THE IMPACT OF R&D ON GROWTH: CROSS-COUNTRY COMPARISON OF OLD AND NEW EU MEMBERS

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ABSTRACT

This paper is an assessment of R&D induced growth in the European Union. Deriving an econometric model form the extended Solow Growth model with physical, human and research capital as inputs I estimate the effect of R&D intensity on the level of GDP per capita and its annual growth in EU between 1995 and 2005 years. The results show a different effect of R&D investment in old and new member states. Although R&D intensity affects the level of GDP per capita in both: new and old EU members, its impact on growth is significant only in old EU members. The GDP growth in the developing EU countries during the period examined was influenced by other factors.

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1. INTRODUCTION

The world is so different: some countries prosper, while others suffer from stagnation. Growth theory tried to explain this phenomena and Robert E. Lucas wrote (1988) “Once one starts to think about [economic growth], it is hard to think about anything else.” Thus, already for more than half of a century, different extensions of Solow Growth Model, which predicts “conditional convergence” (Robert Solow, 1956) have been developed. Accounting for knowledge capital in addition to human and physical capital in growth equations significantly improved the explanatory power of the model.

The improvements in technology have been the real force behind perpetually rising standards of living (Gene M. Grossman and Elhanan Helpman, 1994). But most technological progress requires an intentional investment of resources. Research and development is the major source of technical change that is shown to be a source of increasing returns (Walter G. Park and David A. Brat, 1996). According to the definition in Frascati Manual (Organization for Economic Co-operation and Development (OECD), 1993, p.29) it “comprises creative work undertaken on a systematic basis in order to increase the stock of knowledge and the use of this stock of knowledge to devise new applications”. Investing in R&D also makes easier to imitate the technology that countries encounter in international trade or through foreign direct investment, which in combination with human resources with the required training contribute to the development of the technological capabilities of a country

Previous studies on R&D induced growth differ in terms of the samples, but most of them focus on OECD countries due to the rich available datasets. The results show a positive and statistically significant return on R&D investment on growth for developed countries. In the samples of low income countries of even countries with different levels of development, previous works show different results.

Nowadays, growth and convergence issues are very important in the European Union, as it consists of countries with not fully integrated capital and labor markets and with different technology everywhere, but following similar goals in their way to become a true and prosperous union. This became even more important and problematic since the enlargement of the EU, where countries with different levels of development and history of investment and expenditure policies were exposed to more or less similar conditions and goals.

The decline productivity and stagnation of economic growth in EU led the set up of Lisbon Strategy (European Council, 2000) which aims to “make Europe, by 2010, the most competitive and most dynamic knowledge-based economy in the world, capable of sustainable economic growth with more and better jobs and greater social cohesion” and includes various policy initiatives and objectives that should be taken by all EU member states in order to achieve this goal. As research and technology is considered to have a great impact on economic growth and are the driving force for competitiveness and employment, the European Commission and member states decided upon an increase in research and development investment over GDP in EU up to 3 percent until 2010 and the share funded by business should be rise to two-thirds of the total. (European Council, 2002).

Is not this goal too ambitious? And how realistic has it become since the accession of new members to EU? The R&D expenditures in EU increased both in nominal and real terms since 2000 (Simona Franc, 2006). However, the R&D intensity in EU 25 was less than 2 percent in 2005 and less than 1 percent in new EU members. Also, Portugal and Greece have not reached yet the 1 percent R&D intensity. Sweden and Finland are the only member states that reached the 3 percent target even before the Lisbon Agenda set it up, being ahead of all member states and even US and Japan – the leaders in R&D investment. According to Adam Torok (2005, p.99) classification, in today EU 27 six member states are “leaders” (with gross domestic expenditures on R&D (GERD) to GDP ratio higher then 2 percent), nine are "followers" (GERD share in GDP between 1 and 2 percent), ten – "midfield" (GERD over GDP between 0.5 and 1 percent) and two are still "marginals" (Cyprus and Romania with GERD over GDP ratio between 0.2 and 0.5 percent).

In EU more than fifty percent of R&D expenditures finance basic and applied research, compared to US, China and Japan where R&D expenditures are focused on experimental research. The R&D financed by the business sector constitutes 0.54 in 2005 of total R&D expenditure, a rate lower than in Japan (about 0.75), US (0.63) and China (0.60). This ratio is even lower for new EU member states, only in Czech Republic and Slovenia private R&D represent more than 50 percent of total R&D expenditures. These are the only two new EU members that invest more than one percent of GDP in R&D activities.

Despite the low R&D intensity new member states have a higher annual average growth rate of GDP per capita. The paper is an assessment of R&D induced growth in the European Union, an area not very homogenous since the adherence of the new EU members in 2004 and 2007 but with a strong need for convergence, common goals and similar objectives in R&D policy.

I estimate the effect of R&D intensity on the level of GDP per capita and its annual growth in EU member states for the period 1995-2005, based on the fact that most of the new EU countries faced a decline in output and managed to return to growth only in 1995. I estimate the econometric model derived from the extended Solow model with R&D, human capital and other control variables included, using two econometric techniques: Fixed Effects and first-difference Generalized Method of Moments (GMM). I focus on the differences between old and new EU members and the results show that R&D intensity influences the level of GDP per capita in both: old and new EU members. However, a significant positive effect on growth has been found only for old EU members, which is consistent with some previous works, where only high income countries benefit from R&D investment (Maury Gittleman and Edward N. Wolf, 1996). The low share of business R&D in GERD in new EU countries can explain the insignificance of R&D intensity for growth, as it is considered to have higher and sooner return. As an alternative measure for R&D investment I use human resources in science and technology as share of labour force.

The paper is organized as follows. Chapter 2 – Literature Review - presents the main results of the previous works on R&D induced growth. Chapter 3 – The Model and Data - describes the theoretical growth model, the econometric model which I estimate and the data with the description of variables used. Chapter 4 – Empirical Results – contains a short description of the estimation procedure and the estimated results with the explanation of the coefficients. Chapter 5 concludes.

2. LITERATURE REVIEW

The neoclasical growth theory was developed by Solow (Solow, 1956) and has dominated economists' thinking about long-term movement in per capita income since 1956. Solow focused on the process of capital formation. According to his model there are two possible sources of variation of output per worker: differences in capital per worker and differences in effectiveness of labor. Later, David Romer (2001) finds that only growth in the effectiveness of labor can lead to permanent growth in output per worker, changes in capital per worker having a smaller effect.

An important contribution to the growth theory has been made by Gregory N. Mankiw, David Romer and David N. Weil (1992). They estimated the augmented Solow model with just three dependent variables: investment rate in physical and human capital and population growth and they could explain 78 percent of the variance in cross-country differences in growth for a sample of 98 non-oil producing countries, but only 28 percent of the variation for OECD countries. Although being a basic research on the determinants of growth, this big decrease in R squared when the sample is reduced only to OECD countries stressed out the omitted variables problem and cast doubt on the validity of some assumptions. Grossman and Helpman (1994) in a non empirical paper disagree with their assumption of common rate of technological progress for the whole sample of 98 countries for 25-years period. Edward N. Wolff (1992) provides evidence of different rates in total factor productivity growth only in the sample of OECD countries over a 20-years period.

However, differences in physical and human capital can only partially explain the variation in output. Starting with the beginning of 90's the growth literature examines knowledge inputs and spillovers as another important source of growth. As knowledge can not be measured directly, the most common proxy used is the investment in research and development activities[1]. Papers that accounted for R&D as a determinant of growth suggest that the mean rate of return to R&D investment is much larger than the corresponding return to investment in fixed capital. Also, the return rate is different for different samples of countries, depending on their level of development.

An important study and a relative early one on the empirics of R&D induced growth is Frank R. Lichtenberg's (1992) paper. He examines the role of R&D in cross-country differences in productivity growth and levels in a sample of 53 countries with different levels of development, which is a great advantage over other papers, between 1960 and 1985. He got a positive significant coefficient on R&D intensity which is higher for privately-funded R&D investment. The social rate of return to privately–funded R&D is seven times as high as return to fixed investment. In addition to this he calculates the ratios of fundamental[2] research and non-fundamental research and their return to growth and finds that fundamental research is the only component of R&D investment that influence productivity.

Most studies on the impact of R&D on output growth cover OECD countries due to the rich datasets available. Walter Nonneman and Patrick Vanhoudt (1996) estimate in their paper three regressions: textbook Solow model (only with investment in physical capital), augmented Solow model (with physical and human capital) and extended Solow model which adds to the previous variables investment in R&D. They got that the extended model explains almost 80 percent of variation in cross nation level of output and growth between OECD countries that is higher than the Mankiw et al (1992) results. This indicates that the investment share in R&D was an omitted variable in their analysis. Katarina R. Keller and Panu Poutvaara (2005) showed that the same model performs well also outside OECD countries, explaining 61 to 86 percent of cross-country variation in income and growth over

[1] The same way as expenditure on education arte used as a proxy for investment in human capital
[2] Fundamental research is defined by UNESCO as "experimental or theoretical work undertaken with no immediate practical purpose in mind

the 1960-2000 period. They consider investment in R&D as a good proxy for investing in the adaptation of new technology to fit the country's existing production technology, thus contributing to growth even when knowledge is nonrival. They also estimate the model controlling for more variables, other than investment in physical, human and research capital and population growth.

David T. Coe and Elhanan Helpman (1993) find a positive and statistically significant relation between R&D stock and total factor productivity growth among 22 OECD countries over the period 1971 – 1990. Their novelty consists in the inclusion of a variable for foreign R&D capital, but they do not account for catch-up term, which is significant when used it. In another paper (David T. Coe, Elhanan Helpman and Alexander Hoffmaister, 1995) they study the effect of international R&D spillovers in a sample of 77 countries from Africa, Asia, Latin America and Middle East. Their results show that R&D spillovers from the industrial countries in the North to the less developed country in the south are significant.

Working Party No.1 of the OECD Economic Policy Committee (1993) reports a positive insignificant effect of the growth in R&D capital stock on labor productivity growth for 19 OECD countries and 1960-1985 period (Gittleman and Wolf, 1996). Another OECD study (Dominique Guellec and Bruno van Pottelsbewrghe de la Potterie, 2001) analyses the effect of different types of R&D expenditures on productivity growth: business R&D, public R&D and foreign business R&D for 16 OECD countries between 1980 and 1998. According to their estimates the long-term elasticity of foreign R&D on productivity is three time higher than domestic business R&D elasticity. And smaller countries benefit even more from foreign R&D than larger ones. They also make a detailed evaluation of the effect of different types of public R&D on productivity, which is a contribution to the R&D induced growth for

OECD countries. Their finding is that the elasticity of public R&D is positively affected by the share of universities as opposed to government laboratories in public research.

Walter G. Park and David A. Brat (1996) study the effect of R&D spillovers on output level and growth. They argue that if increased investment in R&D enables a country to grow faster and the evidence show that R&D is higher in more developed countries, this will result in greater international economic divergence. On the other hand, foreign countries benefit from spillovers generated by research activities that lead to greater international economic convergence. As research stocks of different countries are not perfect substitutes, they derive spillover research data of each country by a weighted aggregate of the rest of the world's R&D investments. Another paper (Walter G. Park, 1995) studies to which extent national R&D investments affect productivity growth and R&D investments in other countries. He estimates the model by OLS, FE and RE for private and public R&D separately and jointly and found that private R&D has higher output elasticity than public R&D and physical capital. His sample consists only of 10 OECD countries, but those which account for almost 95 percent of world's research activities.

Gittleman and Wolff (1995) find a significant relation between R&D intensity and growth only for the sample of developed countries. They use a simple OLS estimation and also find that R&D activity has changed in importance over time, in terms of its ability to explain international differences in productivity growth. They explain it like a possible consequence of the shift in technological regime to IT-based process or a speed-up in the pace of international spillovers of knowledge. In their estimation they use two R&D variables: the ratio of R&D expenditures to GDP and the ratio of scientists and engineers engaged in R&D per capita. The results do not change the significance when changing the control variable.

Peter Howitt (2000) sustains the Schumpeterian approach of endogenous growth theory, according to which R&D performing countries converge to parallel growth paths and the other countries stagnate. He explains this by the fact that per capita income varies across countries not only because differences in capital stocks per worker but also because of differences in productivity. His estimation model is similar to Lichtenberg (1993) model but predicts a lower rate of convergence.

The variation in the results of mentioned researches is mainly due to the differences in the econometric specification, data sources and periods of estimation. Most papers use Fixed Effects method and Generalized Method of Moments as common techniques for dynamic panel data. Also non-linear Least –Square is used (Park and Brat, 1995). However, all of them show a significant positive effect of R&D on growth in developed countries, and some of them have found a positive effect for developing countries too. Then why do countries invest so little in R&D if it has such a high return? Daniel Lederman and William F. Maloney (2003) examine the determinants of R&D. They find that R&D rise exponentially with the level of development measured by GDP per capita. They also estimate the growth regression adding to the right-hand-side variables an interaction term between R&D and per capita GDP. It is negative and statistically significant, suggesting a decreasing return to R&D with development.

Charles I. Jones and John I. Williams (1997) examine whether there is too much or too little investment in R&D and by how much it should be increased. Using an estimate of social return of R&D of about 30 percent and private return of the capital of 7 percent they find that the optimal R&D spending as a share of GDP is approximately four times larger than the actual spending.

Another group of studies examine the relation of R&D expenditures and growth at industry or sectoral level. The relation is also positive and the coefficients in most cases are statistically significant (Gavin Cameron, 2000).

In my paper I estimate the effect of R&D on the level and growth of GDP per capita in EU member states as the issue of convergence is very important since the accession of new members in May 2004 and January 2007 and a great emphasis has been given to R&D investment by Lisbon Strategy (European Council, 2000). I estimate the regression for the whole EU and also separately for old and new EU members. Also, for growth equation I use an alternative R&D variable: human resources in science and technology as share of labor force. For old EU members the results are quite predictable as all of them (except Ireland) are OECD members and the studies mentioned show similar positive significant effect of R&D intensity on growth. However, new member states are less developed, and the growth literature provides us different results for developing countries. On the other hand, new EU members are a more homogenous group of countries than those used in other studies, that may give different results.

3. THE MODEL AND DATA

This chapter is composed of two sections. In the first section I make a short description of the macroeconomic growth model with R&D capital as input. Then, I derive the econometric model which I estimate by adding other control variables. The second section describes the variables used in the regression, provides information about data sources used and present the descriptive statistics for these variables.

3.1 Macroeconomic Framework and Econometric Model

The extended growth model where the output production needs physical, human capital and research capital is:

$$Y=K^{\alpha}H^{\beta}R^{\gamma}(A(S)L)^{1-\alpha-\beta-\gamma} \quad (1)$$

where Y denotes the output, K – physical capital, H – human capital, R – research and development capital, L – labor and A is the technical efficiency index, which is assumed to be taken as given for every country (Park and Brat, 1996). α,β and γ are the shares of the three types of capital in the production process. Following the logic of Solow model (Romer D., 2001) CRS (constant returns to scale) assumption is maintained, population grows at rate ***n***, the number of effective units of labor at rate ***n+g***, and the depreciation rate is δ [3].

Thus, production per effective unit of labor is:

$$y(t)=k(t)^{\alpha}h(t)^{\beta}r(t)^{\gamma} \quad (2)$$

where, y(t)=Y(t)/(A(t) L(t)), k(t) =K(t)/ (A(t) L(t)), h(t) (A(t) L(t)) and r(t)=R(t)/ (A(t) L(t)) accordingly.

[3] Mankiw et al (1992) calculated the value of δ , which is 0.03. This value is used in most papers presented in literature review part.

If s_k is the share of GDP invested in physical capital, s_h is the share of GDP invested in human capital and s_r is the fraction of GDP invested in R&D activities the evolution of the economy is given by:

(3a) $$\dot{k} = s_k y_t - (n+g+\delta)k_t$$

(3b) $$\dot{h} = s_h y_t - (n+g+\delta)h_t$$

(3c) $$\dot{r} = s_r y_t - (n+g+\delta)r_t$$

And economy converges to a steady-state defined by:

(4a) $$k^* = \left(\frac{s_k^{1-\beta-\gamma} s_h^{\beta} s_r^{\gamma}}{n+g+\delta}\right)^{1/(1-\alpha-\beta-\gamma)}$$

(4b) $$h^* = \left(\frac{s_k^{\alpha} s_h^{1-\alpha-\gamma} s_r^{\gamma}}{n+g+\delta}\right)^{1/(1-\alpha-\beta-\gamma)}$$

(4c) $$r^* = \left(\frac{s_k^{\alpha} s_h^{\beta} s_r^{1-\alpha-\beta}}{n+g+\delta}\right)^{1/(1-\alpha-\beta-\gamma)}$$

Thus, substituting equations (4) into equation (2) and taking logs, the derived equation for the level of output per effective unit of labor is:

(5) $$\ln y_i = const + \frac{\alpha}{1\text{-}\alpha\text{-}\beta\text{-}\gamma}\ln(s_{ki}) + \frac{\beta}{1\text{-}\alpha\text{-}\beta\text{-}\gamma}\ln(s_{hi}) + \\ + \frac{\gamma}{1\text{-}\alpha\text{-}\beta\text{-}\gamma}\ln(s_{ri}) + \frac{\alpha+\beta+\gamma}{1\text{-}\alpha\text{-}\beta\text{-}\gamma}\ln(n_i + g + \delta) + u_i$$

The corresponding growth equation[4] is:

[4] This model can be estimated using non-linear estimation techniques. Empirical papers estimate the equations both: with and without constraints on the coefficients (ln(n+g+δ) coefficient should be equal to the sum of the coefficients for investment rates in the three types of capital, but with opposite sign)

(6)
$$\Delta \ln y_{ti} = (1-e^{-\mu t})[\frac{\alpha}{1-\alpha-\beta-\gamma}\ln(s_{ki}) + \frac{\beta}{1-\alpha-\beta-\gamma}\ln(s_{hi}) + \\ + \frac{\gamma}{1-\alpha-\beta-\gamma}\ln(s_{ri}) - \frac{\alpha+\beta+\gamma}{1-\alpha-\beta-\gamma}\ln(n_i+g+\delta) \text{-} \ln y_{t\text{-}1,i}] + u_i$$

I derived the econometric model from the theoretical one. I included other control variables in addition to those used in the extended Solow model: government expenditures as a share of GDP, a measure for inflation and a measure for corruption[5].

Thus, the level equation I estimate has the following form:

(7)
$$\ln y_{ti} = const + \alpha_1 \ln(\frac{GERD}{GDP})_{ti} + \alpha_2 \ln(\frac{I}{GDP})_{ti} + \alpha_3 \ln(enrol)_{ti} + \\ + \alpha_4 \ln(\frac{G}{GDP})_{ti} + \alpha_5 (\frac{\pi}{1+\pi})_{ti} + \alpha_6 \ln(corrupt)_{ti} + \eta_i + v_{ti}$$

where as a dependent variable I use GDP per capita. In this case there is no need to control for population growth. Thus, the term $\ln(n_i + g + \delta)$ is omitted from the equation. The corresponding growth equation is:

(8)
$$\Delta \ln y_{ti} = const + \alpha_1 \ln y_{t\text{-}1,i} + \alpha_2 \ln(\frac{GERD}{GDP})_{ti} + \alpha_3 \ln(\frac{I}{GDP})_{ti} + \alpha_4 \ln(enrol)_{ti} + \\ + \alpha_5 \ln(\frac{G}{GDP})_{ti} + \alpha_6 (\frac{\pi}{1+\pi})_{ti} + \alpha_7 \ln(corrupt)_{ti} + \eta_i + v_{ti}$$

where:

- $\ln y_{ti}$ - is the natural logarithm of GDP per capita in country ***i*** in year ***t*** (dependent variable in level equation)

[5] These control variables are also used by Keller and Poutvaara (2005). Instead of corruption they use the rule of law variable and found that it is significant for both level and a growth equation, but only for non-OECD countries. This is because in OECD countries there is almost no variation for this variable. Inflation is significant only for growth equation.

- $\Delta \ln y_{ti}$ - is the annual GDP per capita growth rate in country ***i*** in year ***t.*** (dependent variable in growth equation)
- $y_{t-1,i}$ - lagged log GDP per capita to control for catch-up effect
- $\frac{GERD}{GDP}$ - domestic expenditures on R&D over GDP[6] (variable of interest)

In the growth equation I use an alternative measure for manpower R&D, which is the human resources in science and technology as share of labor force

- $\frac{I}{GDP}$ - gross fixed investment as share of GDP
- $enrol$ - gross secondary school enrolment ratio
- $\frac{G}{GDP}$ - government expenditure as share of GDP
- $\frac{\pi}{1+\pi}$ - measure for inflation. I do not use inflation directly because there are years with hyperinflation (over 800) in some new EU members (Estonia, Latvia, Lithuania and Bulgaria). Thus, using this variable is more appropriate.
- $corrupt$ – corruption index, proxy for the quality of political institutions
- η_i - unobserved country specific effect
- v_{ti} - idiosyncratic error

The data section presents descriptive statistics – means, standard deviation, minimum and maximum values - for all mentioned variables and sources for the data.

Of course, there are other many factors that can influence the level of GDP and its growth. Such potential explanatory variables can be:

[6] Park and Brat (1996) use as dependent variables not only R&D intensity, but also gross investment in R&D and found that both are statistically significant

- Budget deficit or other proxy for government balance. I do not use it since it is highly linearly correlated with government expenditures; its inclusion will render estimates inconsistent.
- Terms of trade (export-import). It is important, but it is very difficult to find data for it.
- Labor market regulation. It is difficult to obtain accurate data, even when it is available it is plagued with severe measurement errors.

Moreover, the economic literature points that increasing the number of right hand-side variables in growth regressions is unlikely to take away the omitted variables bias problems. Therefore, I do not focus on the maximum generality and completeness of explanatory variables but rather focus on the variable of interest – R&D intensity – and robust ways of evaluating its impact.

3.2 Data

My sample consists of 24 EU countries over the period 1995-2005. I excluded Luxemburg from old EU member states as it is an outlier in terms of GDP per capita, and Malta and Cyprus from new EU members as there is no R&D data available before 2000 for Malta and before 1998 for Cyprus. However, the R&D intensity in these two countries is too low to have an impact on economic growth. I estimate the models separately for old and new EU countries because they represent two groups of countries with different level of development and R&D intensity. Also, because the purpose of my paper is to make an assessment of EU enlargement on R&D induced growth. In the following text and presented tables I refer to the whole European Union as EU 27, old member states as EU 15 (although Luxemburg is not included) and new EU members as EU 12 (but, Malta and Cyprus are excluded).

The period 1995-2005 is relatively short, but I chose it as new EU member states were in the transition process after the political events in the late ‘80s and early ‘90s, which led to huge fall in output in almost in all countries. By 1992 only Poland returned to growth. By 1994 the whole Central and South-Eastern Europe together with two former Soviet Union states – Latvia and Lithuania – had arrived to growth, followed by Estonia in 1995. Therefore, the period starting form 1995 is more appropriate for this sample of countries and it also permits to estimate the model by firs-difference GMM, where the use of balanced panel is needed. As data for 2006 is not available yet I limit my sample to 2005 year.

The data for dependent variable[7] - GDP per capita in 2006 US$ (converted to 2006 price levels with updated 2002 EKS PPPs) - is from the Groningen Growth and Development Centre and the Conference Board database.

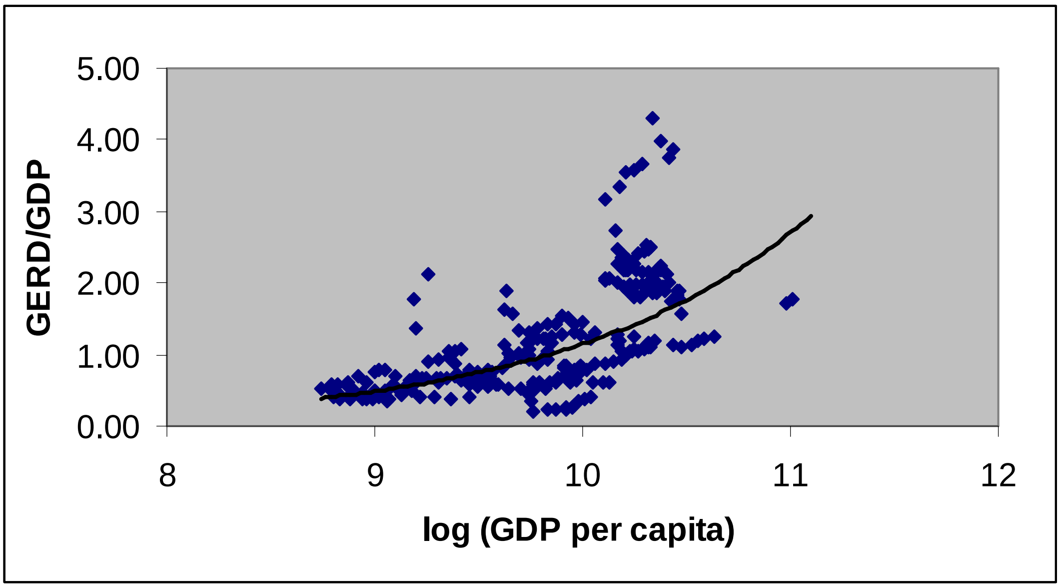
The main explanatory variable of interest is Research and Development (R&D) intensity, which is the share of gross domestic R&D expenditures in GDP. Although the indicator applicable in wide international comparison is R&D over GNP (Torok, 2005, p.73), I use R&D over GDP as this is how it is defined by Lisbon Strategy. The data is from EUROSTAT database, where gross domestic expenditure on R&D (GERD) is composed of: business enterprise expenditure on R&D (BERD), higher education expenditure on R&D, government expenditure on R&D and private non-profit expenditure on R&D.

The ratio of R&D expenditures to GDP increases with the level of development of the country (see Figure 1), being much higher for old EU members than for new ones (as average 2.65 times higher in 2005). The level of development is positively correlated with R&D

[7] I also estimated the equations for the level and growth of GDP per person employed, using as an additional dependent variable $\ln(n+g+\delta)$, where n is the average growth rate of population in each country during the examined period, g – is the growth rate of output in EU27 and δ is the depreciation rate (assumed to be equal for all three kinds of capital) which was taken as in Mankiw, Romer and Weil (1992) equal to 0.03. The coefficients for the R&D intensity and other variables do not differ much, also in some cases I got a significant coefficient for the population growth term.

mainly because rich countries tend to have better IP protection, deeper credit markets, higher Government capacity to mobilize public R&D expenditure and a better quality of research institutions (Lederman and Maloney, 2003). Also there has been found a strong correlation between national R&D and export performance.

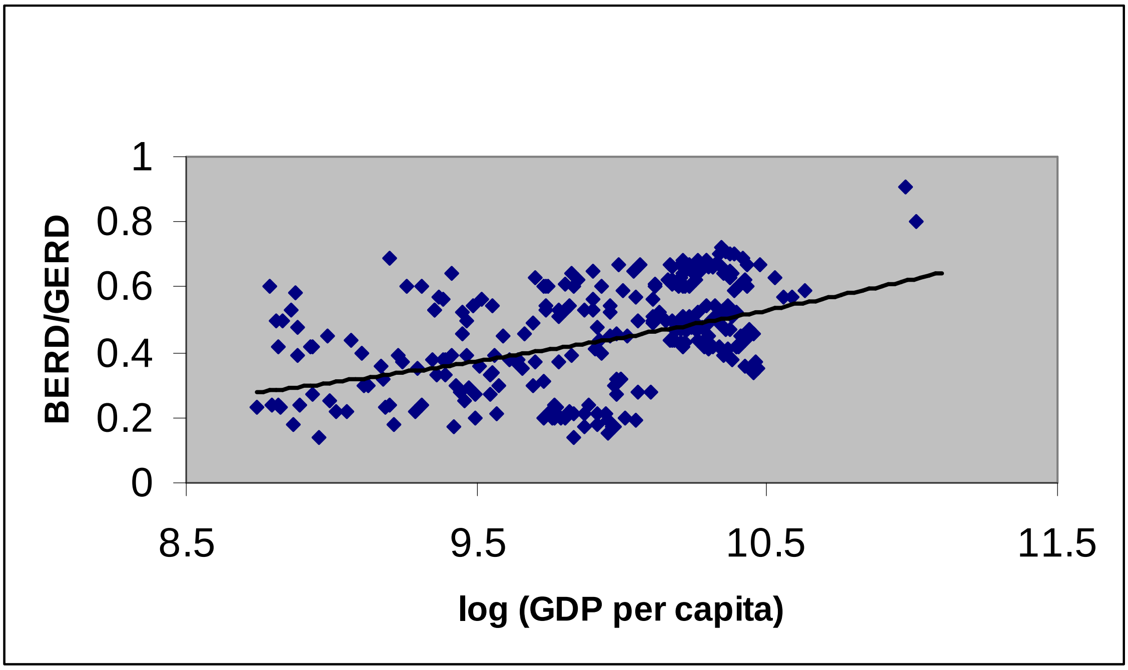
Figure 1. R&D and level of development



From the R&D components mentioned above, BERD is considered to be more efficient and to have greater return on growth. The percentage of Business Expenditures R&D within GERD also increases with the level of development of the economy (see figure 2 for EU 27). Therefore, I use another variable which is calculated as:

$$R\&D_{business} = \frac{GERD}{GDP} \times \frac{BERD}{GERD} \qquad (8)$$

Figure 2. BERD over GERD and level of development



Accounting for business and non-business R&D as share of GDP instead of GERD over GDP, equation (8) becomes:

(9)
$$\Delta \ln y_{ti} = const \ + \alpha_1 \ln y_{t\text{-}1,i} + \alpha_2 \ln(\frac{BERD}{GDP})_{ti} + \alpha_3 \ln(\frac{1\text{-}BERD}{GDP})_{ti} + \alpha_4 \ln(\frac{I}{GDP})_{ti} +$$
$$+\alpha_5 \ln(enrol)_{ti} + \alpha_6 \ln(\frac{G}{GDP})_{ti} + \alpha_7 (\frac{\pi}{1+\pi})_{ti} + \alpha_7 \ln(corrupt)_{ti} + \eta_i + v_{ti}$$

The data for R&D business expenditure over GERD are taken from EUROSTAT and OECD databases. The datasets are compatible.

Since R&D activities affect the productivity not immediately, lagged values of R&D intensity should be used, as their impact may be greater than the present R&D intensity. Different authors use different lags starting with the previous year R&D intensity to 3 year lagged R&D intensity, depending on the significance of the coefficients. Also, it is considered that business and non-business R&D have different delays in affecting the productivity. Guellec and van Pottelsberghe de la Potterie (2001) suggest two lags for business R&D and three lags for public R&D. In my study I use the average R&D intensity for the last three years and thus, there is no need for using lagged values. This approach is also used by other authors but for different number of years. Other authors (Gittleman and Wolff, 1995) use the average for two years. I use the average for three years for both GERD and BERD.

I also estimated the growth regression using an alternative measure for research capital which is the share of human resources in science and technology in labor force. The data is from EUROSTAT database.

As a proxy for human capital investment rate I use the gross enrolment ratio in secondary school. Gittleman and Wolff (1995) use as a proxy gross enrolment rates for primary, secondary and higher education and three corresponding educational attainment rates. The significance of R&D intensity term does not change by changing the education variable. Due to data availability I used secondary enrolment ratio from UNESCO Institute of Statistics database and World Bank Database for more recent years. However, as I discuss later, it is not a good proxy for human capital investment rate, as the current school enrolment may not have an impact on growth; rather its lagged values affect it.

Nonneman and Vanhoudt (1996) specify in their paper that they tried to proxy human capital investment rate by the ratio of direct Governmental expenditure on education to GDP and consider it a better one that the one used by Mankiw et al (1992). But in the final paper they use the percentage of working-age population in secondary school as a proxy in order to able to make comparison with the results in the specified paper. This variable can be a better proxy if the exact shares of investment in every level of education as the return of every level of education is different and it increases with the level of education. However, it might be highly linearly correlated with government expenditures over GDP, which I can not drop from the equation as it is an important factor of growth in new EU members.

Table 1. Descriptive statistics

Variable	Mean	Std.Dev.	Min	Max
Ln(GDP per capita)				
EU 24	9.893	0.513	8.743	10.629
EU 15	10.265	0.177	9.768	10.629
EU 12	9.372	0.348	8.743	10.040
Ln (GDP per capita growth)				
EU27	0.0336	0.0276	-0.0871	0.1154
EU15	0.0253	0.0186	-0.0157	0.1091
EU12	0.0453	0.0335	-0.0871	0.1154
GERD over GDP				
EU27	0.0137	0.0086	0.0038	0.0429
EU15	0.0182	0.0087	0.0048	0.0429
EU12	0.0075	0.0032	0.0038	0.0157
BERD as share of GERD				
EU27	0.4593	0.1463	0.14	0.72
EU15	0.5065	0.1386	0.2	0.72
EU12	0.4011	0.1348	0.14	0.65
Human resources in science and technology as share of labour force				
EU27	0.3420	0.0810	0.165	0.511
EU15	0.3629	0.0823	0.165	0.496
EU12	0.3127	0.0696	0.184	0.511
Investment in physical capital over GDP				
EU27				
EU15	0.2028	0.0485	0.0294	0.3037
EU12	0.2217	0.0228	0.163	0.281
	0.1764	0.0611	0.0294	0.3037
Gross enrolment ratio in secondary education*				
EU27	1.055	0.169	0.77	1.6
EU15	1.14	0.1667	0.9	1.6
EU12	0.9365	0.0787	0.77	1.12
Government expenditure over GDP				
EU27	0.4526	0.0767	0.198	0.671
EU15	0.4837	0.0715	0.198	0.671
EU12	0.4091	0.0612	0.306	0.527
$\pi/(1+\pi)$				
EU27	0.726	0.165	-0.111	0.999
EU15	0.652	0.132	0.091	0.899
EU12	0.831	0.161	-0.111	0.999
Corruption				
EU27	6.157	2.122	2.60	10.00
EU15	7.475	1.679	2.99	10.00
EU12	4.313	1.006	2.60	6.40

*This is defined as the number of students enrolled in the corresponding level of education relative to the total population of the corresponding age group. Therefore, it is possible to have values that exceed 1.0.

The investment in physical capital as share of GDP data is taken from Penn World Tables. Data on inflation is from EUROSTAT and IMF World Economic Outlook Database.

Corruption index is a proxy for the quality of political institutions. Data is available at Transparency International and represents the degree of corruption as seen by business people and country analysts and ranges from 0 (highly corrupt) to 10 (highly clean).

The above table presents the descriptive statistics for the variables mentioned.

As it can be seen the growth rate in new EU member states is higher than in old ones, meaning that there is convergence within EU. However, clearly it is not due to R&D investment as it is more than twice lower in new EU members and did not experience a high growth during the period examined. The next chapter presents the determinants of growth in the EU area and the role of R&D intensity, using the data described.

4. EMPIRICAL RESULTS

This chapter is structured in two sections. In the first section I make a short description of the econometric methods used to estimate the equations: Fixed Effects (FE) and first-difference Generalized Method of Moments (GMM) and the advantage of GMM over FE in estimating dynamic panel data. The second section presents the estimation output and the interpretation of the results.

4.1 Estimation Methods

I have a panel data with 24 cross-sections and 11 years for the level equation and 10 years for the growth equation. First I estimate the models using Fixed Effects (FE) procedure, commonly used in panel data regressions. This technique is robust to the presence of correlation between regressors and unobserved individual effects as it removes the country-specific effects by subtracting time averages before applying the OLS procedure. However, it does not take care of potential endogeneity of investment and government spending. It provides a useful benchmark for the time varying regressors.

As an alternative strategy I use first-difference generalized method of moments (GMM). The advantages of this method are (Stephen Bond, Anke Hoeffler, Jonathan Temple, 2001):

- the estimates are no longer biased by any omitted variables that are constant over time;
- the use of instrumental variables allows parameters to be estimated consistently in models which include endogenous right hand-side variables;
- the use of instruments potentially allows consistent estimation even in the presence of measurement error.

The estimator was originally developed by Douglas Holtz-Eakin, Whitney Newey and Harvey S. Rosen (1998) and Manuel Arellano and Stephen Bond (1991). The approach was introduced in growth literature by Francesco Caselli, Gerardo Esquivel and Fernando Lefort (1996) and since then it is commonly used.

The basic idea is the following. First, the growth regression is written as a dynamic model in the level of per capita GDP. Second, in order to remove unobserved time invariant country-specific effects the first-difference is taken. Third, right-hand-side variables are instrumented using all their lagged values. The last step eliminates the inconsistency arising from endogeneity of the explanatory variables, while the differencing removes the omitted variables bias.

Most of the explanatory variables in equations (7) and (8) are likely to be correlated with the error term due to either endogeneity or omitted variables problems or both, and therefore, use of instruments is warranted. Since the disturbances are serially uncorrelated, lagged values dated ***t-2*** and earlier of regressors can be used as instruments. To check the validity of over-identifying restrictions, Sargan Test has been performed. As one-step and two-step GMM estimators are asymptotically equivalent for the first difference estimator I use one-step GMM.

Although first-difference GMM is widely used, some econometric literature (Bond, Hoeffler and Temple, 2001) suggest that large finite sample biases can occur when instrumental variables are weak. As an alternative method System GMM estimator is suggested (Manuel Arrelano and Olympia Bover, 1995), which combine the standard set of equations in first-difference with suitably lagged levels as instruments, with an additional set of equations in levels with suitably lagged first differences as instruments.

However, I limit my estimation to first-difference GMM and compare the results to FE estimators.

4.2. Estimation Results

Overall, the regression results support our assumption that R&D intensity has a significant effect on the level of output and its growth in developed economies. The new member states benefit from R&D investment only in terms of the level of GDP per capita, and not in terms of growth. Table 2 presents the results for the level equation.

Table 2. Level equation

Dependent variable: log (GDP per capita)

Sample	**EU 27**		**EU 15**		**EU 12**	
Dependent variable	**FE**	**GMM**	**FE**	**GMM**	**FE**	**GMM**
ln(GERD/GDP)	**0.256*** (0.027)**	**0.680*** (0.056)**	**0.386*** (0.046)**	**0.693*** (0.113)**	**0.241*** (0.077)**	**0.291*** (0.081)**
ln(I/GDP)	0.419*** (0.059)	0.225*** (0.033)	0.299*** (0.141)	0.127 (0.083)	0.365*** (0.052)	0.199*** (0.039)
ln(enrol)	-0.181 (0.166)	0.112 (0.103)	-0.438*** (0.123)	-0.355*** (0.130)	0.449*** (0.203)	1.609*** (0.181)
ln(G/GDP)	-0.466*** (0.204)	-0.371*** (0.061)	-0.289* (0.162)	-0.109* (0.061)	-0.818*** (0.150)	-1.001*** (0.133)
cpi	0.004 (0.005)	0.003 (0.005)	0.119* (0.063)	0.047 (0.051)	0.001 (0.010)	-0.008 (0.006)
ln(corrupt)	-0.076 (0.05)	0.079 (0.085)	-0.019 (0.035)	-0.295 (0.286)	-0.196* (0.106)	0.081 (0.097)
N	264	240	154	140	110	100
Adjusted R squared	0.96	-	0.82	-	0.91	-

Standard errors are in paranthesis
*significant at 10% level, **significant at 5% level, ***significant at 1% level

The estimated model shows a positive effect of the R&D intensity on the level of output per capita, which is higher for old EU members than for new EU members. The R squared is very high that it is usual for fixed effect estimation method. When estimating the model using OLS (pooled cross-section) the adjusted R square for the level equation varies between 0.45 and 0.68, the coefficient on R&D intensity changes, but remains of the same sigh and statistically significant. In the equation estimated by GMM the coefficients become higher but do not change their significance.

Other significant dependent variables are the proxy for human capital investment rate, investment in physical capital and government expenditures as share of GDP. Using Business R&D intensity rather R&D intensity no not change significantly the coefficients of the regressions. However, the main interest of the paper is the impact of R&D intensity on the annual GDP per capita growth and I focus on the details on the growth estimated equation.

Although R&D intensity affects the level of GDP per capita in both: new and old EU members, its impact on growth is significant only in old EU members. The estimation results are presented in table 3.

Table 3: Growth Equation

Dependent variable: log (GDP per capita annual growth)

Sample	**EU 27**		**EU 15**		**EU 12**	
Dependent variable	**FE**	**GMM**	**FE**	**GMM**	**FE**	**GMM**
Lag GDP per capita	-0.063***	-0.094***	-0.089***	-0.138***	-0.071***	-0.115***
	(0.013)	(0.041)	(0.019)	(0.015)	(0.017)	(0.028)
ln(GERD/GDP)	**-0.015**	**-0.024**	**0.012***	**0.031***	**0.014**	**-0.033**
	(0.013)	**(0.038)**	**(0.007)**	**(0.019)**	**(0.013)**	**(0.027)**
ln(I/GDP)	0.084***	0.016	0.082***	0.045***	0.066***	0.039***
	(0.01)	(0.018)	(0.03)	(0.016)	(0.012)	(0.015)
ln(enrol)	-0.009	-0.031	-0.047***	-0.057***	0.127***	0.188***
	(0.017)	(0.046)	(0.013)	(0.016)	(0.037)	(0.073)
ln(G/GDP)	0.046***	-0.052**	-0.012	-0.018	-0.119***	-0.286***
	(0.015)	(0.026)	(0.011)	(0.011)	(0.025)	(0.052)
cpi	0.004	0.002	-0.013	-0.009	0.003	0.002
	(0.003)	(0.002)	(0.014)	(0.009)	(0.002)	(0.002)
ln(corrupt)	-0.008	0.052	0.011***	0.012	-0.021	0.008
	(0.015)	(0.047)	(0.004)	(0.027)	(0.023)	(0.032)
N	240	216	140	126	100	90
Adjusted R squared	0.63	-	0.68	-	0.64	-

Standard errors are in paranthesis
*significant at 10% level, **significant at 5% level, ***significant at 1% level

The catch-up term is statistically significant in all regressions, meaning that there is convergence within EU. Its coefficient has a lower negative value for old member states. However, different factors influence economic growth within old and new EU members. The estimation shows that R&D activity is significant in explaining cross-national differences in growth only among old EU member, which experience a 0.012 to 0.0.31 percent increase in GDP per capita growth due to one percent increase in the ratio of GERD over GDP, everything else being equal. The result is consistent with Gittleman and Wolff (1995) findings that R&D spending significantly influences the economic growth only in the sample of developed countries. The coefficient for R&D intensity is higher for GMM than for FE method, but it is positive and statistically significant in both cases.

Adding to the regression the interaction term between the initial level of GDP per capita and R&D intensity results an insignificant coefficient for it and do not change the coefficients of other variables.

Investment in physical capital still has a great impact on growth in EU, its return being higher, than R&D return. The unexpected negative sign for secondary school enrolment rate for EU 15 is also statistically significant. Bond, Hoffler and Temple (2001) who also got a negative and statistically significant effect of school enrolment rate on growth using first-difference GMM, stressed that it is not sensible to expect school enrolment rates to affect growth instantaneously. In the final regression they even exclude it as the current school enrolment may not have an effect on steady state level of per-capita GDP, and thus lagged school enrolment rate may better explanatory variables and may not be valid instruments for first-difference GMM specification. They also consider the first-difference GMM is likely to be biased and estimate the same equation with System GMM. The sign for enrolment rate did not change, but it became insignificant. However, for new EU members the coefficient for the secondary school enrolment rate is positive and statistically significant

The estimation of the growth equation, using manpower measure – human resources in science and technology as a share of labor force – instead of R&D intensity does not change the results. Its coefficient is positive and statistically significant only for old EU members. The sign and significance of the coefficients of other variables do not change. In Gittleman and Wolf (1995), using the ratio of scientists and engineers engaged in R&D per capita instead of ratio of R&D expenditures to GNP also did not change significantly the magnitude of the other coefficients of the regression.

Since R&D requires a fairly high level of education, using a composite index accounting both for expenditures on R&D and manpower may be even more appropriate. For this reason I find the United Nation ranking list of countries based on their level of technological development a more accurate and precise proxy for research capital. This index is based on three indicators. Two of them are input type: GERD and a combined indicator including the number of technical stuff employed in R&D and the number of students admitted to tertiary education. The third indicator compared high-tech exports to total exports for each country. (Torok, 2005, p.83). Unfortunately, these data is not available

The difference in means for the manpower variables between new and old EU members and the positive and statistically significant effect of school enrolment ratio for the EU 12 sample suggest that a necessary condition for the evolution of the economy of new EU members is the accelerated growth of their human capital

Throughout all the regressions, the coefficient on the government expenditures is negative and strongly significant for new EU members. It is significant at 1 per cent level in both: the fixed effects and GMM regressions. Not only does it have the predicted sign but it has also the largest effect, in terms of magnitude, among all the variables entering the regression for this group of countries. The estimate implies that a one percent of GDP reduction in government spending, everything else equal, gives rise to about 0.28 percent increase in the GDP per capita growth rate (according to GMM estimates). Anders Aslund and Nazgul Jenih (2005) also found that in a sample of 20 transition economies - 11 CIS (Community of Independent States) countries, 3 Baltic States, and 6 Central European and South-Eastern European countries – over the period from 1999 to 2004, government expenditures have most explanatory power.

As R&D investment is significant only in EU 15, for this sub-sample I estimate the model specified by equation (9) with business and non-business R&D intensity. The results are presented in table 4.

Table 4. Growth equation

Independent Variables: ln(BERD/GDP) and ln((1-BERD)/GDPP)

Independent variables	FE	GMM
Lagged GDP per capita	-0.086*** (0.019)	-0.137*** (0.017)
ln(BERD/GDP)	**0.006*** **(0.003)**	**0.013*** **(0.007)**
ln((1-BRD)/GDP)	**-0.002** **(0.010)**	**0.010** **(0.024)**
ln(investment/GDP)	0.082*** (0.030)	0.046*** (0.017)
ln(enrolment)	-0.046*** (0.014)	-0.052*** (0.017)
ln(expenditure/GDP)	-0.013 (0.012)	-0.014 (0.011)
cpi	-0.013 (0.014)	-0.007 (0.009)
ln(corruption)	0.012*** (0.04)	0.024 (0.030)
N	140	126
Adjusted R squared	0.67	-

Standard errors are in parenthesis
*significant at 10% level, significant at 5% level, ***significant at 1% level

Only the coefficient for business R&D expenditure is significant now. A smaller insignificant or even negative coefficient on non-business R&D does not imply that it does not contribute to development. The reason might be that often the effect of government research on productivity is not measured, either because it is indirect or because its result is not reflected in GDP (national defense, health or reduction of destruction of environment). The significance of non-business R&D may also depend on the share of universities as opposed to governmental laboratories' research. I do not control for this as there is no available data.

Not only the R&D intensity differs with the level of development but also the impact R&D intensity differs with the level of development. Fist, the impact of R&D might vary by level of development because it might be concentrated in certain industries. Less developed countries, might experience less effective expenditures if these industries are not significant for the country. The composition of their economies tends to be away from R&D intensive sectors. A higher return to R&D in new EU members has been found in automotive and pharmaceutical industries. However, these are still underdeveloped in new EU member with several exceptions: Czech Republic, Hungary and recently Slovakia for automotive industry and Hungary with Slovenia in pharmaceutical industry. (European Techno-Economic Policy Support Network (ETEPS NET), 2005) Foreign direct investments were the main determinants in the expansion on automotive sector in the mentioned countries, which stimulated the national investment in the sector, including R&D investment. Thus, a second reasons that new EU members do not benefit from domestic R&D, but they might benefit form foreign spillovers, and their impact on productivity has been found to be larger in smaller economies (Guellec and van Pottelsberge de la Poterie, 2001).

Third, the low level of private financed R&D activities also diminishes the return to R&D. Government spending on R&D is a partial substitute of business spending on R&D in less-developed economies due to the general lack of business interest in domestic R&D. At the same time, public R&D spending should offer clear and positive incentives for private R&D (Torok, 2005). However, as discussed above, the effect of R&D investment on productivity depends more on the objective of the R&D than on the source of funding (business vs. government). Unfortunately, the availability of data is limited only do he source of funding.

Finally, a significant portion of return to a country's R&D expenditures is likely to be in the form of productivity improvements spilling over from the firm actually undertaking the R&D to other enterprises. The information networks needed for firm to take advantage of this public good aspect of R&D are likely to be more developed in higher income nations (Gittleman and Wolff, 1995). Technical progress in more important in enhancing labor productivity for more developed countries than for less developed ones.

A continuation of low levels of private R&D in the new member states may also hinder the catch-up process and integration of their economies into the EU. Only by increasing domestic investment in R&D new EU members can benefit in terms of higher rates of per capita GDP growth. Taking into consideration that the GERD is an indicator with major trend changes once in decade and also the fact that Foreign Direct Investment increased since their accession to the EU, which somehow influenced the interest for national R&D investments, an increase in R&D intensity may be expected. However, considerable efforts should be done in order to reach the Barcelona target of 3 percent gross domestic expenditures on R&D over GDP. Setting national targets in line with the EU one, as already France, Germany and Slovenia did, may faster the R&D investment.

5. CONCLUSION

Lisbon Strategy (European Council, 2000) set up an ambitious goal “to make Europe, by 2010, the most competitive and most dynamic knowledge-based economy in the world”. It put a great emphasis on research and development, stating that research and technology account for between 25 and 50% of economic growth and is a principal driving force for competitiveness and employment. The deadline is approaching, but Europe is still far from reaching the 3 percent R&D intensity target set up. And this became even more difficult since the enlargement of the EU. The majority of new member states did not reach one percent R&D intensity yet, except Czech Republic and Slovenia. Also two old member states invest less than one percent of their GDP in R&D activities.

On the other hand, there is evidence of convergence within EU. The GDP per capita in new member states grows at higher rates than in old EU members. In my paper I estimated the impact of R&D intensity – the share of R&D investment in GDP – on annual GDP per capita growth in EU between 1995 and 2005. I chose this period because only starting with 1995, the new member states recovered after a big recession and huge decline in output. I excluded from the sample three EU countries: Luxemburg as an outlier in terms of GDP per capita and Malta and Cyprus that hardly show any R&D activities.

I estimated the extended growth model with physical capital, human capital and R&D, controlling also for government expenditures as share of GDP, inflation and corruption. I used two method of estimation: Fixed Effects method and also first-difference GMM and I got the following results:

1. R&D has a higher impact on the level on GDP per capita rather than on growth. A positive significant effect of R&D intensity on GDP per capita has been found both in old and new

member states. However, the effect in old member states is approximately twice higher than in new ones.

2. R&D intensity has a significant impact on growth only in old EU member states, which is consistent with some previous studies that showed that R&D intensity is significant in explaining cross-national differences in growth only among developed countries. There are several reasons for this:

- New EU countries invest too little in R&D activities to get any return on growth. But R&D intensity as well as its impact on growth differ with the level of development. They rather benefit from foreign investment in R&D and international spillovers. There is already a large impact of technologies and processes that were brought to the new member states by foreign direct investment.
- More than a half of R&D investment in new EU members comes from non-business sector and it has been shown that only business R&D has a significant positive effect on growth.
- Not only the source of funding, but also the objective of funding matters. New EU member states invest less in high productive industries. Higher returns on productivity in these countries have the automotive and pharmaceutical industries (ETEPS NET, 2005). But only Czech Republic invest considerable amount of R&D in automotive industry and currently Slovakia. In the pharmaceutical R&D investments Hungary is the leader, followed by Slovenia.

3. The third finding is that even in old EU member states only business R&D has a positive impact on growth. This is due to the purpose of business R&D, which is mainly oriented to increase in productivity, as opposed to government R&D which may have other aims. There is also a social return on business R&D, which is higher than its private return

because it has high spillover effects and enhances the ability of the business sector to absorb technology coming from abroad. (Gullec and van Pottelsberghe de la Potterie, 2001). Government R&D is mainly oriented to increase the social welfare, financing domains like health, environment, national security that usually are immeasurable and are not included in GDP. A different effect is expected to come from universities' R&D and Governmental institutions' R&D, but I did not cover it because of lack of the data.

Although the impact of R&D intensity is positive and significant in developed EU countries, it is still lower than in US. A major difference between EU and other countries is that basic and applied research accounts for more than 50 percent of total R&D expenditures in EU in comparison to US, Japan, China and Russia where experimental research represents between 57 and 74 percent of total R&D expenditures (Franc, 2006).

Other findings of my research are:

- The catch-up term is negative and statistically significant. It is larger in magnitude for old EU members, meaning that there is convergence within EU.
- Investment in physical capital still has a high return to growth in EU.
- New EU member states need an accelerated growth of their human capital for the evolution of their economy.
- A significant part of growth in new EU member states is due to the decrease of governmental expenditures.

Several changes can improve the model. By including trade and capital flows into the econometric model, the countries will not be treated as "islands in the ocean" without any connection to the rest of the world, which is definitely not the case of EU, where the integration tends to take place in every market. Thus, using foreign direct investment and foreign R&D as right-hand-side variables can give supplementary results, expected to be statistically significant to new EU member states. Also, a composite variable for R&D investment, including R&D expenditures and R&D manpower may be a better proxy for R&D capital. As membership in EU may have an impact on growth, controlling for the EU accession in the sample of new EU members may be important. However, I do not have enough observations to do this fact. In few years the model can be estimated accounting for membership in EU for new members and also accounting for the period before and after the Lisbon Strategy, as it may change the trend in R&D intensity.

Thus, at the moment it seems unrealistic that Europe will reach by 2010 the 3 percent target of R&D intensity set up by March 2002 Barcelona European Council, with two thirds funded by private sector. On the other hand, GERD seems to be an indicator in which major trend changes occur once in a decade for most countries (Torok, 2005, p.99) and together with foreign direct investments changes may be expected in R&D intensity in new member states. However, an effort is needed from developed country in EU. Setting a national target in line with European 3 percent objective, as already France, Germany and Slovenia did, may faster the increase in R&D investment and consequently the economic growth in EU.

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