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DO BUSINESS AND PUBLIC SECTOR RESEARCH AND DEVELOPMENT EXPENDITURES CONTRIBUTE TO ECONOMIC GROWTH IN CENTRAL AND EASTERN EUROPEAN COUNTRIES? A DYNAMIC PANEL ESTIMATION

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Abstract

This paper examines the impact of R&D expenditures in business and private sector on economic growth in Central and Eastern European Countries over the period 1998-2008. Using a Generalised Method of Moments estimator, we find that business R&D has a high and stable contribution to economic growth. Public R&D has no effect on growth but does not crowd out private activity. The paper also finds that part of the business R&D effect is accounted for by human capital. The results remain robust after considering macroeconomic control variables.

Keywords: R&D; human capital; economic growth; CEE; dynamic panel-GMM.

JEL codes: O32; O33; O52.

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1. Introduction

In the last decade, the importance of research and development (R&D) to economic growth has been well recognized. Much of the empirical literature on the link between R&D intensity (defined as ratio of R&D expenditure to GDP) and growth is focused on the advanced countries where the intensity of R&D has been relatively stable and high for many years. These countries can afford high levels of R&D expenditure and they can enjoy positive returns and spillover from that.

In the Central and Eastern European (CEE) countries, R&D intensity has been weak, as all these countries have faced a recession after the fall of the socialist regime, followed by a return to positive growth rates in the mid and late nineties. By analyzing the systems of innovation in CEE countries, Kravtsova and Radosevic (2009) show that these countries have lost the advantages in terms of size of R&D which they inherited from the socialist regime. It is thus difficult to expect that even over the long term, this region could catch up with R&D investment levels observed in advanced countries. Accession to the European Union (EU) was expected to stimulate firms to innovate and to speed up the process of taking-off. In the late years the dynamics of R&D spending observed in many CEE countries are positive. Thus, it becomes vital to analyse the contribution of R&D expenditure (private or public) on economic growth. The link between R&D and economic growth is of particular policy relevance, since governments could be actively engaged in the promotion of R&D through direct funding of public and private R&D. Understanding the contribution of R&D allows the policy makers to assess the impact of their expected returns.

To the best of our knowledge, the contribution of R&D on economic growth has not been analysed for the group of CEE countries taken together. This provides a strong motivation for writing this paper. The rest of the paper is organized as follows: section 2 presents the literature review, section 3 presents an overview of GDP and R&D in CEE countries, section 4 presents an augmented Solow model that incorporates R&D and human capital. Section 5 presents the methodology and the econometric results while section 6 outlines the main conclusions and policy implications of our research.

2. Literature review

Endogenous growth theory (EGT) was pioneered by Romer (1990) who focused on the role that R&D expenditure can play in explaining the process of economic growth that use human capital and the existing stock of knowledge.

According to Cohen and Levinthal (1989, 1990) R&D plays first the role of a source of new knowledge, i.e. it is the means by which new discoveries are made. Second, R&D is a learning process that generates and builds "absorptive" capacity within firms, allowing the adoption, imitation and adaptation of others' discoveries. The new discoveries mean the invention of completely new types of capital goods, defined by Grossman and Helpman (1991, p.43) as capital goods that perform completely new functions compared to the existing types of capital goods.

The models of Ulku (2007) and Neuhaus (2006) are based on the strong assumption that governments which stimulate education and R&D will attain positive long-run economic growth rates. Their view is that the constant returns to scale to innovation in terms of human capital employed in the R&D activities generates permanent increases of growth rate of output. This increase is facilitated by improvements in the physical capital stock, in variety or in the quality of capital goods. Such models justify government intervention intended to attain optimal levels of R&D.

Empirical studies are mainly based on a fairly broad agreement among economists that the reasons behind the growth effects are the externalities or spillovers that are inherent in the R&D process (see Harris, 2005). Many of these studies are done mostly at firm or industry level (see Link et al. (2005) for a summary of these studies in countries such as USA, Japan, France and Germany). Results indicate that R&D expenditures have contributed to output growth in a variety of industries in these advanced economies. In the case of developing countries, however, it is often the case that no significant relationship between R&D expenditures and output growth (or productivity growth) can be found (see also Birdsall and Rhee, 1993).

There are also studies using macroeconomic data which focus on newly industrialized countries such as Singapore where R&D expenditures were low some time ago, and then increased rapidly in the recent years. Ho et al. (2009) established a long-term equilibrium relation between R&D investments and Total Factor Productivity (TFP) for 20 years in Singapore. When compared with other OECD countries, the authors conclude that the country needs to increase domestic R&D activity. In a study of OECD (2003), the growth performance of member countries for the period 1998-2000 is analysed. The estimates of OECD show that at an increase of R&D business expenditures of 0.1 percent the real output per capita raises by 1.2 percent. The same study finds no statistical evidence of the impact of public R&D spending on growth. McGrattan and Schmitz (1998) focused on testing the main prediction of AK growth models which state that permanent changes in government policies affecting investment rates should lead to permanent changes in a country's GDP growth. By considering time-series evidence for a larger sample of countries over a long time period (1870-1989), this prediction was confirmed with the exception of the US economy. When they extended the number of countries to 125 and analyzed the period of 1960-1985, they found a positive correlation between investment rates and growth rates. Prodan (2005) analyzes the correlation between R&D expenditure and patent applications in countries such as Hungary, the Czech Republic, Slovenia, Finland and OECD countries and depicts a strong correlation in the case of developed countries.

Griliches (1992) argues that all the estimates of R&D effects on productivity strongly depend on the level of aggregation of the data used. As R&D expenditures generate a lot of spillover effects, their macroeconomic effects cannot be directly obtained if the estimation is done at firm or industry level. In order to accurately capture the macroeconomic effects of R&D investments and their spillover effects into the whole economy, macroeconomic data should be used (Aghion and Howitt, 1998).

Starting from this view, however being constrained by the data availability, we conduct a macroeconomic analysis using annual data for CEE countries[1] for the period 1997-2008. We fill a gap in the literature for CEE countries by estimating an empirical model which is consistent with an augmented Solow growth model, that includes in its specification the ratio of R&D to GDP and also human capital (see also Frantzen (2000); Nonneman and Vanhoudt (1996); Redding (1996); Goel and Ram (1994)).

The main objective of our analysis is to test whether business R&D acts as a stimulus to economic growth, alongside with other important determinants such as foreign direct investment or domestic investment. A secondary aim of the paper is to investigate whether public R&D is

[1] Bulgaria, Czech, Estonia, Latvia, Lithuania, Hungary, Poland, Romania, Slovenia, Slovakia. In the empirical estimation Slovakia will be excluded due to the fact she is an outlier.

significant and crowds out (or crowds in) the impact of business R&D. Furthermore, we investigate if a part of the R&D effect is actually accounted for by human capital. To accomplish our goals, we use dynamic panel data estimators (Generalized Method of Moments) and we account for heterogeneity across countries. We check for the robustness of the results by introducing different sets of macroeconomic control variables (such as government balance and trade openness). We find that business R&D plays a positive and significant role in all the specifications.

3. Patterns of GDP and R&D in Central and Eastern European Countries

In order to enhance economic growth and to create competitive economic area, the EU's Lisbon Agenda set as a main goal an increase in R&D investment.

The level of R&D expenditure was to increase from 1.8% of GDP in the late 1990 to 3% by 2010 (1% public and 2% private). By 2010 these goals were far from being achieved. A possible explanation comes from Van Pottelsberghe de la Potterie (2008), who criticizes these targets for not taking into account the fact that the European market for technology is defragmented. He also argues in favor of a higher level of R&D spending on academic research, which may act as a stimulus for business R&D.

The accession of the new member states to the European Union was expected to contribute to achieving the Lisbon Agenda goals, based on the assumption that larger market size would result in a higher expected return of R&D investment (Guellec and van Pottelsberghe, 2003). The increased competitive pressure as a result of institutional and economic deregulation was expected to stimulate firms to innovate, but private investment in R&D had difficulties in taking-off.

At the beginning of the transition in the early 1990s, all CEE countries experienced a major decline in GDP. Some countries have found their growth paths relatively fast (Poland, Hungary, Slovakia, Czech) while others (Romania, Bulgaria) have experienced longer recession periods and their growth rates picked-up only later, starting with the years 1997-1998. In this latter group of countries, capital accumulation has provided a positive contribution to growth, while labour had a small or even negative contribution (Schadler et al., 2006). Rather than technical progress or innovation, it is probable that the efficiency improvements in the use of capital and labour explained the growth patterns in these countries (Havrylyshyn, 2001).

During the nineties, the increase in productivity was actually accompanied by a decrease in R&D investment, so growth was generated by non-R&D factors (Kravtsova and Radosevic, 2009). Once the transition period completed, the growth process in CEE countries must be sustained by factors like capital intensity, innovation, human capital and competition (OECD, 2003; Van Ark and Piatkowski, 2004). The importance of innovation and technical progress started to be widely acknowledged. The EU membership of these countries has improved their business environment, reshaping conditions and inducing a lot of fundamental changes. As these countries tend to adopt existing technologies transferred from abroad (Verspagen, 2001), both efforts in R&D and human capital can substantially facilitate the effectiveness of this transfer. This can be done by improving the capacity of the receiving economy to implement such innovation originating abroad (Griffith et al., 2004; Aghion and Howitt, 2005) and to speed the catching-up process.

Table 1 presents the R&D intensity in all CEE countries and compares them to EU27. In order to assess the heterogeneity inside the two groups of countries in terms of R&D expenditure to GDP, Pearson's coefficient of variation is computed as the percentage of standard deviation to the mean. To analyse the catching up process, the gap in R&D intensity and the gap in GDP per working age population[2] are also provided.

[*Insert table 1 about here]*

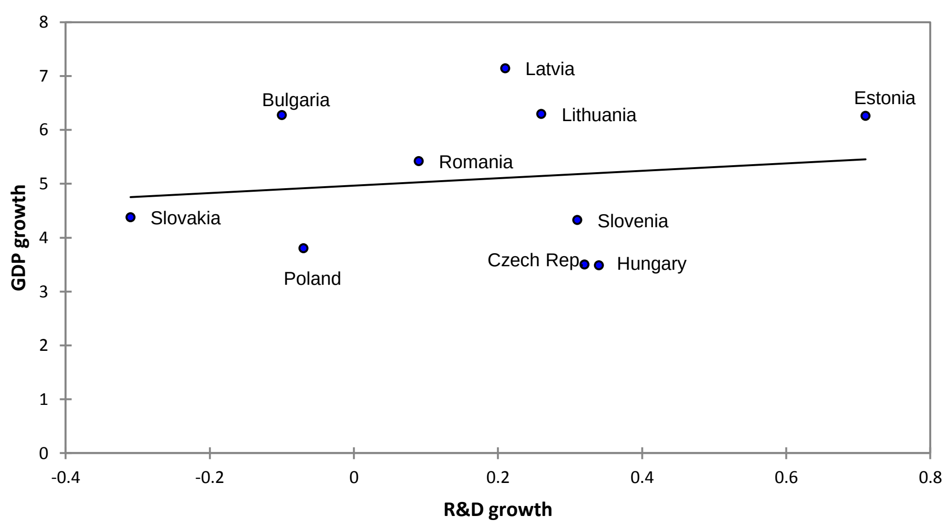
The average of R&D expenditure in GDP is well below 1%, so CEE countries obviously lag behind other members of the EU. As Kravtsova and Radosevic (2009) point out, the R&D intensity in these countries is much below what one might expect given their income level. When it comes to the catching-up process, the gap in R&D intensity has decreased by 7% (from 60% to 53%) in 11 years'. Although there is convergence towards the EU27 in terms of R&D, it is a rather slow process. This is also due to the considerable heterogeneity among EU27 and CEE countries, depicted by Pearson's coefficient of variation, heterogeneity which has accentuated over time for CEE countries. The other gap, in GDP per working age population, has decreased

[2] The gap in R&D intensity is the difference between R&D intensity in EU27 and CEE countries, as a percentage of EU27.The gap in GDP per working age population is computed in an analogous way.

by 8% (from 77% to 69%). The similar drop in both gaps (7% compared to 8%), indicates a possible common convergence process in GDP per working age population and R&D intensity.

To compare the evolution of R&D and economic growth, in Fig. 1 we plot the average growth rates for the period 1998-2008. Though weak, the correlation between the increase in R&D intensity and economic growth is positive. Inside the CEE countries, some patterns emerge. Bulgaria, Poland and Slovakia are the only countries that experience a decrease in R&D intensity. Although they were progressing in terms of economic growth, they allocated less of their income to R&D expenditures.

Fig. 1 R&D versus GDP growth in CEEC, 1998-2008



As we can see, the rest of the countries show positive evolutions in both indicators, so we might expect a positive contribution of R&D to their economic growth. The Czech Republic, Hungary and Slovenia, being among the most advanced transition countries, show a rather stable increase in R&D intensity, accompanied by GDP growth rates around 3-4%. Romania, despite having a weak performance of R&D intensity, has experienced high rates of economic growth, probably due to the role played by FDI and exports.

The Baltic States seem to have the highest potential in innovation driven growth because their constant increase in R&D expenditure was accompanied by sustained GDP growth rates. Estonia appears as the top runner in achieving the Lisbon objectives, more than doubling its share of R&D in GDP during this decade.

In order to analyze in more detail the evolution of R&D expenditures in CEE countries, we look at the two main sectors in which the R&D investments are made: business and public R&D (government and education). If public R&D shows certain homogeneity between CEE countries, the differences with respect to business R&D are pronounced (Table 2). The increase in business R&D is slower than for total R&D. Countries experiencing high business R&D growth are Estonia, Lithuania, Hungary and Slovenia. Estonia has the fastest increase in business R&D, while Slovakia presents a significant decrease. Poland and Romania also experienced a decrease in business R&D expenditures.

[Insert Table 2 here]

The figures on public R&D compensate a part of the business R&D gap, some CEE countries experience levels even higher than the European average (e.g. Estonia). The aggregate trend for EU public R&D shows a slight increase from 0.64% to 0.68% during 1998-2008. This was not sufficient to reach the goal of 1% share of public R&D in GDP set by the Lisbon Agenda for 2010. With an average public R&D investment of 0.48% of GDP in 2008, the CEE countries are still far from achieving this target.

As a general conclusion, CEE countries present a heterogeneous pattern, though a small but positive trend in R&D intensity can be identified. Slovakia appears as an outlier, experiencing a severe decrease in business R&D intensity so we left it aside from our analysis.

4. Theoretical framework

In Romer's (1986) model, the long-run value of income per capita depends on "investments" decisions rather than on unexplained technological progress. In his paper, he presents a fully specified model of long run growth in which knowledge is assumed to be an input in production that has increasing marginal productivity due to the positive externalities from capital accumulation. The work of Romer revives the earlier contribution of Arrow (1962) who had shown that the productivity of labor can increase with experience and as a result of a continuous "learning by doing" process.

In their "augmented" Solow model, Mankiw et al. (1992) introduce a broad concept of capital that included human capital. The model follows the central idea of EGT that broad capital accumulation (physical and human capital) does not experience diminishing returns. Growth is induced by the accumulation of broad capital alongside the production of new knowledge. This production of new knowledge is created through research and development (Snowdon and Vane, 2005, p.625). Nevertheless, the introduction of new technology requires a more skilled workforce. Therefore, some aspects of EGT emphasize that complementarity between R&D and human capital can play an important role in generating innovative output, a higher level of productivity and higher growth rates. Nonneman and Vanhoudt (1996) extend the Mankiw et al. (1992) model by adding the investment rate in R&D for OECD countries. Their results show that R&D explains 73 percent of the cross-country variation in income.

Surprisingly, few studies address the complementarity issue, the majority of them concentrating only on R&D. Human capital is at most seen as an input to the research process. This is a shortcoming of the innovation-driven growth models. Frantzen (2000) develops neoclassical growth models with both human capital and R&D, arguing that the lack of a human capital variable leads to an overestimation of output elasticity with respect to research and development.

For estimation purposes, we use the explicit structure of a country's aggregate production function as a Cobb-Douglas type, as in Goel and Ram (1994), including also human capital. This allows us to link the output of an economy to the R&D investment and other inputs.

$$Y = F(K, RD, HC) \quad (1)$$

Where Y is the real output, K denotes aggregate capital input, L is the total labor input, HC represents the human capital stock and R&D represents the research and development stock. We start by differentiating equation (1) with respect to time:

$$\dot{Y} = \frac{\partial F}{\partial K} \cdot \dot{K} + \frac{\partial F}{\partial L} \cdot \dot{L} + \frac{\partial F}{\partial RD} \cdot \dot{RD} + \frac{\partial F}{\partial HC} \cdot \dot{HC} \quad (2)$$

then writing it in an equivalent way:

$$\dot{Y} = \frac{\partial F}{\partial K} \cdot Y \cdot \frac{\dot{K}}{Y} + L \cdot \frac{\partial F}{\partial L} \cdot \frac{\dot{L}}{L} + \frac{\partial F}{\partial RD} \cdot Y \cdot \frac{\dot{RD}}{Y} + HC \cdot \frac{\partial F}{\partial HC} \cdot \frac{\dot{HC}}{HC} \quad (3)$$

Dividing equation (3) by Y we obtain:

$$\frac{\dot{Y}}{Y} = \frac{\partial F}{\partial K} \cdot \frac{\dot{K}}{Y} + \frac{L}{Y} \cdot \frac{\partial F}{\partial L} \cdot \frac{\dot{L}}{L} + \frac{\partial F}{\partial RD} \cdot \frac{\dot{RD}}{Y} + \frac{HC}{Y} \cdot \frac{\partial F}{\partial HC} \cdot \frac{\dot{HC}}{HC} \quad (4)$$

For an econometric model based on (4) we add an intercept and a stochastic disturbance. We also write the eq. so as to have our variables of interest expressed as shares of Y.

$$\left(\frac{\dot{Y}}{Y}\right)_t = a + \propto_k \left(\frac{\dot{K}}{Y}\right)_t + \beta_L \left(\frac{\dot{L}}{L}\right)_t + \propto_{RD} \left(\frac{\dot{RD}}{Y}\right)_t + \beta_H \left(\frac{\dot{HC}}{HC}\right)_t + u_t \quad (5)$$

where:

$\left(\frac{\dot{Y}}{Y}\right)_t$ is growth rate of real aggregate output;

$\propto_k$; $\propto_{RD}$ represent the marginal products of physical capital and R&D investment respectively[3]

$\dot{K}$, $\dot{RD}$ represent the increase in the tangible capital and R&D inputs, which is the cumulated effect of investments and depreciation

$\left(\frac{\dot{L}}{L}\right)_t$, $\left(\frac{\dot{HC}}{HC}\right)_t$ denote the growth rate of labor input and human capital respectively, in period (year) t;

$\frac{\dot{K}}{Y}, \frac{\dot{RD}}{Y}$ are the shares of the R&D and physical capital increase in the aggregate output;

β_H, β_L denote the elasticity of output with respect to human capital and labor human capital respectively

a and u_t denote constant and error terms,

We also distinguish between foreign (F) and domestic (D) investment and between business (b) and public sector (p) R&D, viz:

$$\left(\frac{\dot{Y}}{Y}\right)_t = a + \propto_{KF} \left(\frac{\dot{KF}}{Y}\right)_t + \propto_{KD} \left(\frac{\dot{KD}}{Y}\right)_t + \beta_L \left(\frac{\dot{L}}{L}\right)_t + \propto_{RDb} \left(\frac{R\dot{D}b}{Y}\right)_t + \propto_{RDp} \left(\frac{R\dot{D}p}{Y}\right)_t + + \beta_H \left(\frac{\dot{HC}}{HC}\right)_t + u_t \quad (6)$$

where:

$\left(\frac{\dot{KF}}{Y}\right)$ $\left(\frac{\dot{KD}}{Y}\right)$ represent the increase of shares of foreign direct investment (FDI) stock and domestic investment stock in aggregate output

and $\left(\frac{R\dot{D}b}{Y}\right), \left(\frac{R\dot{D}p}{Y}\right)$ represent the shares of business R&D and public R&D in aggregate output[4].

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[3] These marginal products can be interpreted as approximations of real rates of return.

[4] We expect the marginal product of public R&D to be small since most of the public R&D is not accounted for in the national accounts.

Equation (6) is valid only if the countries are in their steady-state. Since this is not the case for the CEE countries, we introduce a catch-up term to model the dynamics of these developing economies towards a common stationary state (see Mankiw et al, 1992). The dynamic formulation of the model is also suitable to differentiate between the long run and the short run effects of R&D on economic growth, as recommended in the literature. In our estimated equations we will consider as dependent variable GDP per working age population, catching the impact of labour input in our dependent variable. Thus, we do not include L among our regressors (see also Bassanini et al., 2001; Falk, 2007 ; Nonneman and Vanhoudt, 1996)

We assume that the elasticity of output with respect to different factors is the same across all countries in the sample, leading to fixed effects panel estimation. There is no consensus answer to the questions raised by studies such as Griliches (1979) and Hall et al. (2005), concerning the lag structure to introduce when estimating the effect of R&D on output. Zaman and Goschin (2010) estimate the role of R&D in determining technological progress in Romania and suggest that a 3 year lag structure would be appropriate. Goel and Ram (1994) suggest there is only the risk of underestimating the lagged effect.

5. Methodology and results

Based on the theoretical framework we have presented in the previous section, we proceed to test a dynamic panel specification. In the baseline equation, we test first for the role of business R&D. Our initial growth equation is:

$$\Delta lnGDP_{i,t} = -\phi lnGDP_{i,t-1} + \beta_1 lnFDI_{i,t} + \beta_2 lnKD_{i,t} + \beta_3 lnRDb_{i,t} + \eta_i + \mu_{i,t} \qquad (7)$$

where:

- $\Delta lnGDP_{i,t}$ represents the growth rate of the real GDP per working age population;
- ϕ reflects the speed of adjustment to the long-term value (i.e. to the steady state value according to the economic theory) and $-\phi$ is called the error correction coefficient or adjustment coefficient and represents the adjustment of the system of variables to the long run equilibrium state (a convergence coefficient as stated in Neuhaus (2006)).

- $lnGDP_{i,t-1}$ represents the convergence variable i.e the lagged real GDP per working age population;

- $lnFDI_{i,t}$ represents the natural logarithm of FDI stock as a percentage of GDP;

- $lnKD_{i,t}$ represents domestic investment (computed as Gross Fixed Capital Formation net of FDI flows) as a percentage of GDP;

- $lnRDb_{i,t}$ represents the research and development in business sector, computed as the share of R&D business expenditure flows in GDP;

- η_i represent the individual fixed effects specific to each country and constant in time;

- $\mu_{i,t} \sim N(0, \sigma^2)$ is a random disturbance term;

As a second step in our estimation, we will test whether R&D in public institutions (such as universities and government laboratories) acts as a stimulus to private investment in R&D or whether it crowds out private activity. Next[5], given the theoretical possibility of complementarity between R&D and human capital, we add tertiary education as another explanatory variable[6].

Since there is a possibility that investments in physical capital, in R&D, human capital and the level of GDP could be driven by missing underlying variables, we evaluate the performance of the augmented Solow model including as additional control variables government balance as a share of GDP and trade openness in all the above mentioned equations. These control variables are broadly representative for the existing growth literature and allow us to test whether the relation between R&D activity and economic growth in CEE countries is enhanced in any way by inside country factors (such as government policies) or by interaction with the outside world (through trade). It is widely acknowledged in the literature the role that government plays in stimulating R&D activity, as well as the benefits that an open economy has in terms of R&D diffusion and growth. Our final extended growth equation is as follows:

$$\Delta lnGDP_{i,t} = -\phi lnGDP_{i,t-1} + \beta_1 lnFDI_{i,t} + \beta_2 lnKD_{i,t} + \beta_3 lnRDb_{i,t} + \beta_4 lnRDp_{i,t} + \beta_5 lnHC_{i,t} + \gamma_1 Gbalance + \gamma_2 \ln trade + \eta_i + \mu_{i,t} \quad (8)$$

[5] We won't give here the expressions of these equations for parsimony reasons. We use the final extended equation in order to explain the methodology.

[6] Ideally, we should have also used qualitative measures for human capital in these countries. However, we were unable to do so due to data constraints

where the new variables additional to eq.(7), have the following significance:

-*lnRDp* is the ratio of public R&D flows (defined as the sum of R&D expenditures in the governmental and the educational sectors) in GDP;

-*lnHC* measures the share of students enrolled in tertiary education in their corresponding age group;

-*Gbalance* measures the percentage of government balance in GDP;

-*lntrade* is the trade openness calculated as the ratio of the sum of exports and imports to GDP;

We use yearly observations from 1998 to 2008 for all CEE countries that are part of the EU27, except Slovakia that we identified as being an outlier. Data are taken from Eurostat database and UNCTAD database (for the FDI inflows) and are expressed in 2000 constant prices. Estimating this model by the OLS method raises several concerns. First, the presence of the lagged dependent variable $lnGDP_{i,t-1}$, which is correlated with the fixed effects η_i, gives rise to dynamic panel bias (Nickell, 1981). The coefficient estimate for lagged lnGDP is inflated[7] by attributing a predictive power that actually belongs to the country's fixed effect. Second, as Mileva(1997) points out, since causality between endogenous and right hand side variables could run in both directions (i.e. from GDP to FDI), regressors may also be correlated with the disturbances and therefore violate OLS assumptions. Last, it is known that OLS estimators of panel data models with a lagged dependent variable produce biased coefficients estimates in small samples, especially when the time period is small (Judson and Owen, 1999).

A reliable solution for the efficient estimation of dynamic panels was set by Arellano and Bond (1991) by using the Generalized Method of Moments (GMM). This estimator has become extremely popular, especially in the context of empirical growth research, because it allows relaxing some of the OLS assumptions. The Arellano and Bond estimator corrects for the endogeneity in the lagged dependent variable and it also allows for individual fixed effects, heteroskedasticity and autocorrelation within individuals.

Before estimating our growth equation with GMM, it is more convenient to write it in an equivalent way as:

[7] Note that in our panel T = 11. If T were larger, the impact of one year's shock on the country fixed effect would dilute and the endogeneity problem would become less important.

$$lnGDP_{i,t} = \alpha lnGDP_{i,t-1} + \beta_1 lnFDI_{i,t} + \beta_2 lnKD_{i,t} + \beta_3 lnRDb_{i,t} + \beta_4 lnRDp_{i,t} + \beta_5 lnHC_{i,t} + \gamma_1 Gbalance + \gamma_2 \ln trade + \eta_i + \mu_{i,t} \quad (9)$$

where $\alpha = -\phi + 1$

The first step of the GMM procedure is to remove the individual effects:

$$\Delta\, lnGDP_{i,t} = \alpha \Delta lnGDP_{i,t-1} + \beta_1 \Delta lnFDI_{i,t} + \beta_2 \Delta lnKD_{i,t} + \beta_3 lnRDb_{i,t} + \beta_4 \Delta lnRDp_{i,t} + \beta_5 \Delta lnHC_{i,t} + \gamma_1 \Delta Gbalance + \gamma_2 \Delta \ln trade + \Delta\mu_{i,t} \quad (10)$$

In the differenced eq. (10), there still exists the problem of correlation between the errors $\Delta\mu_{i,t}$ and the independent variable $\Delta lnGDP_{i,t-1}$, which has to be corrected by instrumenting $\Delta lnGDP_{i,t-1}$. As Roodman (2009) recommends we have taken into consideration the small dimension of our sample, instructing the program to make the necessary corrections to the covariance matrix estimate, and therefore to report t instead of z test statistics for the significance of the coefficients. Our instrument set contains the third lag of the dependent variable lnGDP and the differences of the independent regressors which are treated as exogenous and "instrument themselves" (Roodman, 2009). These variables are percentages in GDP and thus it is unlikely that they will be influenced by the levels of GDP per capita. In our instrument set, in order to improve the quality of our instrumentation (see Roodman, 2009), we augmented standard GMM estimation techniques by adding an additional external instrument: the transition index provided by European Bank for Reconstruction and Development (EBRD) as in Mileva (2008). The index consists of a number of different scores grouped by four main categories: enterprise privatization and restructuring, prices and trade liberalization, financial institutions development and infrastructure reforms. The indicators range from 1 to 4 with 1 representing little or no change from central planning and 4 indicating an industrialized market economy (EBRD, 2005).

The coefficients of Eq. (9) and, equivalently, those of Eq. (8) are considered short-term estimates. Since growth is a long-term process and the contribution of different factors should be evaluated in the long-run, we computed also the long-run coefficients. These are easily deduced from Eq. (8):

$$\Delta\, lnGDP_{i,t} = -\phi(lnGDP_{i,t-1} - \theta_1 lnFDI_{i,t} - \theta_2 lnKD_{i,t} - \theta_3 lnRDb_{i,t} - \theta_4 lnRDp_{i,t} - \theta_5 lnHC_{i,t} - \theta_6 Gbalance - \theta_7\, ln\, trade) + \eta_i + \mu_{i,t} \quad (11)$$

where: $\phi = (1-\alpha)$ and $\theta_j = \frac{\beta_j}{(1-\alpha)}$, *j=1..7.*

The relationship in the brackets from Eq.(11) is considered the long-tem relationship among the variables and the parameters θ_j are considered the long-run coefficients of the model.

In the Appendix, Table 3 reports the results in the short run, as given by the GMM estimation of Eq. 9. It also provides information about the validity of our GMM estimation.

[Insert table 3 about here]

Table 3 presents the results of the estimation in the short run. We followed the rule of thumb recommended by Roodman (2009) to keep the number of instruments smaller than the number of individuals (5<9) by collapsing the instrument matrix. The coefficients of the variables obtained in this way were very similar to those obtained with the un-collapsed form of the matrix, proving that our models are quite robust[8]. The p-values obtained for the Hansen test in the collapsed estimation (between 0.33 and 0.53) ensured us that the instrument sets are orthogonal to the regressors and therefore valid for estimation. The Arellano and Bond test confirmed the null hypothesis of absence of second order autocorrelation, meaning that our instrument – the third lag of the dependent variable – is a valid instrument (Roodman, 2009).

Column 1 in Table 3 shows the baseline equation (Eq.7). Column 2 and 3 subsequently introduce the public R&D and human capital proxied by tertiary education. Column 4, 5 and 6 are the estimates of the same equations in the presence of two macroeconomic control variables i.e., government balance and trade openness, which are broadly representative for the existing literature on economic growth. As we can see, in the short-term, all variables have the expected signs and are significant in the baseline equation (Column 1). An increase of 1% in the share of business R&D expenditure in GDP will raise GDP per working age population by 0.025% in the short run. As expected in these countries, FDI contributes more than domestic investment to the

[8] Tables with results in the un-collapsed matrix can be provided upon request. When we used the un-collapsed form of the matrix, the results of the Hansen Test confirm Roodman(2009)'s theory: the p-values were implausibly good (p-values of 1.000) which was a clear sign of too many instruments.

economic growth. When including public R&D, we notice that it has a negative sign. Bassanini et al. (2001) finds a similar result for the case of OECD countries when including public R&D in their estimation. This result could suggest that the research expenditures in the public sector crowd out resources that could have been used by the private sector.

In section 2 of our paper (Table 2), the shares of public R&D were, in many countries, higher than the shares of business R&D and induced a higher increase in the shares of total R&D. It might be the case that that a longer time period is needed for public R&D to raise technology levels. This would imply longer lags in estimation for public R&D which is difficult due to the constraints of short time series for R&D expenditures in these countries. Human capital, proxied by tertiary education is significant in the short run and in its presence the R&D business coefficient slightly decreases, becoming significant at 5% level compared to 1% level in the baseline equation (from 0.025- Column1 to 0.018- Column 3). The estimated coefficient of the R&D business variable in the short run remains highly significant at a 1% level in the presence of our macroeconomic control variables, government balance and trade openness (Column 4, 5 and 6 in Table 3) while public R&D is insignificant but it has a positive sign.

Table 4 reports the long term coefficients of our initial growth equations, more precisely the estimations of Eq. (11).

[Insert table 4 about here]

When focusing on the long-run estimates (Table 4), we notice that the impact of the 1% increase in the share of business R&D in GDP will generate an increase in terms of economic growth (of 0.159% - Column 1'). This confirms our expectations in line with theory that the impact of R&D is significant in the long run, pointing out the need for a certain time horizon so as to obtain the returns on investment. The catch-up term $-\phi$ has the expected negative sign and is statistically significant in all columns (1'-6'), depicting a conditional convergence process inside CEE countries.

When we add public R&D in the long-run (Column 2'), we notice again that it is not significant and it has a negative sign, while business R&D remains highly significant. Since a part of government research is not accounted for by existing measures of GDP, while the R&D

performed by universities is not a direct measure of output (Guellec and van Pottelsberghe, 2003), results are not that surprising especially for CEE countries. In these countries it is difficult to transpose the public R&D efforts into an increase in productivity.

The inclusion of human capital in the model has reduced the impact of R&D business on economic growth. Its role is found to be significant at the 10% level (Column 3'). Redding (1996) argued that human capital accounts for aspects of innovation not captured by the R&D sector, such as "learning by doing" or "on the job training" and that it further enhances the ability of the workforce to learn, absorb and work with new technologies. Our result is consistent with the view that a part of the R&D effect is actually accounted for by human capital and that the omission of human capital variable leads to an overestimated R&D coefficient[9].

Addition of control variables increases the coefficient of business R&D in the baseline equation from 0.159 to 0.178 (Column 4' vs. Column 1'). This confirms the theory that a more open economy has a positive effect on the linkage between R&D expenditure and economic growth, due to trade spillovers and the greater chance for technological diffusion. In our case, our results confirm this hypothesis, since the coefficient of business R&D increases when we add trade openness as a control variable. In the presence of the macroeconomic control variables, in the long run, tertiary education still remains significant while public R&D is not significant but at least has the expected sign (Column 5'and 6'). Adding the public R&D intensity in the presence of macroeconomic variables does not crowd out the effect of business R&D on economic growth in the long-run.

6. Conclusions

One of the main challenges in policy agendas and especially in the Lisbon agenda is to increase private and public R&D, so that the countries (including CEE countries) may benefit in terms of economic growth. A question of interest in this respect is to see if the new member states can contribute to the overall goal and whether they are on their way to reaching shares of R&D in their GDP that would bring growth benefits.

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[9] We have examined a number of variants of our model specification. For instance, we have included in our estimations some interaction terms i.e. human capital with R&D, FDI with human capital and FDI with R&D. Although our model was robust in terms of R&D business, these coefficients were not significant except FDI*HC. When excluding schooling, they do not yield positive results in any case. Tables with results can be provided upon request.

Our results show that the impact of R&D business on economic growth is high in the long run and it remains high when public R&D is included. Public R&D, although not significant, does not crowd out the positive effect of private R&D in the long-run. When human capital proxied by the share of students is included, it is significant at 10% while the R&D business coefficient decreases severely.

In the presence of other macroeconomic variables (such as government balance and trade openness) our variables remain significant. Further research is needed in this area to include measures of outputs of R&D (such as patents) and to analyze the magnitude of R&D spillovers at the disaggregated level- based on larger and more comprehensive samples- to see whether this result can be further qualified. More theory-based hypotheses should be developed to investigate the interactions among human capital, innovation and FDI.

The R&D expenditures of the business sector are an important indicator for innovation activities. In comparison with the EU 27 level, we have seen that in these countries there is a far smaller ratio in GDP. The lack of cooperation among business, science and research technological centers in innovative projects is definitely a cause of poor funding. The positive fact is that the gap is decreasing, although in a small manner, and the expected returns of business R&D on economic growth have a positive impact.

For an efficient transfer of research into new products, there should be a strong link between all participants in the innovation system. As policy recommendations, government must promote innovative activity in firms through direct spending on education and training, patent protection, regulation and competition policy. To increase the impact of public R&D upon economic growth, more channels of cooperation between universities and research labs on one side, and firms, on the other side, should be encouraged. For the moment, our results show that the public R&D has neutral effect, in the sense it does not stimulate growth, but it does not crowd out the positive effect of private R&D either. If in the future the government would promote legislation that opens venues for the cooperation between universities and firms, an interesting hypothesis would have to be tested. That is, would a higher level of R&D spending on academic research act as a stimulus for business R&D?[10]

[10] Possibly through a significant increasing influence on the marginal contribution of the business R&D on growth, a hypothesis that can be tested in a standard linear specification.

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Table 1. R&D intensity in CEE countries and the catching up process, 1998-2008

		1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008
EU27	R&D intensity	1.79	1.83	1.86	1.86	1.87	1.86	1.83	1.82	1.85	1.85	1.92
	Variation coef.	60%	69%	63%	72%	67%	71%	67%	65%	63%	62%	61%
CEEC	R&D intensity	0.72	0.70	0.72	0.75	0.75	0.73	0.75	0.80	0.87	0.85	0.89
	Variation coef.	42%	45%	46%	48%	49%	45%	47%	47%	49%	48%	49%
Gap in R&D intensity		60%	62%	61%	60%	60%	61%	59%	56%	53%	54%	53%
Gap in GDP/working age population		77%	77%	76%	76%	75%	74%	73%	72%	71%	70%	69%

Source: R&D intensity (percentage of R&D expenditure in GDP) and GDP data provided by EUROSTAT (2011). The rest is our own calculations.

Table 2. R&D expenditure as a percentage of GDP, by main components

R&D intensity	**Total R&D**		**Business R&D**		**Public R&D**	
	1998	2008	1998	2008	1998	2008
EU27	1.79	1.92	1.15	1.24	0.64	0.68
Bulgaria	0.57	0.47	0.11	0.15	0.46	0.32
Czech Republic	1.15	1.47	0.75	0.91	0.40	0.56
Estonia	0.58	1.29	0.12	0.59	0.46	0.70
Latvia	0.40	0.61	0.08	0.15	0.32	0.46
Lithuania	0.54	0.8	0.01	0.20	0.53	0.60
Hungary	0.66	1.00	0.29	0.55	0.37	0.45
Poland	0.67	0.6	0.28	0.19	0.39	0.41
Romania	0.49	0.58	0.38	0.17	0.11	0.41
Slovenia	1.34	1.65	0.71	1.07	0.63	0.58
Slovakia	0.78	0.47	0.52	0.21	0.26	0.26

Source: EUROSTAT, 2011

Table 3. Short-Run Coefficients

Estimation Method: Difference GMM						
Dependent Variable: $lnGDP_{i,t}$						
	Column1	Column2	Column3	Column4	Column5	Column6
$lnGDP_{i,t-1}$	0.842***	0.854***	0.736***	0.868***	0.861***	0.748***
	(0.052)	(0.040)	(0.058)	(0.040)	(0.035)	(0.053)
$lnFDI_{i,t}$	0.056**	0.054**	0.046**	0.036**	0.037**	0.031*
	(0.021)	(0.018)	(0.016)	(0.013)	(0.014)	(0.014)
$lnKD._{i,t}$	0.024*	0.025*	0.027*	0.017*	0.016	0.018*
	(0.012)	(0.013)	(0.013)	(0.008)	(0.009)	(0.009)
$lnR\&DBusiness_{i,t}$	0.025***	0.024***	0.018**	0.023***	0.024***	0.018***
	(0.004)	(0.006)	(0.008)	(0.005)	(0.006)	(0.006)
$lnR\&DPublic_{i,t}$		-0.014	-0.025		0.011	0.002
		(0.041)	(0.039)		(0.025)	(0.024)
$lnTertiary_{i,t}$			0.164*			0.160**
			(0.086)			(0.067)
$lnTrade_{i,t}$				0.020	0.018	0.004
				(0.034)	(0.038)	(0.024)
$GBalance_{i,t}$				0.006	0.007	0.007
				(0.005)	(0.004)	(0.004)
No. of observations	81	81	81	81	81	81
No. of instruments (collapsed)	5	6	7	7	8	9
Hansen Test (p-value)	0.505	0.494	0.642	0.1416	0.393	0.559
AR(2) (p-value)	0.199	0.298	0.907	0.209	0.194	0.608

Note: Standard errors in brackets.*, ** and *** denote significance levels of 10%, 5% and 1%

Table 4. Long-Run Coefficients

Dependent Variable: $\Delta lnGDP_{i,t}$	Column1'	Column2'	Column3'	Column4'	Column5'	Column6'
-ϕ	-0.158*** (0.052)	-0.146*** (0.040)	-0.264*** (0.058)	-0.132*** (0.040)	-0.139*** (0.035)	-0.252*** (0.053)
$lnFDI_{i,t}$	0.353*** (0.096)	0.368** (0.116)	0.173** (0.063)	0.274** (0.113)	0.267** (0.103)	0.123 (0.067)
$lnKD_{i,t}$	0.154** (0.060)	0.168* (0.074)	0.102** (0.043)	0.127** (0.053)	0.117* (0.056)	0.070* (0.036)
$lnR\&DBusiness_{i,t}$	0.159** (0.059)	0.166*** (0.050)	0.067* (0.036)	0.178** (0.070)	0.174** (0.058)	0.073** (0.032)
$lnR\&DPublic_{i,t}$		-0.096 (0.278)	-0.093 (0.137)		0.080 (0.182)	0.007 (0.095)
$lnTertiary_{i,t}$			0.619** (0.225)			0.633*** (0.181)
$lnTrade_{i,t}$				0.154 (0.254)	0.129 (0.278)	0.017 (0.093)
$GBalance_{i,t}$				0.049 (0.034)	0.048 (0.033)	0.027 (0.017)

Note: Standard errors in brackets.*, ** and *** denote significance levels of 10%, 5% and 1%.