered its main shortcoming. In addition to this deficiency, the fact is that neoclassical economists failed to explain huge differences regarding residuals among countries at similar levels of technological development (Todaro & Smith, 2006).

Notwithstanding the above-mentioned findings, it should be noted that the neoclassical considerations paved the way for the recognition of research and development activities as increasingly important drivers of economic growth of economically leading countries in the last decade of the previous century (Švarc, 2009). Moreover, these views have encouraged the governments of most countries to invest significant funds in research and development activities. This point is often overlooked by modern economic analysts (Švarc, 2009), although it is very important in view of arriving at acceptable answers to the research question in this paper. In addition, in our opinion, Arrow's (1962) views on the reduction of the average cost of production based on the learning curve (learning by doing) are important too, as well as the dynamic general equilibrium model, conceived by Judd (Judd, 1985), which explicitly includes research activity in the model and justifies the existence of monopolistic profits in view of the functioning of the research sector.

Arrow considers that new ideas are the logical outcome of the use of old ideas, i.e., that they occur during the performance of production activities (Arrow, 1962). Individuals are better when they produce more, while at the level of industries, a production process allows each manufacturer to learn from the experiences of other manufacturers.

Technological changes in Judd's general equilibrium model exhibit diminishing returns, and, therefore, cannot lead to long-term sustainable growth. Judd assumed that a company can create new products by investing a fixed amount of resources in innovation (Judd, 1985). Furthermore, any such company can protect its innovation by the patent which gives it the exclusive right to sell over a specified period of time. The problem with the model stems from the fact that the subsequent innovators generate less profit due to rising competition. The profit of subsequent innovators is not sufficient even to cover the cost invested in research and registration of patents.

Models of a particular type, characterised by monopoly power, basically assume the existence of a separate technological sector in the economy, which supplies other sectors by new technology. Manufacturers buy new technology, and thus acquire the right to use it. They also charge a price that is higher than the marginal cost of their production in order to achieve an income of the amount that can cover costs, including the initial investment in new technology. In this regard, investment in innovation projects does not involve diminishing returns. This means that the productivity of new investment in innovative activity is not reduced, which, at the macro level, allows steady and sustainable economic growth. In these models, the growth rate depends on the amount of funds allocated for research and development, the degree to which new technology can be used for private purposes, and the time horizon of investors.

For example, Romer mathematically formalised the idea that knowledge leads to continuous economic growth, which marked a new theoretical approach to the analysis of economic growth factors, the so-called endogenous growth (Romer, 1986, 1987). Unlike Judd's model, according to Romer, innovation does not exhibit diminishing returns, which removes the main obstacle to the achievement of long-term sustainable growth.

In Romer's model, growth rests on the results of research and development, embodied in technological changes, which companies use to maximise profit. In this regard, Romer points to the fact that technology is different from all other goods, as it is uncompetitive and a partially excludable good.

There are three basic assumptions of Romer's model: (a) technological changes represent an essential factor of economic growth; (b) they result from the activities of economic agents (individuals and businesses), driven by market motives; and (c) technology is distinguished by non-competitiveness and partial excludability. These three assumptions directly point to the conclusion that the balance is not possible under conditions of perfect competition, but only under monopoly. In fact, if all factors were paid according to the amount of the marginal product, the company would have losses, resulting from additional costs, associated with the previous investment in research and development. In Romer's model, there are four basic factors of production: physical capital, labour, human capital, and technology (Romer, 1993, 1994). The economy has, therefore, three sectors. The first is the research sector, which uses human capital and the current level of accumulated knowledge (technology) to produce new knowledge. More specifically, that sector produces 'new designs' for the production of intermediate capital goods. The second is the sector of intermediate capital goods, which uses new designs coming from the research sector, together with the previously created final product (which has not been spent, but saved) for the production of various new intermediate capital goods. The final goods sector uses labour, human capital, and intermediate capital goods to produce final consumer goods (Romer, 1989).

The model implies that the long-term equilibrium growth rate is determined by the level of accumulated human capital. In a stable equilibrium, too little human capital is intended for research and development activities. The integration of national economies into the global market increases the growth rate. Growth is more pronounced with a more favourable proportion of human capital in the research and development sector and total accumulated human capital (Valdés, 1999).

Unlike Romer's model, which constantly increases the number of new designs as a result of research, new products can replace the old ones. This feature of technological progress has been particularly studied by Grossman and Helpman (Grossman & Helpman, 1991) and Aghion and Howitt (Aghion & Howitt, 1992, 1998).

In conditions of perfect competition, companies can use the results of research and development for free, which leads to demotivation of people to deal with them. Conversely, under conditions of monopoly and patent protection, such stimulus exists. Specifically, when a new and more efficient design is created, to be used for the production, the company that is the first to use this new design wins the market share of its competitors, as it can offer a better product at the same price, or the same product, in terms of quality and functionality, at a lower price. Competitors respond to that by introducing the same or more recent design, or completely lose their market share. According to these models, each product can be improved indefinitely, with a new generation of products always with better performance per unit cost than the previous generation. The point is that each new generation of products includes research and development expenditures. Therefore, the market winner retains the monopoly rent until the emergence of new innovation. Investment in innovation projects is not characterised by diminishing returns, and increases the productivity of all new innovative projects, thus enabling constant sustainable economic growth.

Models based on research and development are often used to explore the role of economic openness. The simplest channel through which greater openness can affect faster growth is the spillover of new knowledge. Rivera-Batiz and Romer show that equilibrium growth is faster in an integrated world than in isolated countries, even when there is no exchange of goods between countries (Rivera-Batiz & Romer, 1991). In a world of relatively cheap communication, knowledge created in one country becomes easily available to researchers in other countries. Nevertheless, there are also other ways in which openness encourages faster technological progress. In fact, companies in open economies have the opportunity to sell their innovations on the world market and, anticipating higher profit, invest in research and development, better than companies that sell only on the national market. In addition, one part of the models based on research and development is focused on analysing the process whereby technologically less advanced countries imitate technological developments in the technologically leading countries.

Numerous empirical studies show that the private sector invests in research and development far below the socially optimal level. Some authors even estimate that the total investment in research and development amounts to less than a quarter of an optimal level (Jones, 1995). Insufficient investment of private capital in the field of research and development partly results from market imperfections that can make these investments bigger and incomparably riskier than other forms of investment.

From the perspective of companies, the question of the profitability of investments in applied research can be treated in the same way as the profitability of other investments. The company will invest as long as it expects the profit from the research project to at least cover its costs. Average profit from research and development projects for the company is high, ranging from 20 to 30%, but the social returns are much more pronounced, and often go over 50%. This spillover happens when others use research results and diffuse them in the directions that innovators often cannot imagine. The spillover means that the company, an investor in the field of applied research, achieved part of the profit, generated from the application of the results of the specific research and development project. Because of this, companies invest less in research and development than they would in case they could realise the overall benefits that are the result of their own research. In other words, some research projects, which would have positive overall net benefits (i.e., the sum of private and social revenue minus the cost of the project), are privately unprofitable because the investor, logically, does not effectuate social benefits. If, in this case, there were no certain market interventions, the private sector would not undertake research projects even though they are in the interests of society. The concept and application of aggressive economic strategy based on innovation includes the growth of public and especially private investment in research and development, where the state, through its tax policy, should reduce taxes on corporate investment in research and development (Atkinson & Ezell, 2012).

Taking into account all these facts, the following section will present our attempt to quantify the link between investment in research and development activities and the dynamics of economic growth in the 28 EU countries in the period from 2002 to 2012.

3. Data and methodology

The precise expression of the levels of innovation activities in a national economy is an extremely important factor in empirical research on the impact of innovation on economic growth rate. The most commonly used data on innovative activities in one country are the share of research and development expenditure in GDP. This approach is highly acceptable because it is suitable for quantitative and qualitative analysis. Furthermore, the section of the European statistics that refers to the level of innovation in a country includes these data in its official annual reports.

In our study, the dependent variable is the real growth rate of gross domestic product. Data on this value have been taken from the official statistics of the European Union, i.e., Eurostat. It is known that gross domestic product is a measure of economic activity in a national economy, measured by the value of output (goods and services). Calculating the real growth rate of gross domestic product allows one to follow the dynamics of the level of economic activity, both in different economies, and in different time periods. The real economic growth rate further excludes the impact of inflation on the measurement of dynamics of the level of economic activity at the national level.

The main task of this study is to determine 'whether the share of research and development expenditure in one country has an impact on economic growth'. In this regard, our dependent variable is the share of research and development expenditure as a percentage of GDP. Data on this variable are available from Eurostat.

The model that we want to construct in our research will be enriched by additional variables, which we believe to have additional impact on the real economic growth rate, which is why we want to examine their impact on economic growth in the observed economies.

The first on the list of control variables is gross fixed capital formation as a percentage of GDP. The level of gross fixed capital formation is a macroeconomic concept, used in official national accounts, such as the United Nations System of National Accounts (UNSNA), National Income and Product Accounts (NIPA), and the European System of Accounts (ESA). The 1937 study by Simon Kuznets is an essential source of this indicator, which has been used as a standard macroeconomic indicator since 1950. In statistical terms, gross fixed capital formation shows the value of purchasing new or existing fixed assets by business entities, government, and households (excluding entrepreneurs), minus the value of alienated fixed assets. In a word, gross fixed capital formation is the component of gross domestic product, aimed at investment, rather than personal consumption.

There are numerous studies that examine the link between gross fixed capital formation and economic growth. In particular, there are the results of empirical study, which, based on data from 65 countries in the period from 1960 to 2000, prove a positive relationship between the average rate of investment in fixed assets and the average growth rate of gross domestic product per employee (Sørensen & Whitta-Jacobsen, 2010).

The second on the list of control variables in our study is the share of government final consumption expenditure in GDP, referring to the value of goods purchased or created by the state and directly aimed at households for the purpose of personal consumption. This information has also been taken from Eurostat.

The third control variable in the model is the fertility rate, referring to the mean number of children that would be born alive to a woman during her lifetime if she were to pass through her childbearing years conforming to the fertility rates by age of a given year. For mere regeneration of the population, a level of around 2.14 children per woman is required, at low mortality conditions. It is logical that, without people, there is no economic growth, which is the reason why we included this variable in our research.

Table 1. Descriptive statistics and names of variables.

Variable	Obs.	Mean	Std. dev.	Min	Max
Real GDP growth rate	308	0.0209416	0.039242	–0.177	0.11
General government final consumption expenditure as a percentage of GDP	308	0.203237	0.0306502	0.148	0.298
Gross fixed capital formation as a percentage of GDP	308	0.2147175	0.0413092	0.106	0.36
R&D expenditures as a percentage of GDP	308	0.142662	0.0093467	0	0.0394
Fertility rate	308	1.5325	0.2289985	1.17	2.1

Source: Research results.

The third control variable is the financial crisis. Specifically, the global economic crisis, which began in the United States in late 2008, soon spilled over to the European continent. We could see that its emergence did not only endanger the global financial system. More or less, all economic sectors in Europe were exposed to the consequences of its occurrence. All economies within the European Union were exposed to the negative impact of the financial crisis. In the economies that are the subject of our study, it is evident that the economic growth rate in 2008 was lower, compared with the previous year, or even reached negative levels. In 2009, all economies within the European Union had a negative economic growth rate. This is the reason why we introduced an artificial binary variable (dummy variable) in our study, which had a value of one for all countries in the crisis years (2008 and 2009), and a value of zero for all remaining years observed.

In our research, we use a multiple regression model with fixed effect (FE). The reason for such an approach lies in our decision to analyse the influence of selected variables that change over time. The fixed effect explores the link between, on the one hand a dependent and on the other hand independent and control variables, within each entity individually (in our case, the observed countries). Each entity has its own characteristics, which determine the influence of independent and control variables on the dependent variable (in our case, the real growth rate of gross domestic product).

When using FE, we assume that something within the countries may impact on the predictor or outcome variables, and we need to control this.

Another important assumption of the FE model is that those time-invariant characteristics are unique to the entity, and should not be correlated with other entities' characteristics. Each entity is different, therefore, the entity's error term and the constant (which captures individual characteristics) should not be correlated with the others entity's error terms. (Wooldirdge, 2002).

If the error terms of two entities are correlated, then FE is not suitable for prediction. In this case, the model should be replaced by random-effect modelling (RE). For testing the suitability of the model (FE vs. RE), we use the Hausman test.

4. Regression, tests and results

We begin our analysis with a summary of descriptive statistics in Table 1.

The mean real GDP growth rate is 2%, and the standard deviation is almost two times greater. The explanatory variables (dependent variable and control variables) also showed great deviation. This could be one of the indicators for using the fixed effect model in some future regressions of this paper. We suppose that every country has some characteristics that influence real GDP growth differently. The mean is based on observations from all

Table 2. Correlation matrix between independent variable and predictors.

Variable	Real GDP growth rate	General government final consumption expenditure as a percentage of GDP	Gross fixed capital formation in % GDP	R&D expenditures as a percentage of GDP	Fertility rate
Real GDP growth rate	1.0000				
General government final consumption expenditure in % of GDP	−0.2721	1.0000			
Gross fixed capital formation in % GDP	0.4129	−0.3787	1.0000		
R&D expenditures in % GDP	−0.1711	0.6052	−0.3214	1.0000	
Fertility rate	−0.2123	0.4949	−0.2900	0.5536	1.0000

Source: Research results.

Table 3. Simple linear regression.

Source	SS	df	MS	Number of obs	308
Model	0.227066261	5	0.045413252	F (5, 302)	55.82
Residual	0.245694687	302	0.000813559	Prob > F	= 0.0000
Total	0.472760948	307	0.001539938	R-squared	= 0.4803
				Adj R-squared	0.4717
				Root MSE	=.02852

Real GDP growth rate	Coef.	Std. Err.	*t*	*P* > |*t*|	95% conf. interval	
General government final consumption expenditure as a percentage of GDP	−0.104752	0.0706987	−1.48	0.139	−0.2438764	0.0343725
Gross fixed capital formation as a percentage of GDP	0.4136173	0.434353	9.52	0.000	0.3281432	0.4990915
R&D expenditures as a percentage of GDP	0.1281297	0.2364936	0.54	0.588	−0.3372542	0.5935137
Fertility rate	0.0026363	0.0089174	0.30	0.768	−0.0149118	0.0201843
Dummy	−0.0557686	0.0043036	−12.96	0.000	−0.0642374	−0.0472999
_cons	−0.0423081	0.020662	−2.05	0.041	−0.0829679	−0.0016483

Source: Research results.

countries, and that could be the reason for a great standard deviation. When we use fixed effect model to get entity errorr, the error is correlated with other predictors in equity. Those entity errors are unobserved time invariant characteristics of every country.

Table 2 represents a correlation matrix between independent variables and predictors.

The simple correlation with a growth rate of GDP and other predictors is modest. Interestingly, the correlation of real GDP growth rate is not even positively associated with the R&D expenditure as a percentage of GDP. There is not a strong correlation between independent variables, which is good for our future regressions.

First, we will run a simple linear regression. The dependent variable we use is real GDP growth rate. The independent variables are government final consumption expenditure, gross fixed capital formation, R&D as a percentage of GDP, fertility rate, and we also include our dummy variable, which represents financial crisis. The regression is given in Table 3.

The value of R-squared, which is 48.03% of the variance of the dependent variable real GDP growth rate, is explained by our regression model. Adjusted R-Squared has a similar interpretation, but we take into account the numbers of variables we have in our regression model. We are basically interested to find it out if there is any evidence between our independent variable and a dependent variable controlling for the other variables. In order to prove that, we must formulate a null hypothesis. Null hypotheses test the following model:

> There is no relationship between Real GDP growth rate and final government consumption expenditures in percentage of GDP, gross fixed capital formation in percentage of GDP, R&D as a percentage of GDP, fertility rate, and dummy variable which represents financial crisis.

The multiple regression coefficients have a *ceteris paribus* interpretation. The first thing we noticed in this regression is that the p-value for the R&D expenditure as a percentage of GDP, final government consumption expenditures in percentage of GDP and fertility rate are particularly high and suggest no significant effect from them. Other variables are significant.

We have two main reasons to believe that model made with OLS regression does not work. The first is that our independent variable does not have significant p value, and also two of the control variables did not have significant p values. Second, for the panel data, it is more acceptable to use a Fixed Effect or Random Effect regression model.

5. Econometric model

We have a multiple regression model for 28 countries $i = 1, \ldots, 28$, observed at several time periods $t = 1, \ldots 11$.

$$y_{it} = \alpha + x'_{it}\beta + c_i + u_{it} \tag{1}$$

where y_{it} is dependent variable, α is intercept, x'_{it} is a K-dimensional row vector of explanatory variables, β is a K-dimensional column vector of parameters, c_i is country specific effect and u_{it} is error overall term.

The T ($T = 11$) observations for each country are summarised by the following matrices:

dependent variable y_i, it is represented by:

$$y_i = \begin{bmatrix} y_{i1} \\ . \\ . \\ y_{i5} \\ . \\ . \\ y_{i11} \end{bmatrix}, y_i = [11 \times 1].$$

For independent variable X_i, it is represented by:

$$X_i = \begin{bmatrix} x'_{i1} \\ . \\ . \\ x'_{i5} \\ . \\ . \\ x'_{i11} \end{bmatrix}$$

$X_i = [11 \times 5]$, as we have five independent variables in regression.

And for the overall error term matrix is:

$$u_i = \begin{bmatrix} u_{i1} \\ . \\ . \\ u_{i5} \\ . \\ . \\ u_{i11} \end{bmatrix}, u_i = [11 \times 1].$$

Let's denote the last country in set i with $N(N = 28)$ and last year in set t with $T(T = 11)$. Now we can write NT observations for all countries and time periods as follows.

For dependent variable y, it is represented by:

$$y = \begin{bmatrix} y_1 \\ . \\ . \\ y_i \\ . \\ . \\ y_{28} \end{bmatrix}, y = [NT \times 1].$$

For independent variable X, it is represented by:

$$X = \begin{bmatrix} X_1 \\ . \\ . \\ X_i \\ . \\ . \\ X_{28} \end{bmatrix}, X = [NT \times K].$$

For independent variable X, it is represented by:

$$u = \begin{bmatrix} u_1 \\ . \\ . \\ u_i \\ . \\ . \\ u_{28} \end{bmatrix}, X = [NT \times 1].$$

The data generation process is described by linearity: $y_{it} = \alpha + x_{it}'\beta + c_i + u_{it}$, where $E(u_{it}) = 0$ and $E(c_t) = 0$.

The model is linear in parameters α and β, individual effect $c_i$and overall error $u_{it.}$

Independence: $\{X_i, y_i\}_{i=1}^{N}$, (independent and identically distributed).

The observations are independent across individuals but not necessarily across time. This is guaranteed by random sampling of countries.

Strict exogenicity: $E = (u_{it}|X_i, c_i) = 0$.

The overall error term u_{it} is assumed uncorrelated with the explanatory variables of all past, current and future time periods of the same individual. This is a strong assumption which, for example, rules out lagged dependent variables. This also assumes that the overall error is uncorrelated with the individual specific effect. Further assumptions allow us to distinguish the random effects model and the fixed effects model (Schmidheiny, 2013).

In our study, the dependent variable is the real growth rate of gross domestic product. Data on this value have been taken from the official statistics of the European Union, i.e., Eurostat. It is known that gross domestic product is a measure of economic activity in a national economy, measured by the value of output (goods and services). Calculating real growth rate of gross domestic product allows following the dynamics of the level of economic activity, both in different economies, and in different times.

6. The random versus fixed effects model

In the random effect model, the individual-specific effect is a random variable that is uncorrelated with the explanatory variables.

Unrelated effect: $E(c_i|X_i) = 0$.

This assumption says that the individual-specific effect is a random variable that is uncorrelated with the explanatory variables of all past, current and future time periods of the same individual. This is a very strong assumption that usually economists do not like. From this we can conclude that the random effect model would not be used in this paper. Later, we proved this by the appropriate test.

In the fixed effects model, the individual-specific effect is a random variable that is allowed to be correlated with the explanatory variables.

Related effect: $E(c_i|X_i) \neq 0$.

Variance effect: $V(c_i|X_i) = \sigma^2 < \infty; V(c_i|X_i) = c_{c,i}^2(X_i) < \infty$.

This assumes constant variance of the individual specific effect.

Identifiability rank $(\ddot{X}) = K < NT$ and $E(x_i^{\prime\prime}\ddot{x})$where typical element $x_{it} \doteqdot x_{it} - \bar{x}$ and $\bar{x} = \frac{1}{T}\sum x_{it}$. This assumes that the explanatory variables are not perfectly collinear, that all regressors have non-zero within-variance. Hence x_{it} cannot include a constant or any other time-invariant variables (Schmidheiny, 2013).

7. Results

7.1. Results for fixed effect regression model

Taking into account all the facts mentioned above, we perform multiple regression with fixed effects for independent, dependent, and control variables. The results are shown in Table 4.

Table 4. Multiple regression using fixed effect model.

Fixed-effects (within) regression		Number of obs	308
R-sq: within	=0.5881	Number of groups	= 28
between	=0.2031	Obs per group: min=	11
overall	=0.3608	avg=	11.0
		max=	11
		F (5, 275)	78.54
corr (u_i, Xb)	= −6,652	Prob > F	= 0.0000

Real GDP growth rate	Coef.	Std. Err.	*t*	*P* > |*t*|	95% Conf. Interval	
General government final consumption expenditure as a percentage of GDP	−0.2920951	0.1474043	−1.98	0.049	−.5822793	−.0019109
Gross fixed capital formation as a percentage of GDP	0.6057583	0.0573201	10.57	0.000	.4929163	.7186003
R&D expenditures as a percentage of GDP	1.113281	0.4922553	2.26	0.025	.1442138	2.082349
Fertility rate	−0.0866793	0.0200049	−4.33	0.000	−0.1260616	−0.047297
Dummy	−0.0492339	0.0043043	−11.44	0.000	−0.0577074	−0.0407604
_cons	0.0761444	0.0488425	1.56	0.120	−0.0200083	0.1722972
sigma_u	0.02793542					
sigma_e	0.02508093					
rho	0.55368604		(fraction of variation due to u_i)			
F test that all u_i=0:	(27, 275) = 4.28			Prob > F = 0.0000		

Source: Research results.

Table 4 shows that all predictors have a statistically significant *p* value (with a note that the control variable, government final consumption expenditure as a percentage of GDP, is at the limit level). The conclusion arising from Table 4 is that, with the clause *ceteris paribus*, an increase in the share of research and development expenditure in GDP by 1% will have an impact on the real growth rate of GDP by 1.11 percentage points in the observed economies in the observed period. The coefficient of determination amounts to 58.81%.

In order to improve the validity and applicability of the model, i.e. that the variable government final consumption expenditure as a percentage of GDP has a lower *p* value, but also point to the growing importance of investment in research and development for economic growth, we performed the time adjustment of our control variables. Therefore, on the basis of a number of iterative steps, we constructed a multiple regression model, in which we observed the effects of fertility rates with a one-year lag (Table 5).

Table 5 points to the conclusion that, with the clause *ceteris paribus*, an increase in the share of research and development expenditure in GDP by 1% will have an impact on the growth rate of real GDP by 2.27 percentage points. The coefficient of determination in this case is higher, and amounts to 64.88%. In addition, in this case, correlation between entity error and predictors is different from zero, and, in our case, amounts to −0.704. Based on a negative correlation value, it may be concluded that predictors are included in the model, and the description of a predicted variable is better when the error is getting smaller. If we

Table 5. Multiple regression using fixed effect model with time lag for one year for fertility rate.

Fixed-effects (within) regression		Number of obs	280
Group variable:	Country	Number of groups	=28
R-sq: within	=0.6488	Obs per group: min=	10
between	=0.1371	avg=	10.0
overall	=0.3470	max=	10
		F (5, 247)	91.25
corr (u_i, Xb)	= −0.7040	Prob > F	=0.0000

Real GDP growth rate	Coef.	Std. Err.	t	$P > \|t\|$	95% Conf. Interval	
General government final consumption expenditure as a percentage of GDP	−0.3426468	0.1532971	−2.24	0.036	−0.644583	−0.0407105
Gross fixed capital formation as a percentage of GDP	0.5710302	0.0604717	9.44	0.000	0.4519242	0.6901362
R&D expenditures as a percentage of GDP	20.278597	0.06757759	3.37	0.001	0.9475789	30.609615
Fertility rate	−0.1345203	0.0199685	−6.74	0.000	−0.1738506	−0.0951899
Dummy	−0.0488182	0.0040576	−12.03	0.000	−0.0568102	−0.0408262
_cons	0.1494699	0.051206	2.92	0.004	0.0486138	0.2503261
sigma_u	0.03374226					
sigma_e	0.02416864					
rho	0.66091853		(fraction of variation due to u_i)			
F test that all u_i=0:	(27, 247) = 5.62			Prob > F = 0.0000		

Source: Research results.

add to this the fact that the F-test is a good value, we confirm that all coefficients are different from zero. From the point of all these facts, we can construct our model.

$$\begin{aligned} (Real\ GDPgrowth\ rate)_{it} = \\ 0,5710(Gross\ fixed\ capital\ formation\ in\ \%\ GDP)_{it} - \\ 0,3426(Final\ consumption\ expenditure\ of\ general\ government\ in\ \%\ GDP)_{it} + \\ 2,2785(R\&D\ expenditure\ in\ \%\ of\ GDP)_{it} - 0,1334\ (Fertility\ rate)_{it-1} - \\ 0,0488(Dummy)_{it} - 0,1494 + c_i + u_{it} \end{aligned} \quad (2)$$

7.2. Hausman test for endogenity of the model

In order to decide between fixed or random effects we run a Hausman test where the null hypothesis is that the preferred model is random effects versus the alternative, fixed effects. It basically tests whether the unique errors (u_i) are correlated with the regressors, the null hypothesis is that they are not.

We have to make the regression with a random effect model in order to compare the significance of an estimator versus an alternative estimator. The regression is shown in Table 6.

The result of Hausman test is presented in Table 7.

Table 6. Regression using random effect.

Random-effects GLS regression		Number of obs	280
Group variable:	Country	Number of groups	= 28
R-sq: within	=0.6031	Obs per group: min=	10
between	=0.2119	avg=	10.0
overall	=0.4797	max=	10
		Wald chi2 5)	324.47
corr (u_i, X,)	= 0 (assumed)	Prob > chi2	= 0.0000

Real GDP growth rate	Coef.	Std. Err.	*z*	*P* > |*z*|	95% Conf. Interval	
General government final consumption expenditure as a percentage of GDP	−0.1093287	0.0979131	−1.12	0.264	−0.3012348	0.0825774
Gross fixed capital formation as a percentage of GDP	0.5149059	0.0512039	10.06	0.000	0.4145482	0.6152637
R&D expenditures as a percentage of GDP	0.8291209	0.3412089	2.43	0.015	0.1603638	10.497878
Fertility rate	−0.0319011	0.0124928	−2.55	0.011	−0.0563866	−0.0074156
Dummy	−0.0549785	0.0041318	−13.31	0.000	−0.0630766	−0.0468803
_cons	−0.020601	0.0283531	−0.73	0.467	−0.0761721	0.03497
sigma_u	0.00933555					
sigma_e	0.02416864					
rho	0.12983113	(fraction of variation due to u_i)				

Source: Research results.

Table 7. Hausman test results.

	- Coefficients -			
	(b) fixed	(B) random	(b-B) Difference	Sqrt (diag (V_b-V_B)) S.E.
General government final consumption expenditure as a percentage of GDP	−0.3426468	−0.1093287	−0.2333181	0.1179535
Gross fixed capital formation as a percentage of GDP	0.5710302	0.5149059	0.0561243	0.0321713
R&D expenditures as a percentage of GDP	2.278597	0.8291209	1.449476	0.5833092
Fertility rate	−0.1345203	−0.0319011	−0.1026192	0.0155779
Dummy	−0.0488182	−0.0549785	0.0061603	

Source: Research results.
b = consistent under Ho and Ha; obtained from xtreg
B = inconsistent under Ha, efficient under Ho; obtained from xtreb
Test: Ho: difference in coefficients not systematic
chi^2 5) = (b-B) [(V_b-V_B) ^ (-1)] (b-B) = 111.01
Prob>chi^2 = 0.0000 (V_b-V_B is positive definite)

The null hypothesis is highly rejected. We can say that our (u_i) is highly negative correlated with regressors which mean that as error is smaller regressors are more consistent and there is not endogenity in the model, which means that we have proved that investing in R&D activities in EU countries in the period 2002–2012 is statistically significant determinant of the real growth rate of gross domestic product.

We also want to emphasise one more interesting result that we get by using the multi-factor regression method. It is obviously a negative coefficient in front of the fertility rates, as in the model with the fixed, and the random effect. Using the clause *ceteris paribus*, this means that with the increase in fertility rates, economic growth in the EU28, will slow. One of the logical explanations, in the context of our study, would be that the results of research and development were used for the implementation of the so-called labour-saving technological change. In other words, the results of scientific-research activities contribute to the increase of efficiency of existing workers, but not the creation of new jobs. More specifically, it is realised the so-called intensive economic growth. Economic growth with better factor productivity. The theoretical basis for this conclusion is found in the neoclassical growth model of Robert Solow. Of course, this is only an assumption, which should be demonstrated by some new research. We conclude that the results obtained in this study open a new research question for which time and adequate inputs are required.

8. Conclusion

After reviewing the relevant literature and empirical studies that link the complex of research and development with economic growth, in this paper we set the research question of whether the investment in research and development in the period from 2002 to 2012 in the European Union had a positive effect on economic growth. For this purpose, we constructed a multiple regression model, in which the dependent variable was the real rate of economic growth, and the independent variable the value of research and development expenditure as a percentage of GDP. In order to have a better model, in addition to the independent variable, we introduced a control variable, with a significant impact on the real rate of economic growth. As control variables, we used gross fixed capital formation as a percentage of GDP, general government final consumption expenditure as a percentage of GDP, fertility rate, and financial crisis as a dummy variable. The obtained results unambiguously confirmed that, under conditions of the financial crisis, investment in research and development has a positive effect on the real economic growth rate. The constructed multiple regression model with fixed effects showed that, with the application of the clause *ceteris paribus*, an increase in the share of research and development expenditure in GDP by 1% causes GDP growth of 2.2% in 28 countries of the European Union in the period 2002 to 2012.

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