Chapter 3.

Can R&D expenditures be found a growth factor in the new EU countries?

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3.1. Introduction

There is a number of economic relationships, which are intuitive and seem to be so obvious that one does not need any proofs to believe in them. Generally, it is clear that economic growth, understood as GDP growth (at least if measured in PPP) should result in improvement of living conditions, thus itself could be treated as an aim of economic policy. Following this fact, it seems intuitive, and finds confirmation from empirical studies over a few decades, that it is the technology, which accounts for huge share of GDP growth (it is estimated to be some 50% in most industrialized countries, except Canada; see Boskin and Lau, 2000). Finally, it seems to be obvious, that technological progress cannot take place without proper investment loadings. These include all the technical costs of introducing new strategies, solutions and so on, but also – if not mostly – the cost of research that must be carried out to develop new technologies.

Thus, one might find a series of – apparently – natural causal relationships. The higher the expenditures on research and development (R&D), the faster the technological development. Then, the faster the technological development, the faster economic growth and, as a result, the faster the improvement of the situation of the entire nation. To give an example of such kind of logic, according to the data gathered by the U.S. Bureau of Economic Analysis, it is accounted that research and development programs contributes 6.5% to the country's economic growth between 1995 and 2002 (*Monthly…*, 2006). But is it really that obvious? In this paper, we will concentrate on the first part of the issue: can we find evidence that an increase in R&D expenditures has been a positive stimulant of economic growth considering the situation in the new EU countries? In order to address this question, we will analyze aggregate macroeconomic data from these countries over the past few years.

Having a look at the literature, one cannot draw absolutely clear conclusions. A number of results can be found, attained with the use of various techniques and based on different data from various countries. Firstly, the results that can be found might be divided into conclusions drawn on mostly microeconomic and mostly macroeconomic level. In the first case, those were single enterprises or national industry sections and branches, which were considered in the research. The author tried to construct models or find simple correlations between R&D loadings and indices that characterize the way that a company or branch is doing, such as productivity, value added per unit of invested capital or various competitiveness indices. In the case of macroeconomic research, analyses are based on the aggregate data on the entire economy of a country, thus the aim is to attain relationship between R&D expenditures as a whole, or possibly divided into some groups, and such macroeconomic indices as GDP growth (measured in various ways) or total factor productivity. This article can be classified as belonging to the second group.

Since the conclusions drawn by the researchers so far should be considered an important reference, section 3.2 of this paper is a very brief review of some research in the field. In section 3.3, we discuss the data that are used and the model that is constructed, while the estimation results are given in section 3.4. Finally, in section 3.5 we present some concluding remarks.

3.2. Previous research

Numerous results can be cited in both cases and naturally, only a few of the articles that have been published are reviewed here. Sylwester (2000) is one of the authors who, apart from his own results, present also a review of literature. Hereon only a couple of papers, in many cases less known, have been selected as to present varying results, though it should be emphasized that, in general, majority of authors do find some evidence for the dependence of R&D expenditures and economic growth on either micro- or macroeconomic level measured in a certain way.

A number of macroeconomic analyses considering the influence of R&D on – in most cases – GDP (sometimes GNP) or total factor productivity are available. For example, Goel and Ram (1994) use cross-sectional data on 52 countries, dividing them into two groups considering their level of development. While building a simple model of economic growth rate as a function of changes of labour force, investment and R&D expenditures they conclude that there is no significant influence of the latter either in the group of non-developed countries or in the entire set of countries under consideration. Nevertheless, considering a more developed convergence-type model where initial GDP level (and additionally level of schooling) is concerned, they conclude that R&D expenditures are in fact an important factor determining the rate of economic growth. They explain this divergence in the obtained results by the presence of omitted variables bias in the first case, which indeed is a potential problem in the case of all the analyses based on simple correlations and simple regressions.

On the other hand, Keller and Poutvaara (2005) analyze the extended Mankiw *et al.* (1992) model with human capital and R&D for three country groups studied by them and additionally for the group of countries excluding OECD group, to examine if R&D is as important to growth of less developed countries as to OECD countries. Mankiw *et al.*'s research was further developed by Nonneman and Vanhoudt (1996) who extended the model by adding the investment rate in research and development (R&D) for OECD countries. Both Keller and Poutvaara (2005) and Nonneman and Vanhoudt (1996) conclude, that in general R&D should be found a significant growth determinant. However, Keller and Poutvaara come to a result that while some control variables are included, R&D expenditures "lose their significance". They conclude that their findings suggest that the extension of Mankiw *et al.*'s (1992) augmented Solow's model by Nonneman and Vanhoudt to include R&D performs remarkably well in explaining cross-country differences in income and growth for the extended time period 1960-2000 and the broader country groups studied by Mankiw *et al.*, as well as when excluding OECD countries, but also that including a list of explanatory variables makes R&D investment (among others) lose its significance on a typical significance level. Although the authors do not motivate this result, probable explanation of the fact is indeed included in their own conclusion: they do explain differences *between countries* but actually do not follow changes *within* particular countries. Thus, the effect of R&D investment that they spot in the simple model might be spurious and truly caused by difference in control variables values. Supposedly, one would need to use a panel-type-model or control for a number of factors determining growth rate to draw valuable conclusions in such a case, which might yield opposite conclusions as far as significance of R&D expenditures is concerned and makes the inference based on the model with controls more reliable. Thus, in this case R&D expenditures cannot be considered an important growth determinant in the OECD group, whereas they can be considered as such in the case of other country groups.

Yet another case, where different conclusions are drawn for different groups of countries is the analysis of Bilbao-Osorio and Rodriguez-Pose (2004). They propose a two-step procedure. Firstly, they try to find the dependence between R&D expenditures and innovation progress with the use of standard knowledge production function (Griliches, 1979) with number of applications for patents per capita being a measure for innovation change. Secondly, they relate the innovation level and change to economic growth. Dividing EU countries into peripheral and non-peripheral (in geographical sense) makes them conclude, that for non-peripheral region, privately funded research seems to be the main motor of innovation, while for peripheral regions, besides private research, it is the research conducted by higher education institutions, which reports positive returns. Still public-funded R&D in general does not seem to contribute much to innovation process (another example of analysis in which R&D is divided into research performed by various sectors: the business sector, the public sector and foreign firms is the paper of Guellec and Van Pottelsberghe de la Potterie (2003) in which authors use data on a panel of 16 major OECD countries from the 1980-1989 period to conclude that the influence of R&D on productivity depends on its source). However, surprisingly only in peripheral regions have they found innovation to be an engine of economic growth with no significant relationship in non-peripheral countries.

As far as the microeconomic case is concerned, Griliches (1979) and Mohenen (1992) provide wide reviews of earlier works on the topic. The empirical conclusion in majority of the cases is that private R&D expenditures have greater influence on industrial productivity, while public expenditures do not have such influence, though one might suppose that they stimulate private expenditures thus stimulating productivity growth mostly indirectly and in longer time horizon.

An example of recent study is a paper by Kafouros (2005), in which the UK firm-level data (78 firms, 1989-2002) are analyzed. He finds that the contribution of R&D to productivity is approximately 0.04, still the estimated R&D elasticity of large firms (0.044) is higher than the corresponding elasticity of small firms (0.035). In contrast to this small difference, the R&D elasticity is considerably high for high-tech sectors (0.11), but statistically insignificant for low-tech sectors. This demonstrates differences in conclusions drawn for different types of firms in this microeconomic study, similar to differences on the macroeconomic level, described above. But the author also finds drastic changes in the R&D elasticities in time: although until 1995 the R&D-elasticity was approximately zero, after 1995 it increased dramatically to 0.09. These, apart from the difficulties with accessing adequate data, are the reasons for which a more or less homogenic group of countries observed over a relatively short period of time (shortly after economic transformation in most of them) has been selected for the analysis in this article.

Another type of microeconomic analysis is the one based on the industry level data. To give an example from the Central-Eastern Europe countries, Witkowski and Weresa (2006) analyze panel data for industry sections and branches in the 1994-2004 period (using yearly data) in Poland. They try to construct three models in which yearly production sold, gross value added and labour productivity are a function of – among others – loadings on research and development and on innovation. However, the empirical evidence can only be found while analyzing the influence of innovation loadings lagged by one year on the amount of production sold. It seems natural that the amount of expenditures on innovation defined as the cost of introducing new technologies that have been developed is a consequence of the fact that previously some R&D costs had to be borne since otherwise there would be nothing to introduce. However, due to short time series, it was not possible to check for empirical evidence of the influence of R&D expenditures on the dependent variables since probably further lagged R&D spendings would have to be considered. This, indeed, is a problem in many empirical studies on the influence of R&D expenditures on economic growth on both micro- and macroeconomic level: what lag structure should be used? In the mentioned paper the first and the second lag could be included in regression (further lags would have made the series too short for trustworthy inference) yielding no empirical evidence of their significance.

Thus, even in this brief review it can be seen that depending on the level of analysis, countries or companies of interest, time period, the conclusions might be different.

3.3. Data and the model

Different conclusions drawn by authors might obviously be explained by a number of factors, some of which have been mentioned. Still, it is also obvious that the analyzed relationship might simply take place in some countries or regions and might not take place in others at the same time, as well as they might depend on a number of socio-economic factors. Following the short literature review, we will try to see if the new EU countries can be considered a group in which evidence for positive influence of R&D expenditures on economic growth can be found. Furthermore, as concluded in Bilbao-Osorio and Rodriguez-Pose (2004), it is also the sector of R&D investment that might matter, thus we will include this factor in the model as well.

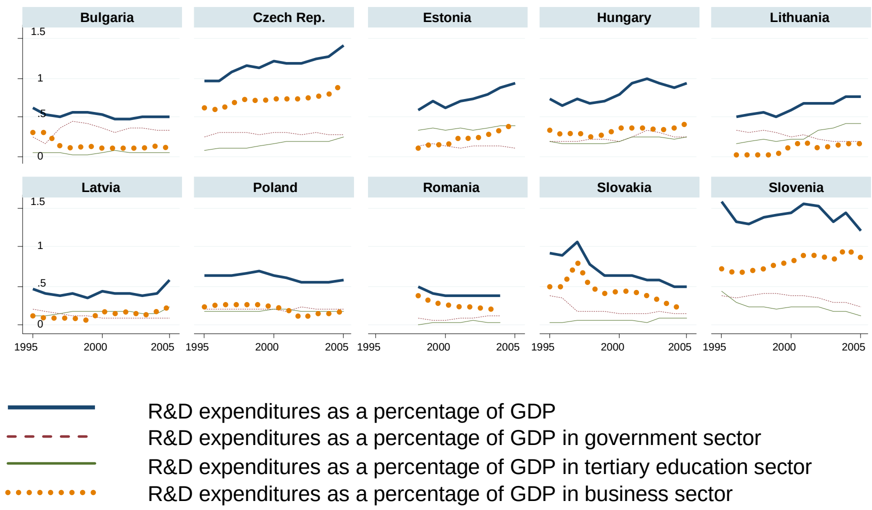
3.3.1. Data

The analysis discussed in this article is based on the data from 10 new member countries of the European Union, which joined the Union in 2004 and later, except Malta and Cyprus. Thereby, the selected countries are Bulgaria, Czech Republic, Estonia, Hungary, Latvia, Lithuania, Poland, Romania, Slovakia, and Slovenia. Such selection causes that the considered units form a relatively similar group considering their level of economic development and geographical placement. The data used in the analysis in most cases include yearly observations over the 1997-2005 period, although previous observations (from 1995 and 1996) on R&D expenditures are used as explanatory lagged variables. The exceptions are Romania, in the case of which the data from 1998 on are used, and Latvia (1997 on). This means that in the analyzed models the number of effective observations accounts to about 80 (differing slightly between particular specifications, depending on whether R&D expenditures were decomposed into sectors of origin or not and whether lags of R&D expenditures were used or not).

The reason for using such relatively short time series that form the panel is that previous data are not available in common sources for certain categories for some of the countries, but also that the countries of interest either underwent economic transformation or had just appeared (or reappeared) relatively shortly before that date. Such short time series make it unreasonable to analyze each country separately except for purely descriptive reasons and the process of modeling is based on the panel of the above-mentioned countries.

Figure 3.1 presents the magnitude of R&D expenditures as a percentage of GDP in the analyzed countries over the considered period.

Figure 3.1. R&D spending over the 1995-2005 period decomposed into groups by sector of performance

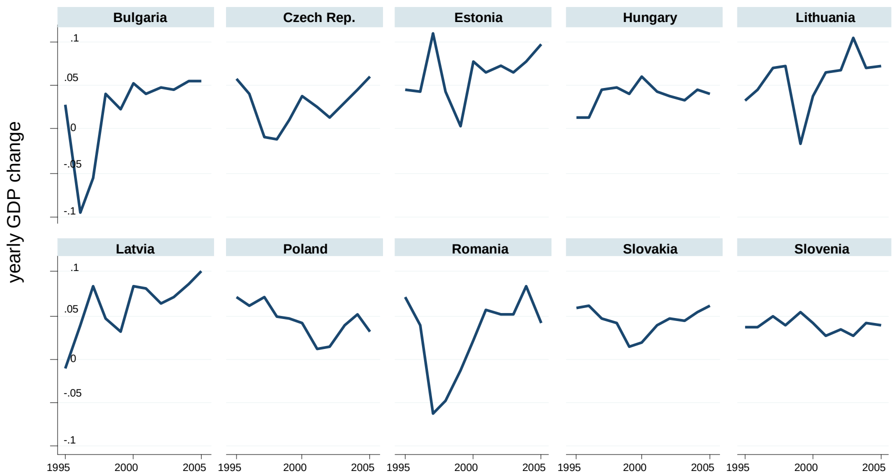


Source: Eurostat data.

In none of the countries, the total research and development expenditures have exceeded significantly 1.5%.[1] On the other hand, if we compare the R&D as share of GDP in subsequent years, notable changes may be seen in some of the countries. The Czech Republic is a good example. Czech R&D share of GDP rose from 0.95% in 1995 to 1.42% in 2005, which means an increase of more than 50%. A notable increase can also be seen in the case of Estonia, Lithuania and Hungary, whereas in the other cases we the decrease or just fluctuations. Still, one must remember that the GDP share of R&D expenditures is very low and might be below the threshold beyond which such expenditures begin to really matter from the growth's point of view.

One could attempt drawing the first conclusions having a look at the tables presenting R&D as a share of GDP changes and GDP growth. Observing both one might suggest (or not) the existence of certain relationship between them. These can be seen in figure 3.2.

Figure 3.2. Annual GDP per capita growth



Source: IMF data.

It seems difficult to spot any clear relationship between the R&D expenditures in any sectors and GDP growth. However, having a look at more aggregate results allows for certain conclusions. If we correlate the relative change of GDP and relative change of R&D expenditures over the 1997-2005 period, a correlation of 0.23 is obtained, while correlating yearly changes of GDP with yearly changes

[1] Actually, in Slovenia in 1995 they accounted for the 1.57% of GDP, going down afterwards.

of R&D expenditures results in correlation of 0.35. Obviously, although these are statistically significant on practically every significance level, despite not being sufficient proof of true influence of R&D expenditures on GDP growth this is somehow promising. Still, to be more confident of the results, multivariate analysis should be carried out. Thus, we will try to estimate a regression model that will allow us to account also for some other factors that could have influence on the GDP growth. This may lead us to conclusions on existence of stronger relationship between the considered indices but might well show that the attained correlations are actually spurious or are due to some exogenous factors.

3.3.2. Model specification

While constructing the model, we will base the estimation on Cobb-Douglass-type function, which, typically applied by most authors, is easily motivated (see Barro and Sala-i-Martin, 1995). Obviously, since we concentratee on the economic growth, we will try to explain the change of GDP with the use of appropriate factors. Again, it seems natural to include variables defining physical and labour capital that influence growth. Thus, we begin with constructing a three-factor production-function-type model in which R&D expenditures play the role of an additional factor as a basic model, while in further specifications we will consider decomposition of R&D expenditures into three groups by sector of performance: business, government and higher education. Naturally, it might be reasonable to consider including further control variables in the model; nevertheless, the number of observations is very low. This means that including further regressors brings the number of degrees of freedom of the model to a yet lower, risky in terms of inference level.

There are a number of questions to be answered while constructing a model and choosing an estimation technique. Firstly, there is no single, common opinion on the exact functional form. Although most researchers apply some variation of Cobb-Douglass type function, it is not obvious whether the level of R&D loadings or their intensity understood as the R&D expenditures as a percentage of GDP, should be included in the model, as well as which (if any) control variables should be used and in which form. We begin with a model in which changes of GDP are explained by R&D intensity and country specific effects only. In this case the model is

$$\Delta \ln GDP_{it} = \alpha_i + \beta_0 + \beta_1 \ln GDP_{i,t-1} + \beta_2 \ln RDI_{it} + \varepsilon_{it}, \qquad (1)$$

where:

$\Delta \ln GDP_{it}$ - the change of natural logarithm of real GDP in country *i*, year *t*,

$\ln GDP_{i,t-1}$ - lagged logarithm of GDP level in year t-1,

$\ln RDI_{it}$ - logarithm of R&D expenditures intensity in country i, year t,

α_i - country specific effect,

ε_{it} - random factor.

This typically applied log-log specification assumes constant elasticities of the dependent variable with respect to independent variables, while the dependent variable, as it can be easily shown, is a very close approximation for the relative real GDP change. The same specification might be slightly reorganized by adding $\ln GDP_{i,t-1}$ to both sides, yielding a typical autoregressive equation

$$\ln GDP_{it} = \alpha_i + \beta_0 + \gamma \ln GDP_{i,t-1} + \beta_2 \ln RDI_{it} + \varepsilon_{it} , \quad (2)$$

with γ being equal to β_1+1. Such type of equation has been frequently used by many authors; nevertheless, there might be some doubts about it. It is doubtful whether the R&D expenditures may have such immediate influence on GDP growth. Thus, we should rather consider R&D lags as independent variables. Possible reason for which some authors conclude significance of RDI in the above equation is that RDI_{it} are usually somehow correlated with RDI in previous periods, thus they are a sort of proxy for earlier R&D expenditures or expenditures' intensity and truly it is not the relationship between current RDI and GDP growth but rather between lagged RDI and current GDP growth that causes spurious significance of the $\ln RDI_{it}$ variable. Moreover, it needs to be noted that there is risk of $\ln RDI_{it}$ actually depending on the growth rate, which results in endogeneity of this independent variable. Some authors do not take account of this fact, while – if true – it results in serious estimate bias and possibly wrong conclusions. Thus, instead of considering current expenditures (which, by the way, would result significant in the above equation if we estimated that and took its results seriously), we will include lagged by one and two years R&D expenditures intensity as independent variables (possibly some further lags should also be tested, but there is not enough data to do so), yielding:

$$\ln GDP_{it} = \alpha_i + \beta_0 + \gamma \ln GDP_{i,t-1} + \beta_2 \ln RDI_{i,t-1} + \beta_3 \ln RDI_{i,t-2} + \varepsilon_{it} . \quad (3)$$

Still, as it has been described in the previous section, including control variables may change the results significantly. First of all, this is the case when the controls are correlated with the included independent variables and relevant in the model. In such a case, while omitting them, estimation is biased. Again, following other authors (and common sense, as well), it seems natural to include human and technical capital in the model. As a proxy for technical capital we will apply the logarithm of capital fixed formation lnFF_{it}.[2] There is a question of what proxy for human capital to use. One alternative is population stock or working force stock. However, changes in population stock over such short time period as it is considered here are not big and thus they do not probably have particular influence on real GDP change. What seems to possibly matter is the structure of working force in terms of its preparation, which can be approximated by the education level. Thus, as a proxy for human capital variables EDU2 and EDU3 will be included, standing for the percentage of working force with, respectively, secondary, and tertiary education. Thus, the second model of interest is

$$\begin{aligned}\ln GDP_{it} = \alpha_i + \beta_0 + \gamma \ln GDP_{i,t-1} + \beta_2 \ln RDI_{i,t-1} + \beta_3 \ln RDI_{i,t-2} + \\ + \beta_4 \ln FF_{it} + \beta_5 EDU2_{it} + \beta_6 EDU3_{it} + \varepsilon_{it}\end{aligned} \quad . \qquad (4)$$

where:

lnFF_{it} - logarithm of capital fixed formation
$EDU2_{it}$ - percentage of working force with secondary and tertiary education
$EDU3_{it}$ - percentage of working force with secondary and tertiary education

The next issue that has been discussed in literature is to what extent they are the R&D expenditures themselves and to what extent – R&D expenditures coming from different sources that affect growth rate. To answer this question in the considered case, R&D expenditures are decomposed into three parts in terms of their performance sector: governmental, business, and educational. This means replacing in the considered models (3) and (4) the ln*RDI* lags with proper lags of particular ln*RDI* components: ln*RDIG*, ln*RDIB*, and ln*RDIE*. Thus model (3) after this decomposition turn into the following specification:

$$\begin{aligned}\ln GDP_{it} = \alpha_i + \beta_0 + \gamma \ln GDP_{i,t-1} + \beta_2 \ln RDIG_{i,t-1} + \\ + \beta_3 \ln RDIB_{i,t-1} + \beta_4 \ln RDIE_{i,t-1} + \beta_5 \ln RDIG_{i,t-2} + \\ + \beta_6 \ln RDIB_{i,t-2} + \beta_7 \ln RDIE_{i,t-2} + \varepsilon_{it}\end{aligned} \quad , \qquad (5)$$

where:

$\ln RDIG$ - logarithm of the governmental R&D expenditures intensity,

[2] Some suggest that it is the change of technical capital that influence growth but we will follow a more natural idea that it is the level of capital that has influence on economic growth as it is the stock of capital, not its change that is working.

$\ln RDIB$ - logarithm of the business R&D expenditures intensity,
$\ln RDIE$ - logarithm of the educational (university) R&D expenditures intensity
in period *t* and *t*-1 respectively.

Following the same rule, the model (4) gives the last specification of interest, which is estimated and presented in this article:

$$\begin{aligned}\ln GDP_{it} = \alpha_i + \beta_0 + \gamma \ln GDP_{i,t-1} + \beta_2 \ln RDIG_{i,t-1} + \beta_3 \ln RDIB_{i,t-1} + \\ + \beta_4 \ln RDIE_{i,t-1} + \beta_5 \ln RDIG_{i,t-2} + \beta_6 \ln RDIB_{i,t-2} + \\ + \beta_7 \ln RDIE_{i,t-2} + \beta_8 \ln FF_{it} + \beta_9 EDU2_{it} + \beta_{10} EDU3_{it} + \varepsilon_{it}\end{aligned} \quad (6)$$

3.3.3. Estimation technique

The second important question concerns the estimation technique. A number of analyses that can be found are based on simple correlation coefficients, which is a rather risky way of drawing conclusions, for it does not allow for considering an influence of a number of factors on the dependent variable. Another group of authors base their research on one-dimensional data, which means time series for a given country or cross-section for a number of countries at a given point. Each of the two approaches has its big disadvantage. In the case of research based on a single time series one can suspect that in a longer horizon such phenomena as economic cycles will have influence on the GDP growth, thus making the true relation harder to determine. On the other hand, if a single cross section of countries is considered, it will be difficult to decide whether faster GDP growth in a given country is truly caused by R&D expenditures or actually results from some individual country specifics. The use of panel data allows for at least partial resolving of both problems and one might expect the results obtained with the use of panel data most trustworthy. The model discussed in the article is an autoregressive one, which causes problems with the traditional methods, applied for static panel data based models estimation. Regrettably, independent variable $GDP_{i,t-1}$ can by no means be treated as a strictly exogenous one (as there is no independency of random factor in each period $s \in \{1,\dots,T\}$), which leads to the classical estimators bias (i.e. Wooldridge, 2001). Application of estimation method based on instrumental variables method, generalized method of moments or bias corrected fixed effects method could be a proper solution of this problem. Most authors apply difference estimator, proposed by Arellano and Bond (1991) or system estimator described by Blundell and Bond (1998). Albeit, certain shortcomings of these methods should be mentioned. The first of them is less restrictive on the assumptions being made, but on the other hand, as the later research show, particularly in the situation when the true value of autoregression parameter equals approximately one, Arellano and Bond's estimator in small samples has significant downward bias. In the presented research, the number of observations does not exceed 90 and, therefore, in the light of a generalized method of moments' requirements this should be treated as a small sample. This problem is not as serious when the second of the mentioned estimators – Blundell and Bond's system estimator – is applied. But still, it should be kept in mind that it is based on the generalized method of moments and in practice it requires bigger samples even if there is plenty of researchers applying it when investigating definitively smaller samples comparing to the one used here and thus exposing themselves to the risk of estimation's inaccuracy resulting from the small sample size. The above-mentioned problems with questionable properties of the generalized method of moments in small samples inspired the researchers to search for alternative estimation methods which could be applied even in small samples and which would not require numerous observations to be right. Bruno (2004) proposed an algorithm consisting in the application of the corrected by asymptotic bias of classical fixed effects type estimator (i.e. Wooldridge, 2001). While estimating the discussed models, the results obtained with the use of each of the mentioned methods are given, although is seems that due to small sample size the application of Bruno's method is most appropriate.

The models described in this paper have been estimated with STATA 8.0 software. The estimation with Blundell-Bond method was performed using xtabond2 routine by David Roodman and in the estimation by bias corrected fixed effects estimator, xtlsdvc routine by Giovanni Bruno was applied.

3.4. Estimation results

Estimates for model (3) are given in table 3.1. Conclusions that could be drawn are quite natural and – to a certain point – expected. Firstly, as in most convergence–type models, the estimates on lagged GDP level variable are slightly below 1.

An interesting result is that the R&D intensity lagged by one year, contrary to R&D intensity lagged by two years, is a positive and (except for the conclusions from LSDVC estimation) significant factor determining the rate of GDP growth. This would suggest that some evidence for quite immediate positive influence of investing in R&D has been found.

Table 3.1. Estimates for the model (3)

lnGDP	AB	BB	LSDVC
lnGDP(t-1)	0.844**	0.990**	0.959**
	0.063	0.004	0.024
lnRDI(t-1)	0.049*	0.088**	0.040
	0.026	0.031	0.028
lnRDI(t-2)	-0.038	-0.011	-0.040
	0.023	0.033	0.028
constant	0.009**	0.269**	-
	0.003	0.094	-

Note: standard errors are given below the estimates with ** denoting significance on the 0,05 level and * denoting significance on the 0,1 level. AB column presents the Arellano-Bond estimation results, BB presents the Blundell-Bond estimation results and LSDVC presents Bruno's bias-corrected LSDV estimation results.
Source: Own calculations with STATA 8.0 software.

However, they are the LSDVC estimates that in the considered small sample are most trustworthy. This, despite quite high elasticities of lagged R&D intensities, should be considered the first warning and may mean that the relationship that could be concluded from the AB and BB regression might be spurious. Thus, the next model of interest is model (4) in which control variables as described in section 3.3 are introduced.

There are a few issues considering the results from model (4) that should be discussed. Firstly and most importantly, it must be noted that the result obtained here is pretty similar to the one obtained by Keller and Poutvaara (2005), that is introducing relevant control variables makes the R&D variables lose their significance. It is likely that in the primary model (3) it was actually the relationship between the "general" level of the whole economy production engines (total investment, human capital, and so on) that made the R&D intensities look like a relevant growth factor, whereas taking account of the key growth factors diminishes this effect. Thus, there is no reason to find R&D expenditures a significant growth engine in the considered case.

In model (4), the only factors that can be found significant on a conventional level are the lagged GDP and the proxy for technical capital: the logarithm of capital fixed formation. It needs to be noted that the coefficient on lagged GDP level is very low in the model estimated with the use of Arellano-Bond method.

This is a typical case discussed by many authors, for example by Blundell and Bond (1998). When the true coefficient is close to one, Arellano-Bond's method often underestimates its value. In this case, we would have to believe in incredibly fast economic convergence, which certainly is not true, and could make us confused with other conclusions from the whole model.

Table 3.2. Estimates for the model (4)

lnGDP	AB	BB	LSDVC
lnGDP(t-1)	0.708**	0.944**	0.904**
	0.052	0.010	0.032
lnRDI(t-1)	0.007	0.029	0.011
	0.022	0.027	0.023
lnRDI(t-2)	-0.023	-0.58	-0.026
	0.020	0.038	0.027
lnFF	0.062**	0.052**	0.062**
	0.013	0.010	0.015
EDU2	-0.003	0.001	0.001
	0.001	0.001	0.001
EDU3	0.002	-0.001	0.001
	0.002	0.001	0.003
constant	0.012**	0.967**	-
	0.003	0.173	-

Note: standard errors are given below the estimates with ** denoting significance on the 0,05 level. AB column presents the Arellano-Bond estimation results, BB presents the Blundell-Bond estimation results and LSDVC presents Bruno's bias-corrected LSDV estimation results.
Source: Own calculations with STATA 8.0 software.

However, in the other two models the parameter on lagged GDP level is not surprising anymore. Unexpectedly, the human capital variables do not matter. But this is easily explainable by short time period under consideration and – in consequence – only minor changes of the population number and structure. Applying other proxies for human capital does not change the conclusions: one should believe that in such a short time period hardly palpable population and educational changes could affect economic growth.

As some authors have noted, R&D expenditures are not a fully homogeneous phenomenon and there is a possibility that depending on their performance sector, some part of them might indeed be relevant, some – might not and unifying all the R&D expenditures in one group may result in increasing the total standard error of estimation and making the impression of all the R&D expenditures being an insignificant predictor. To resolve this problem, we have discussed models (5) and (6) in which R&D expenditures (and so the same applies to their intensities) are decomposed, considering their performance sector. Table 3.3 presents the results of estimation of model (5).

A look at the model estimates allows us to note that they are mostly the business and governmental R&D expenditures (and obviously lagged GDP level) that have influence on the economic growth rate, whereas no such effect can be found in the case of educational R&D expenditures.

Table 3.3. Estimates for the model (5)

lnGDP	AB	BB	LSDVC
lnGDP(t-1)	0,918**	0,992**	0,951**
	0,075	0,004	0,034
lnRDIG(t-1)	0,051**	0,029*	0,041**
	0,015	0,016	0,017
lnRDIG(t-2)	-0,013	-0,027	-0,023
	0,013	0,017	0,017
lnRDIE(t-1)	0,021	0,029*	0,025
	0,014	0,016	0,022
lnRDIE(t-2)	-0,013	-0,020	-0,006
	0,013	0,016	0,017
lnRDIB(t-1)	0,022**	0,013*	0,019**
	0,007	0,017	0,007
lnRDIB(t-2)	-0,006	-0,011	-0,012
	0,007	0,007	0,007
constant	0,006*	0,222**	-
	0,003	0,099	-

Note: standard errors are given below the estimates with ** denoting significance on the 0,05 level and * denoting significance on the 0.1 level. AB column presents the Arellano-Bond estimation results, BB presents the Blundell-Bond estimation results and LSDVC presents Bruno's bias-corrected LSDV estimation results.
Source: Own calculations with STATA 8.0 software.

However, again the estimated regression may be spurious in view of the model with further control variables, thus the table 3.4 presents the result of the final model (6), where both R&D intensities have been decomposed into the previously mentioned parts and the control variables as in model (2) have been introduced.

As it can be seen in the results of the model (6) estimation given in table 3.4, in the view of control variables inclusion, government-funded R&D lagged by a year lose their significance; however, business R&D expenditures remain significant on the 0.05 (0.1 in the case of LSDVC) level, with lagged GDP level and capital fixed formation remaining significant as in the model (4) as well. This again confirms the results of most microeconomic research partly discussed in section 3.2, saying that it is the private R&D initiative that is an engine of growth. The relevance of expenditures on university and governmental research is – in the light of these results – doubtful. Obviously, it means most likely the same as previous authors concluded: R&D expenditures in a non-business sphere do matter, but their influence is more difficult to capture.

Table 3.4. Estimates for the model (6)

lnGDP	AB	BB	LSDVC
lnGDP(t-1)	0.778** 0.088	0.937** 0.012	0.884** 0.058
lnRDIG(t-1)	0.023 0.014	0.019 0.014	0.024 0.017
lnRDIG(t-2)	-0.018 0.012	-0.018 0.015	-0.024 0.019
lnRDIE(t-1)	0.001 0.014	0.010 0.015	0.004 0.022
lnRDIE(t-2)	-0.003 0.012	-0.004 0.015	0.001 0.016
lnRDIB(t-1)	0.013** 0.006	0.012** 0.007	0.015** 0.007
lnRDIB(t-2)	0.003 0.006	-0.009 0.007	-0.004 0.008
lnFF	0.070** 0.017	0.058** 0.012	0.066* 0.021
EDU2	-0.002 0.002	-0.001 0.001	0.001 0.002
EDU3	-0.003 0.003	-0.001 0.001	0.001 0.003
constant	0.012** 0.004	0.912** 0.020	- -

Note: standard errors are given below the estimates with ** denoting significance on the 0,05 level and * denoting significance on the 0,1 level. AB column presents the Arellano-Bond estimation results, BB presents the Blundell-Bond estimation results and LSDVC presents Bruno's bias-corrected LSDV estimation results.
Source: Own calculations with STATA 8.0 software.

3.5. Concluding remarks

In the view of the estimation results given in the previous section we must conclude that the issue of relevance of R&D expenditures from the point of view of economic growth is not as obvious as it might seem. Firstly, having a look at a simple analysis with only the lagged R&D expenditures (as one group or decomposed into sector) as independent variable one may have an impression that the amount (or actually the intensity) of R&D expenditures does have serious influence on the rate of economic growth. However, when we look at the developed model in which typical human and technical capital control variables have been included, the relationship between the R&D expenditures and GDP growth has not been so clear anymore in the new EU countries over the past few years. The final conclusion is that **the evidence for the relationship between the R&D expenditures in business sector and economic growth can be found among the new EU members, whereas there is no empirical evidence for the existence of any dependence between the governmental and educational R&D expenditures and the rate of growth**.

These conclusions, confirmed by all the estimators that have been applied, do not seem strange. In fact, they do confirm findings of some researchers, mostly in microeconomic studies, saying that they are the business-sourced R&D expenditures that work as an engine of growth; however, the expenditures on R&D in other sectors cannot be considered as unimportant. Most likely, again confirming others' results, government-driven expenditures on research should bring some benefits, though they are most likely of the long-horizon type. We might expect them to show some results within, possibly, a few years; still, it is most certainly difficult to capture their influence both because it is mostly indirect and because very long time series would be essential for that reason. This would most likely expose us to some other problems, such as instability in time, business cycles, and so on.

The results confirm the need of investing in R&D, suggesting that it indeed is budget-consuming innovativeness that allows for building competitive position, which leads towards economic growth and, as a further consequence society's welfare. Demonstrating importance of R&D investment in mostly applicable, not just strictly theoretical, initiatives that come in business sector implies also the need for not just investing in research, but investing in research in the applied way in order to maximize the returns.

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