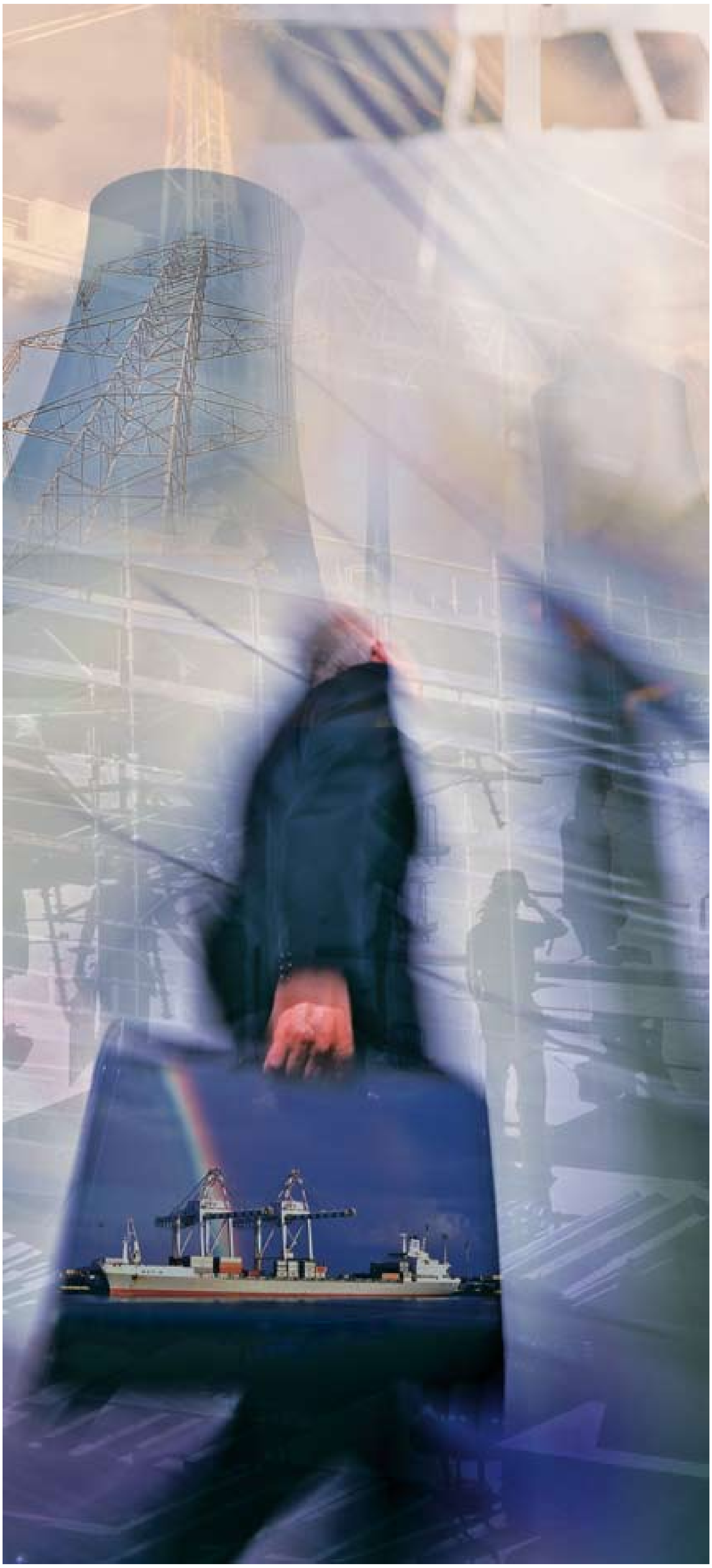

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Welcome

The Economic Society of Australia warmly welcomes you to the Gold Coast, Queensland, Australia for the 37th Australian Conference of Economists.

The Society was formed 83 years ago in 1925. At the time, the Society was opposed to declarations of policy and instead focused on open discussions and encouraging economic debate. Nothing has changed today, with the Society and the conference being at the forefront of encouraging debate.

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The Paper following forms part of - *Proceedings of the 37th Australian Conference of Economists*
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WHAT IS THE OPTIMAL RATE OF PUBLIC AND PRIVATE R&D INVESTMENT TO MAXIMIZE PRODUCTIVITY GROWTH?

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Abstract: Governments in modern economies devote much policy attention to enhancing productivity and continue to emphasize its drivers such as investment in R&D. This paper analyzes the relationship between productivity growth and levels of public and private R&D expenditures. The economic analysis shows that the magnitude of R&D expenditure by business enterprise equal to 1.74% (% of GDP) and R&D expenditure government - Higher education of 1.025 (% of GDP) maximize the long-run impact on productivity growth. These optimal rates are the key to sustained productivity and technology improvements that are more and more necessary to modern economic growth.

Keywords: R&D investment, Productivity growth, Optimization, Economic growth

Introduction

Scientific research today absorbs very considerable resource since it increases technological progress (Griffith *et al*., 2004) and productivity growth (Mayhew and Neely, 2006) that have a central role as engine of economic growth in modern economies (Jones and Williams, 1998). In fact, post war growth it is argued was largely based on capital accumulation, whereas what is needed now for countries to improve economic growth is to increase the intangible capital accumulation, based on knowledge, through Research and Development (R&D) investments, that have more and more a great influence on firms and countries to increase their competitive advantage (Porter, 1990). Nowadays policy makers, to sustain modern economic growth, devote much attention to enhancing productivity based on R&D investments but in order to put effective economic policies into practice and for an efficient allocation of public resources, they have need know:
what is the optimal amount of public and private R&D expenditures that maximizes the productivity growth?
This economic problem has spawned a large theoretical and empirical literature (Hall and Mairesse, 1995; Jones and Williams, 1998; Bartelsman and Doms, 2000; Griffith *et al.,* 2004; Brécard *et al.,* 2006). However, theory alone is unable to provide an answer to optimal magnitude of public and private R&D investment to boost productivity and economic growth. The purpose of this research is to analyze the relation between levels of public and private R&D expenditures and productivity growth which can both steer national decisions about economic policies in the right direction and improve the governments' ability in facilitating the process that leads to long run economic growth and wealth increase of countries, driven by accumulation and effective employment of knowledge and technologies (Griffith *et al.,* 2006). Before to discuss the main economic problem, let me introduce the theoretical framework and methodology of research.

Theoretical framework

The present-day economic and political debate revolves around the understanding of the causes of certain countries' economic success, based on strategic drivers that should be pulled in order to increase economic growth in modern economies (Maddison, 1982; Denison, 1985; Abramovitz, 1989; Grossman and Helpman, 1991).
Patterns of economic growth involve the analysis and assessment of productivity[1]. Mayhew and Neely (2006)

[1] *Productivity* measures the ratio of outputs to inputs. Labour productivity is defined as 'real' (constant price) output divided by labour inputs (measured in terms of persons or hours). *Multi-factorproductivity* (MFP) represents the residual portion of output growth that cannot be explained by changes in labour and capital. MFP growth is labour productivity growth minus the effect on productivity of change in the capital-labour ratio (usually more capital per worker, or in other words, capital deepening). MFP growth in the long-run is explained by factors such as technological progress, rising education standards and changes in the socioeconomic environment. In

describe productivity growth as stemming either from gains in static efficiency or gains in dynamic efficiency[2]. Since productivity growth plays a main role in increasing Gross Domestic Product (GDP), it is important to understand the factors underlying productivity growth, even if quantify their importance is a difficult task. Much of the research that examines the relationship between some factors and productivity growth is limited to showing a correlation between productivity and variables that influence it, and does not determine the causality and magnitude. There is a huge literature dealing with factors affecting productivity growth. Some of the factors that have recently been examined include managerial ability, technology and regulation (Bartelsman and Doms, 2000). UK government emphasizes the five drivers of productivity growth: investment, innovation, skills, enterprise, and competition (DTI, 2006). Nelson (1981) emphasizes the importance of technological change in firm productivity growth. Lichtenberg and Siegel (1991) and Hall and Mairesse (1995) documented the correlation between R&D and productivity at micro level. Amendola *et al.* (1993) present a well documented evidence that R&D has an important effect on productivity growth and also on competitiveness, whereas Hall (1996) points out that R&D is often associated with product improvement. Hall and Mairesse (1995) also argue that a long history of R&D expenditures is a more potent predictor of productivity growth. According to Brécard *et al.* (2006), R&D produces its full effects on two form of innovation: the global productivity gains of factors and improvements to the quality of products. Growth is led by increased demand due to falling costs and prices and R&D leads simultaneously to an increase in GDP and in the use of factors. Aghion and Howitt (1998) recognise this by noting that "technological knowledge is itself a kind of capital good and it can be accumulated through R&D". Griffith *et al.* (2004) argue that innovation and technology transfer provide two potential sources of productivity growth for countries behind technological frontier. They examines whether R&D has a direct effect on total factor productivity growth (innovation) in a panel of industries across twelve OECD countries. They state that the greater the potential for technologies to be transferred through R&D and the higher the rates of productivity growth. R&D contributes to total factor productivity (TFP) not only through innovation but also through technology transfer. In addition, they argue that R&D has played a role in the convergence of TFP magnitudes within industries across OECD countries.
The growth impact of R&D has received considerable attention within the context of spillovers (Griliches, 1979). Grossman and Helpman (1991) argue that cross-country R&D spillovers are an important source of productivity growth. A consensus has emerged around the fact that R&D contributes significantly to cross-sectional variation in productivity. Hall (1996) reports an elasticity of 0.1 to 0.15, Griliches (1995) reports an estimated elasticity of output with respect to R&D capital of between 0.06 and 0.1. The impact of R&D on productivity assessed from a macroeconomic perspective is analyzed by Jones and Williams (1998) that formalize a model similar to that of Romer (1990). They calibrate the model and estimate that optimal investment in R&D is two to four times larger than actual investment in the United States.
Machin and Van Reenen (1998) investigate whether a directly observed measure of technical change (R&D intensity) is closely linked to the growth in the importance of more highly skilled workers in United States and other six OECD countries. They probe and show a significant association between skill upgrading and R&D intensities in all countries. Van Reenen (1997) examines why Britain has slower growth in R&D compared to other countries using industry data. He shows that the significantly lower R&D in UK is partially accounted for by lower demand growth and faster withdrawal of government funding for R&D in the 1980s. Parisi *et al.* (2006), using a rich firm level data-base for Italy, state that R&D spending is strongly positively associated with the probability of introducing a new product, moreover the effect of fixed investment on the probability of introducing a process innovation is magnified by spending R&D spending internal to the firm. This implies that R&D can affect productivity growth by facilitating the absorption of new technologies.
Despite a large amount of economic literature on these topics, the relationship between the levels of public and private R&D investment and productivity growth has not yet been wholly clarified. In particular a main question is:

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some of the literature MFP is referred to as total factor productivity (TFP). *Capital deepening* measures the increase in the value of capital per worker. As capital deepening is measured in volume terms, it also captures the effect of falling ICT prices on labour productivity growth. *Growth accounting* refers to the disaggregation of labour productivity growth into components, such as MFP growth, the effect of capital deepening and in some studies also the effect ofrising education level.

[2] *Static efficiency* is equivalent to use existing factors of production as effectively as possible. This can be achieved by measures to make markets operate more competitively and efficiently. *Dynamic efficiency* is all about the investment. R&D investment if translated into organizational operations allows labour and capital to be put to more productive use.

what is the optimal rate of R&D Expenditures by Business Enterprise and Government, within countries, that boosts productivity growth at aggregate level?
The following section describes data and their sources applied into present research, and the methodology used to answer this main economic problem for modern economic growth.

Methodology, the data and their sources

Since analyses of aggregate productivity across countries are central to many questions concerning long-run economic growth (Bernard and Jones, 1996), an important issue is to probe the role of Business Enterprise and Government R&D expenditures underlying productivity growth. A common indicator used to measure R&D investments across countries is represented by Research and Development (R&D) Expenditure as a percentage of the Gross Domestic Product (Griffith *et al.*, 2006). Instead, concerning productivity growth, researchers employ two metrics: labour productivity and total factor productivity. In this article I concentrate on the former that has different measures at aggregate level; in particular I use labour productivity per hour worked, since it is the most direct indicator of productive efficiency. This research uses data of Eurostat (2007), which collects some key indicators, relating to both general economic background and innovation/research, referring to the 1990s and to the early years of the 21st century. The indicators considered are – Research and development expenditure: Business enterprise sector (% of GDP), Research and development expenditure: total Government sector (% of GDP) which also includes Research and development expenditure for Higher education sector (% of GDP). Variables used in the models are described in the Table 1.

Table 1: Variables

Indicators	Abbreviations and period	Description
Research and development expenditure: all sectors (% of GDP)	R&D All Sectors 1995-2005	Research and experimental development (R&D) comprise creative work undertaken on a systematic basis in order to increase the stock of knowledge, including knowledge of man, culture and society, and the use of this stock of knowledge to devise new applications. R&D expenditures include all expenditures for R&D performed within the business enterprise sector (BERD) on the national territory during a given period, regardless of the source of funds. R&D expenditure in BERD are shown as a percentage of GDP (R&D intensity).
Research and development expenditure: Business enterprise sector (% of GDP)	R&D Business enterprise sector 1995-2005	
Research and development expenditure: Government sector (% of GDP) and Research and development expenditure: Higher education sector (% of GDP)	R&D GovEdu sector 1995-2005	
GDP per capita in Purchasing Power Standards (PPS) (EU-27 = 100) Please be aware that this indicator has been rescaled, i.e. data is expressed in relation to EU-27 = 100	GDPPS 1997-2006	Gross domestic product (GDP) is a measure for the economic activity. It is defined as the value of all goods and services produced less the value of any goods or services used in their creation. The volume index of GDP per capita in Purchasing Power Standards (PPS) is expressed in relation to the European Union (EU-27) average set to equal 100. If the index of a country is higher than 100, this country's level of GDP per head is higher than the EU average and vice versa. Basic figures are expressed in PPS, i.e. a common currency that eliminates the differences in price levels between countries allowing meaningful volume comparisons of GDP between countries.
Real GDP growth rate Growth rate of GDP volume - percentage change on previous year	Growth rate of GDP volume 1997-2006	Gross domestic product (GDP) is a measure of the results of economic activity. It is the value of all goods and services produced less the value of any goods or services used in producing them. The calculation of the annual growth rate of GDP volume allows comparisons of economic development both over time and between economies of different sizes, irrespective of changes in prices. Growth of GDP volume is calculated using data at previous year's prices.
Labour productivity per hour worked. GDP in Purchasing Power Standards (PPS) per hour worked relative to EU-15 (EU-15 = 100)	Labour productivity per hour worked 1995-2005	GDP per hour worked is intended to give a picture of the productivity of national economies expressed in relation to the European Union (EU-15) average. If the index of a country is higher than 100, this country level of GDP per hour worked is higher than the EU average and vice versa. Basic figures are expressed in PPS, i.e. a common currency that eliminates the differences in price levels between countries allowing meaningful volume comparisons of GDP between countries. Expressing productivity per hour worked will eliminate differences in the full-time/part-time composition of the workforce.
Countries: Austria, Belgium, Cyprus, Czech Republic, Denmark, Estonia, EU (15 countries), EU (25 countries), EU (27 countries), Euro area (12 countries), Euro area (13 countries), Finland, France, Germany, Greece, Hungary, Iceland, Ireland, Italy, Japan, Latvia, Lithuania, Luxembourg, Malta, Netherlands, Norway, Poland, Portugal, Romania, Slovakia, Slovenia, Spain, Sweden, Switzerland, United Kingdom, United States		

Source: Eurostat (2007)

The geographical area is EU Member States, Candidate Countries, Iceland, Norway, Switzerland, Japan and the USA.
The model hypotheses (Hp), based on theoretical background, are the following:

Hp1: Productivity growth is an indicator of the country's economic growth.

Hp2: The public and private R&D expenditures as % of the GDP are a driver of productivity growth of the *i* country.

Hp3: Expenditures in R&D as % of the GDP until period *n* shall increase the productivity growth from the *n+1* period. In fact, the R&D investments is followed by a period of deployment of the effects of innovation, which leads to sustained demand and improved competitiveness and long term economic growth.

The conceptual model is:
Relative growth of Labour productivity per hour worked = f (Public or private R&D expenditure as % of the GDP).
The statistical information drawn from the Eurostat data undergo a preliminary process of horizontal and vertical cleaning. The normal distribution of the data is checked by statistics based on arithmetic mean, standard deviation, skewness, and kurtosis, the normal Q-Q plot, Kolmogorov-Smirnov and Shapiro-Wilk tests of normality using statistics software SPSS. After that we apply a non linear regression using a quadratic function. In fact, the operative model is a quadratic dynamic linear regression model, since this model portrays the variables' functional links very well and it suitably fits to data scatter. In particular I apply the leading indicator model that is a special case of dynamic linear regression model (Hendry and Richard, 1982; Spanos, 1986):

$$y_{i,t} = \beta_0 + \beta_1 x_{i,t-1} + \varepsilon_{i,t}$$

$$\text{Re}\mathit{lative\ Variation\ Labour\ productivity\ per\ hour\ worked}_{i,t} = \beta_0 + \beta_1 R\&D\_Expenditure_{i,t-1} + \beta_2 R\&D^2\_Expenditure_{i,t-1} + \varepsilon_{i,t} \quad [1]$$

Where *i* subscripts denote countries, *t* subscripts denote time. Moreover, since R&D is inherently a dynamic process and countries will not immediately adjust to long-run levels because of adjustment costs and other factors, a lag of R&D is included in the specification (Van Reenen, 1997).
The parametric equation is estimated by Ordinary Least Squares (OLS) method (Verbeek, 2005). In addition to eliminate the problem of serial correlation the estimations are carried out with the autoregression using the Prais-Winsten estimation method.
The estimation of the parameters and the statistical analysis are performed by statistics software SPSS (Statistical Package for the Social Sciences).
The functions of one (real) variable from the econometric estimated relationship are polynomial functions of an order higher than the first. Since these functions [1] are continuous and infinitely differentiable, we seek to maximize these objective functions applying the classic mathematical optimization methods (Rudin, 1991).
In short, one of the necessary requirements of the functions of one variable in order for the solution $x=x^*$ to be a maximum or a minimum is $\frac{df(x)}{dx} = 0 \quad for\ x = x^*$ [2]
In this case *x* is a stationary point. Moreover, if the function is concave (or convex)[3], then condition [2] is not only necessary but also sufficient in order for x* to be an overall (global) maximum (minimum).

Results of empirical analysis and mathematical optimization

The statistic of Kolmogorov-Smirnov and Shapiro-Wilk test normality of variables such that it is possible to apply the econometric models of parametric estimations. The results are summarized in table 2, whereas figures 1 and 2 display the fitted lines of polynomial regression function.
Models estimated by ordinary least squares (OLS) method have been corrected by the Prais-Winsten estimation method that in the models has eliminated the problem of autocorrelation at the final iteration 4. This correction has provided robustness estimates; in short, the parametric estimates of the models are unbiased estimations, the *t*-test returns meaningfulness of the parameters equal to 1‰. The explanatory power of the model is good, as indicated by high R^2 adjusted values (the coefficient of determination adjusted) that is over 64% in model 1 (with R&D expenditure of business enterprise) and over 29% in model 2 with R&D Government expenditure

[3] Let f be twice differentiable on (a,b), and f''(x)>0 for all x in (a, b), then the graph of f is concave upwards. Similarly if f''(x)<0, the graph is concave downwards.

and Higher education. The result of the Durbin-Watson test (D-W), after the correction with the Prais-Winsten estimation method, is no serial correlation (5% significance level). In short, the performances of the corrected models are excellent.

The estimated parametric equations are quadratic polynomial functions (continuous and differentiable functions) that make it possible to apply classic optimization methods (Rudin, 1991). In particular, these equations have the quadratic term negative and the increase is less than linear because it is exerting a downward force on the equations.

Table 2: Parametric estimations of model

Models	Estimated relationship by OLS of leading indicator dynamic linear regression model		
Model 1	(Quadratic-Autocorrelation corrected-iteration 4)		
$y_{i,t}=$	$35.33^{***} + 85.34x_{i,t-1}^{***} - 24.51x^2_{i,t-1}{}^{***}$	R^2 *adj = 64.1%*	*DW=1.997*
N=163	(3.34) (7.27) (3.38)	*S= (17.84)*	
Model 2	(Quadratic-Autocorrelation corrected-iteration 4)		
$y_{i,t}=$	$13.30 + 181.73z_{i,t-1}^{***} - 88.68z^2_{i,t-1}{}^{***}$	R^2 *adj =29.4%*	*DW=1.976*
N=163	(10.59) (34.49) (26.57)	*S= (25.33)*	

*** Parameter is Significant at the 0.001

Notes: Autocorrelation corrected by Prais-Winsten estimation method. The second column is the estimate of the constant and of β_i. Underneath them, in parentheses, their standard error. The third column has adjusted R^2 of the regression and below it, the standard error of the regression. In the last column the Durbin-Watson test which is an indicator of autocorrelation.

$y_{i,t}$ = Relative labour productivity growth per hour worked

$x_{i,t-1}$ = R&D Expenditure of Business enterprises as percentage of GDP

$z_{i,t-1}$ = R&D Expenditure of Government and Higher Education as percentage of GDP

Moreover, *i* subscripts denote countries, *t* subscripts denote time.

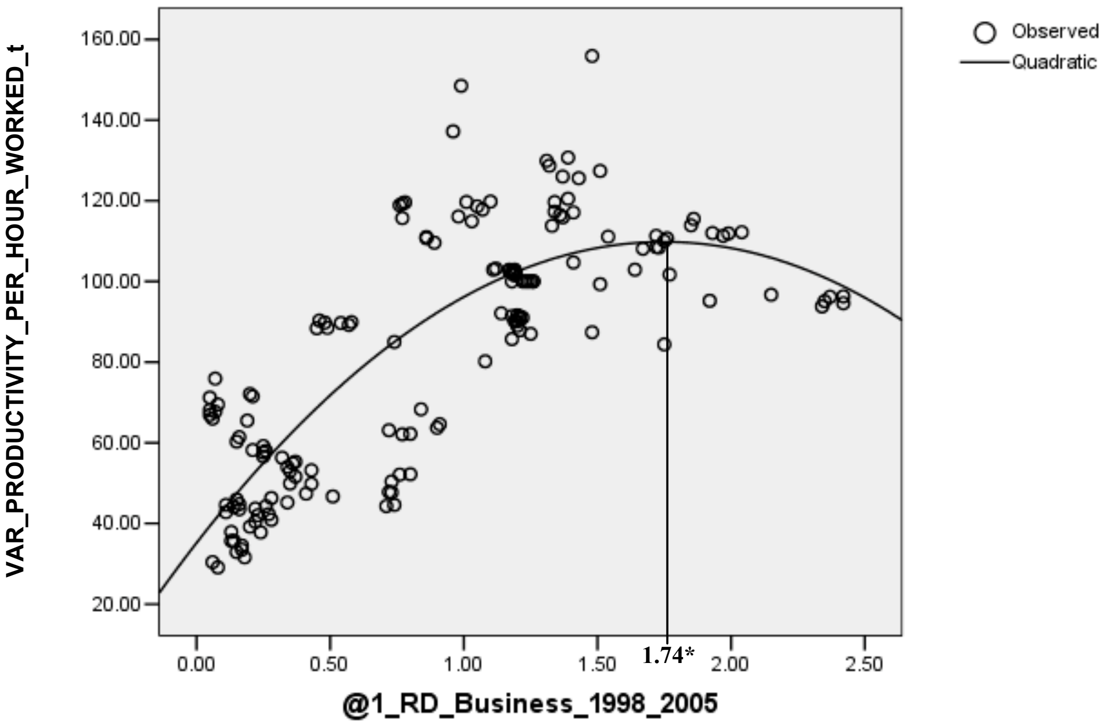

Figure 1: Regression of relative labour productivity growth per hour worked (t) on BERD-R&D expenditure of Business Enterprise as % of the GDP

Equation 1 (corrected) is the estimation of the relationship that considers $y_{i,t}$ = Relative Labour productivity growth per hour worked (t); $x_{i,t-1}$ = R&D Business Enterprise as % of the GDP. Estimated relationship is:

$y_{i,t} = 35.33 + 85.34x_{i,t-1} - 24.51x^2_{i,t-1}$ $\quad$ R^2 adj. = 64.1%

Necessary condition for the calculation of the maximum is formula [2] described in the methodology section:

$\frac{dy}{dx} = y'(x) = 85.34 - 2 \cdot (24.51)x$

$y'(x) = 85.34 - 49.02\,x$

Let us set the first derivative[4] equal to 0, which gives us:
$y'(x) = 0$ $49.02\,x = +\,85.34$ so $x = +1.74 \in \Re$ (the set of real numbers)

When the R&D expenditures of Business Enterprise as % of the GDP are 1.74%, productivity growth is maximized in the following point:
A (R&D expenditures of Business Enterprise as % of the GDP; Relative Labour productivity per hour worked t)

A (1.74; 109.62)

Moreover

$y'(x) > 0$ in [0; 1.74[, $y'(x) < 0$ in]1.74; + [

$y''(x) = -49.02 < 0 \Rightarrow y(x)$ is a concave function

The mathematical and geometric analyses (Figure 1) show that the function is concave; therefore condition [2] is sufficient for the global maximum, too.

Equation 2 (corrected) is the estimation of a relationship that considers $y_{i,t}$ = Relative labour productivity growth per hour worked (t); $z_{i,t-1}$ = R&D Expenditure of Government and Higher Education as percentage of GDP. Estimated relationship is:
$y_{i,t} = 13.30 + 181.73 z_{i,t-1} - 88.68 z^2_{i,t-1}$ R^2 adj. = 29.4%

Necessary condition for the calculation of the maximum is formula [2]:

$\frac{dy}{dx} = y'(x) = 181.73 - 2 \cdot (88.68)z$

$y'(x) = 181.73 - 177.36\,z$

Let us set the first derivative equal to 0, which gives us:
$y'(x) = 0$ $177.36\,z = +181.73$ so $x = +1.025 \in \Re$

When the R&D Expenditure of Government and Higher Education as percentage of GDP is 1.025%, relative productivity growth is maximized in the following point:
A (R&D Expenditure of Government and Higher Education as percentage of GDP; Relative labour productivity per hour worked t)
A (1.025; 106.41).

Moreover:
$y'(x) > 0$ in [0; 1.025 [, $y'(x) < 0$ in] 1.025; + [

$y''(x) = -177.36 < 0 \Rightarrow y(x)$ is a concave function

The mathematical and geometric analyses (Figure 2) show that the function is concave; therefore condition [2] is sufficient for the global maximum, too.
In addition Model 1 shows that when R&D Expenditure of Business Enterprise as percentage of GDP increases by 1%, the estimate average productivity growth is given by linear term 85.34 and quadratic term –24.51 which

[4] The derivative function also gives us the value of the rate of change at every point.

represents the damping factor, in other words the friction of productivity growth due to diminishing returns of R&D Expenditures. Model 2 presents an impact of R&D Expenditure of Government and Higher Education as percentage of GDP equal to 181.73 and –88.68 (quadratic term).

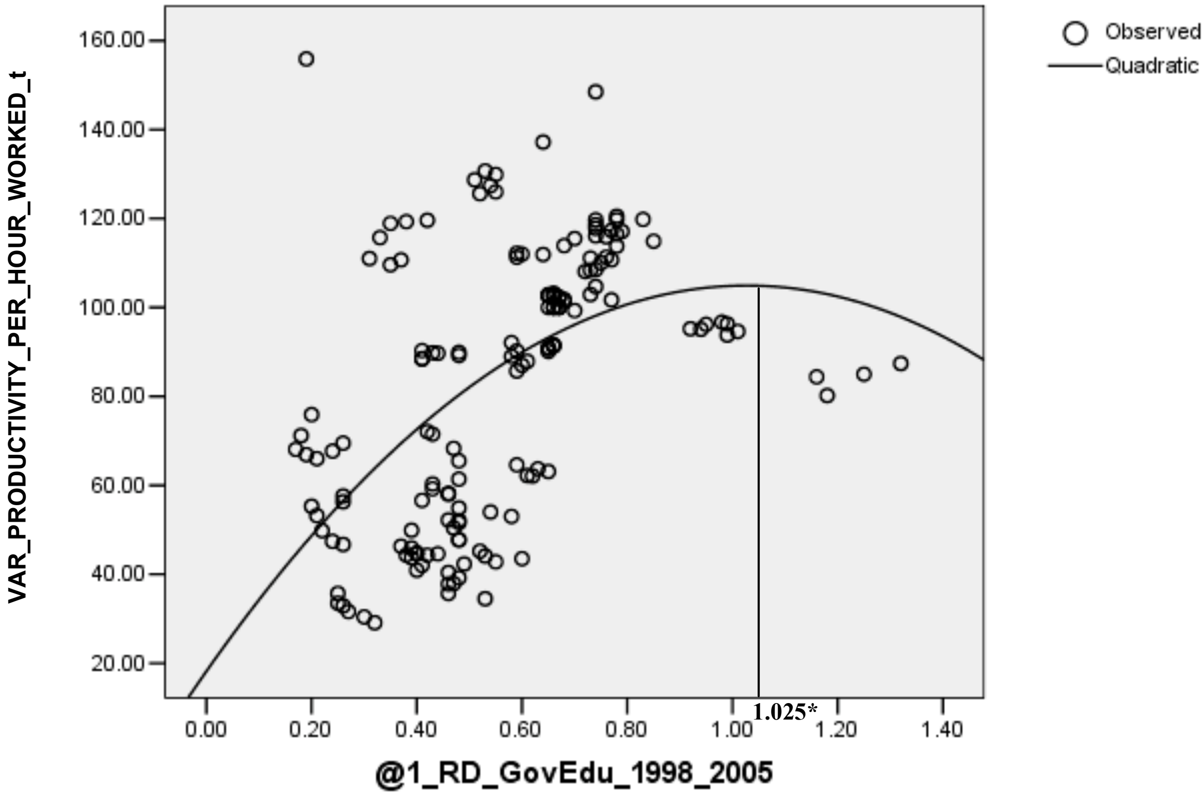

Figure 2: Regression of relative labour productivity growth per hour worked (t) on R&D Expenditure of Government and Higher Education as percentage of GDP (GOVERD)

Lessons learned and discussion

This paper investigates the relationship between levels of public and private R&D expenditures and productivity growth across open economies. Public and private R&D expenditures as percentage of GDP are an important driver of productivity growth, as showed by models. Lessons learned from this research are the following:

- PROPOSITION *1*: the *relative productivity growth = f (Public or Private R&D Expenditure as % of the GDP)* is concave function.
  Proof: The concavity of this function (see graphs of *f* in figures 1, 2, and models) is due to diminishing returns to research investments that play a similar role to diminishing returns to capital accumulation into standard neoclassical growth model (Solow, 1956; Cass, 1965).
- PROPOSITION *2*: the long run magnitude of Public R&D expenditure as percentage of the GDP that maximizes productivity growth is about 1.03%, whereas the long run magnitude of R&D expenditure of business enterprises as percentage of the GDP that maximizes productivity growth is about 1.74%.
  Proof: See mathematical optimization applied to models.
- *REMARK*: if the magnitude of Public / Private R&D investment is higher than the optimum level (proposition 2), the productivity growth is not maximized (because of concavity of the function,

proposition 1), thus generating a productivity growth that can be reached with a lower level R&D expenditures, so that resources can be achieved and allocated in a more efficient way in other sectors.

- *REMARK*: To increase productivity and economic growth the long run magnitude of Public R&D expenditure as percentage of the GDP has to be lower than R&D expenditure of business enterprises as percentage of GDP. In fact, Steil *et al.* (2002) analyzing the economic and technological performance of a number of countries, find out that there are strong similarities in dynamics of R&D investment across countries. In the USA, as well as Japan, Germany, France, and the UK, the Government intervention in R&D investment -particularly in industrial policy and labour market- has been reduced, thus favouring the action of market forces, which have become more and more important in allocating resources.
- *REMARK*: Total R&D investment magnitude to maximize productivity growth, within advanced countries, should be about 2.7% of the GDP.

In Europe some governments have concentrated on reforms to achieve static efficiency gains based on supply-side revolution. Relatively little was done specifically to stimulate R&D investments. As the incentive to invest in R&D is determined by the private return and not the social return, R&D is held back in many countries by underdevelopment of financial markets or inappropriate government research policies. This is the reason since some countries do not invest more in R&D. In addition, the long-run growth in R&D spending is surely linked to growing influence of science in the process of production and greater market competition at home and abroad in knowledge era may force countries to increase R&D expenditures in order to produce new or better product (Scherer, 1992; Van Reenen, 1997). This is the reason why an increasing number of countries have introduced fiscal incentives and subsides for R&D that may increase innovative activity of firms (Heijs *et al*., 2007), but they may also alter the strategic interactions between firms that determine market shares.

Politicians and bureaucrats to increase the economic performance of their countries, they should focus their decisions on the total magnitude of R&D investments, which should be about 2.7% of GDP in the long run. In achieving these aims the policy makers have to ensure better coordination of policy and recognise the complex chain of causation that can be triggered by polling on R&D investment. In addition, the magnitude of gross domestic expenditure on R&D (GERD) should have a particular composition of the three significant contributors (Coccia, 2008): over 60% has to be by business enterprises (BERD), whereas about 30% by government (GOVERD), and a mere 10% by abroad investments. For instance the US has an arithmetic mean of GERD as % of GDP equal to 2.6% over 1995-2005 period, which is split in: 1.9% financed by business enterprises, 0.3% by government, 0.4% by other sectors (Eurostat, 2007).

Productivity growth enhancing can be archived by a magnitude of public and private R&D expenditures close the optimal rate that supports the competitiveness in the long run, a complex matter based on quality improvements and product niche that should be of vital interest to any government, rather than competitiveness in the short run based on price and cost. Contrary to expectations and to much of the literature (Brécard *et al.,* 2006), it is not true that higher is R&D expenditures as percentage of GDP, higher is productivity growth, since the function *Relative Productivity growth = f (R&D expenditures* as % of the GDP*)* is concave due to diminishing returns to R&D investments.

The poor productivity performance of European countries in comparison with the USA has been an important focus for government policy. United States are technological leader because of high R&D contribution to productivity growth that is largely due to innovation (Griffith *et al.,* 2004). European Union with 15 countries (EU15) has a R&D expenditure of business enterprises equal to 1.23% of GDP, whereas R&D expenditure of government and higher education is 0.66% of GDP vs. 1.93 and 0.64 in USA (Table A.1, in appendix). This situation leads to a European growth of labour productivity per hour worked and GDP per capita lower than the US. Europe is lagging behind the USA but there are larger differences across European countries in labour productivity development and level of R&D Expenditures. According to Borrás (2004), despite institutional efforts, the conceptualization of a European Innovation System is still premature in the European Union. In response to recent concerns about lagging productivity and poor performance in Europe, the European Union has set itself the ambitious target of increasing R&D expenditure to 3 per cent of GDP by 2010 (this is part of 'Lisbon agenda'; European Commission, 2004; Room, 2005).

Is the 3 per cent the correct level to increase the economic performance of EU?

I answer no because empirical evidence shows that *relative productivity growth = f (GERD as % of the GDP)* is concave function, then the 3 per cent of GDP is a higher magnitude to maximize productivity and economic growth; in addition it is necessary to reckon not the total level of national R&D expenditure but the composition between public and private sector. The latter (i.e. R&D expenditure of business enterprises) should be higher (and equal to about 1.7% of GDP) than the former (i.e. total R&D expenditure of the government) to maximize productivity growth. In addition, several EU countries are far from reaching the optimum magnitude of public and private R&D investment as % of GDP, because of weak industrial structure and macroeconomic problems that breed a technological and economic delay in the 1990s and early 2000s, leaving Europe far behind in comparison to the US economy. The optimal rate of public and private R&D investment that maximizes the productivity growth in the long run is based on a set of open economies operating in the same geo-socio-economic and politic area. It is important to always consider *social-economical specificity of each country.* In facts, each country has a specificity represented by his macroeconomic (public debt, inflation, real GDP growth) and industrial structure (traditional rather than high tech industries) such that, given a fixed level of R&D expenditures, this may breed different effects and economic performances for several countries.
Table A.2 in Appendix shows that the magnitude and composition of public and private R&D expenditures change with the level of development of nations: *countries with high and medium GDP per capita* have R&D expenditure of business enterprises higher than Total R&D expenditure of government, whereas *less developed countries* have a Total R&D expenditure of government > R&D expenditure of business enterprises because of fragile and less dynamic industrial structure. In fact, if we consider the ratio public R&D expenditure / Private R&D expenditure, using arithmetic mean of countries over 1998-2005, econometric linear model shows that if GDP per capita increases of 1% per cent, this ratio decreases of −0.012 (see appendix table A.3 and figure A.1). These results show that economic development of a country is associated with the reduction of Total R&D expenditure of government and high increases of R&D expenditure of business enterprises, if these countries would like follow high economic growth avenues.
For instance, Italy even if is a developed country (it belongs to G7) has a composition of Public and Private R&D expenditures similar to developing countries with low GDP per capita. This wrong research policy applied by Governments of different coalitions has been producing low economic performances such as low productivity growth and Growth rate of GDP volume (see Table A.1).
On an international level, converging strategies are adopted in relation to science and technology policies to boost productivity and economic growth (Dodgson and Bessan, 1996; Tassey, 1997). Despite these converging initiatives, countries have diverging results in terms of economic performance and productivity growth (Van Reenen, 1997), because of differences in magnitudes and composition of public and private R&D expenditures, heterogeneous economic-financial situation and other natural-socio-political-economic factors.
The governments realize that it is critical to be aware of the relative importance of different factors that might influence productivity growth. However, it is equally important for researchers to help government more acutely aware that the ultimate impact of any increase in spending on R&D depends critically upon complex, interwoven strings of causations which are not necessarily constant over time and across countries, because of globalization and turbulence of markets. In short, *ceteris paribus,* research evidence suggests that the underlying political economy of growth that should be adopted to boost productivity gains in the long run and therefore competitive advantage of open economies seems simple at first glance, given a stable socio-economic-financial situation and low public debt: *raising the long run R&D expenditure of business enterprise as percentage of the GDP at around 1.7%, whereas R&D expenditure of Government and higher education should be about 1% of GDP, ceteris paribus the stability of their economic systems.* The challenge for policy makers is how to ensure that such magnitudes of public and private R&D expenditures (as % of GDP) are integrated in national political economy, considering country specificity, to maximize their positive impact on modern economic growth.

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Appendix A

Table A.1: Arithmetic mean of variables per countries

Country	*Arithmetic mean*					
	GDP per capita in PPS 1997-2004	*R&D Expenditure: Business 1998-2005*	*R&D Government and higher education 1998-2005*	*R&D Expenditure: Business* minus *Government and higher education expenditures*	*Labour productivity per hour worked 1999-2005*	*Growth rate of GDP volume 1997-2004*
Austria	130.9	1.41	0.69	0.72	99.5	2.2
Belgium	124.6	1.36	0.54	0.82	127.9	2.3
Cyprus	88.9	0.06	0.21	−0.15	68.2	3.6
Czech Republic	71.8	0.76	0.46	0.30	48.4	2.0
Denmark	129.6	1.59	0.75	0.85	102.7	1.9
Estonia	47.3	0.24	0.49	−0.25	39.3	7.2
EU (15 countries)	114.7	1.23	0.66	0.57	100.0	2.3
EU (25 countries)	104.7	1.19	0.65	0.54	91.0	2.5
EU (27 countries)	100.0	1.19	0.65	0.54	-	2.4
Euro area (12 countries)	113.6	1.18	0.66	0.51	102.6	2.2
Euro area (13 countries)	113.3	1.18	0.66	0.51	102.3	2.2
Finland	115.1	2.30	0.97	1.33	95.4	3.7
France	114.9	1.36	0.78	0.58	117.3	2.4
Germany	119.5	1.71	0.75	0.96	109.7	1.4
Greece	79.1	0.19	0.43	−0.24	68.6	4.2
Hungary	57.9	0.34	0.47	−0.13	50.6	4.6
Iceland	133.6	1.41	1.20	0.21	84.6	4.2
Ireland	131.1	0.81	0.37	0.45	115.0	7.6
Italy	115.6	0.53	0.55	−0.02	96.0	1.5
Japan	117.0	2.26	0.74	1.52	-	0.9
Latvia	39.1	0.15	0.28	−0.13	32.2	6.7
Lithuania	42.9	0.12	0.53	−0.42	39.4	6.2
Luxembourg	236.7	1.45	0.17	1.28	154.3	5.1
Malta	80.0	0.26	0.19	0.07	76.1	0.2
Netherlands	131.5	1.04	0.71	0.33	117.8	2.7
Norway	154.6	0.92	0.71	0.22	141.6	2.7
Poland	48.6	0.20	0.40	−0.20	43.7	4.1
Portugal	77.2	0.23	0.44	−0.21	58.7	2.6
Romania	29.0	0.26	0.14	0.13	-	4.2
Slovakia	53.2	0.37	0.24	0.13	52.3	3.4
Slovenia	78.9	0.85	0.55	0.30	64.0	3.9
Spain	98.2	0.52	0.45	0.08	89.4	3.9
Sweden	121.7	2.92	0.93	1.99	101.2	3.0
Switzerland	143.1	2.03	0.66	1.37	101.0	1.7
United Kingdom	118.2	1.18	0.59	0.59	88.8	3.0
United States	156.8	1.93	0.64	1.29	113.4	3.2

Source: Eurostat (2007)

Table A.2: Statistics of countries per level of GDP per capita

Level of GDP per capita	*Variables*	*Mean Statistic*	*Std. Deviation Statistic*
HIGH	R&D Expenditure Business Enterprise 1998-2005	1.39	0.41
	R&D Government and higher education 1998-2005	0.70	0.19
	GDP per capita in PPS 1997-2004	125.89	18.68
	Growth rate of GDP volume 1997-2004	3.09	2.18
	Labour productivity per hour worked 1999-2005	107.94	13.80
	Valid N (listwise)	84	
MEDIUM	R R&D Expenditure Business Enterprise 1998-2005	0.44	0.30
	R&D Government and higher education 1998-2005	0.42	0.13
	GDP per capita in PPS 1997-2004	82.28	9.68
	Growth rate of GDP volume 1997-2004	3.21	1.73
	Labour productivity per hour worked 1999-2005	66.58	13.76
	Valid N (listwise)	36	
LOW	R&D Expenditure Business Enterprise 1998-2005	0.25	0.11
	R&D Government and higher education 1998-2005	0.39	0.12
	GDP per capita in PPS 1997-2004	47.98	7.32
	Growth rate of GDP volume 1997-2004	4.77	2.69
	Labour productivity per hour worked 1999-2005	43.75	7.74
	Valid N (listwise)	37	

Table A.3: Parametric estimations of model

	Estimated relationship			
k_i=	*2.25**** *–0.012y_i****	*R^2 adj. = 27.3%*	F = 13.79 (sig. 0.001)	*N=35*
	(0.367) (0.003)	*S= (0.798)*		

*** Parameter is Significant at the 0.001 level

Notes: The second column is the estimate of the constant and of β_i. Underneath them, in parentheses, their standard error. The third column has adjusted R^2 of the regression and below it, the standard error of the regression. In the last column the *F* test and its significance level.

k_i = R&D Expenditure of Government and Higher Education as percentage of GDP – (minus) R&D Expenditure of Business enterprises as percentage of GDP, arithmetic mean over 1998-2005 period

y_i = GDP per capita in PPS, arithmetic mean over 1997-2004 period

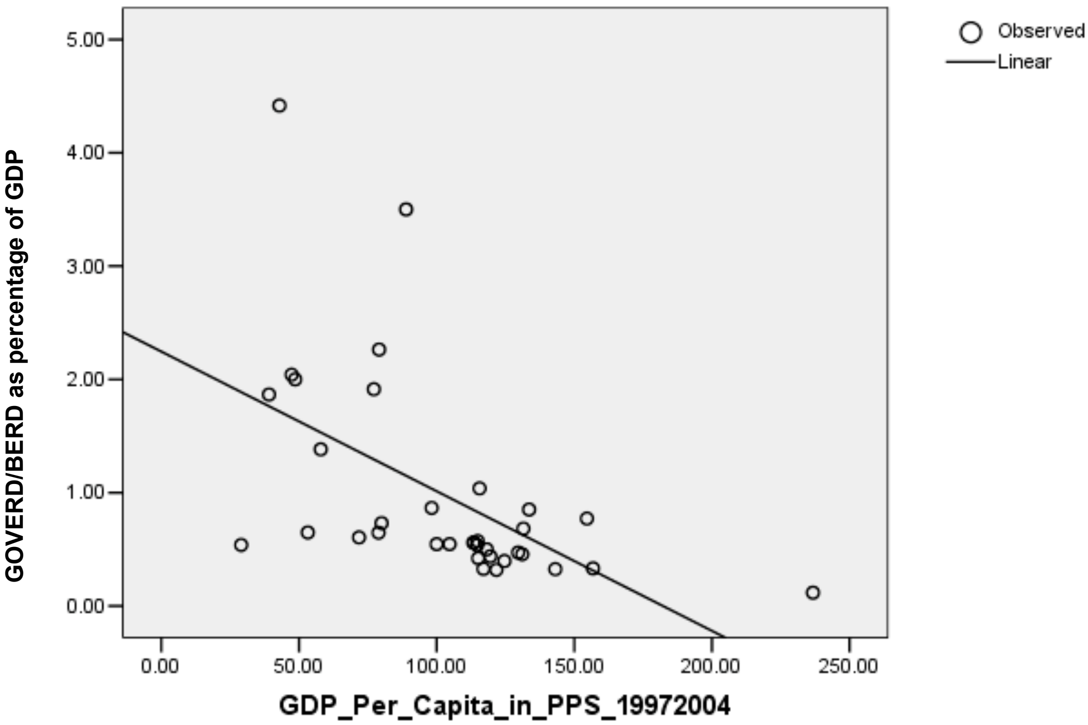

Figure A.1: Regression of R&D Expenditure of Government and Higher Education as percentage of GDP / R&D Expenditure of Business Enterprise on GDP per capita in PPS