MODELLING R&D AND HUMAN CAPITAL FOR UNITED STATES AND EUROPEAN UNION ECONOMIES

A Master's Thesis

by
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July 2012

To My Family

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of
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I certify that I have read this thesis and have found that it is fully adequate, in scope and in quality, as a thesis for the degree of Master of Arts in Economics.

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ABSTRACT

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In this thesis, regarding technological improvements and formation of human capital as the engine of growth, I investigated public policy whose objective is to enhance Total Factor Productivity (TFP) through investments in innovation for United States (US) and European Union (EU) economies. To this end, first I documented and compared the R&D expenditures and human capital expenditures of US and EU countries for last two decades. Then, taking 2008 as base year I constructed Social Accounting Matrices (SAM) for both economies. Finally, I conducted subsidization policy with a general equilibrium model and investigated effects of public policy on economic growth, social wealth and welfare. In this study, I found that R&D subsidization policy enhances economic growth, social wealth and welfare in both countries but the enhancement is larger for EU economy.

Keywords: General Equilibrium, R&D, Subsidy Policy

ÖZET

AMERİKA BİRLEŞİK DEVLETLERİ VE AVRUPA BİRLİĞİ EKONOMİLERİ İÇİN AR-GE VE BEŞERİ SERMAYE MODELLEMESİ

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Bu tezde, teknolojik gelişmeleri ve beşeri sermaye oluşumunu büyümenin temeli olarak görerek Total Faktör Verimliliğini (TFV) icatlara yatırım yaparak arttırmayı amaçlayan bir kamu politikasının etkilerini Amerika Birleşik Devletleri (ABD) ve Avrupa Birliği (AB) Ülkeleri ekonomileri için inceledim. Bu amaçla, ABD ve AB'nin Ar-Ge harcamalarını ve beşeri sermaye harcamalarını son 20 yıl için araştırdım ve karşılaştırdım. Daha sonra, 2008 yılı için bu iki ekonominin Sosyal Hesaplamalar Matrislerini (SHM) oluşturdum. Son olarak, genel denge modeli kullanarak teşvik politikası uyguladım ve bu politikanın ekonomik büyüme, sosyal refah ve zenginlik üzerine etkilerini inceledim. Bu çalışmada, Ar-Ge teşvik politikasının her iki ülke içinde ekonomik büyümeyi, sosyal refahı ve zenginliği artırtıdığını ancak bu artışın AB için daha fazla olduğunu buldum.

Anahtar Kelimeler: Genel Denge, Ar-Ge, Teşvik Politikası

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CHAPTER 1

INTRODUCTION

In the standard neoclassical growth models, the source of growth is capital accumulation while the transitional dynamics have been taking place. These models are not genuinely a sustained growth model because investments are made in capital fail to be the reason of economic growth in the long run. Unless there would be an exogenous technology shock, the economy would reproduce itself over and over again for years. In the neoclassical world research activities can be seen as an alternative form of capital investment. The formulation of neoclassical technology is updated by Paul Romer as the ultimate source of growth in a market optimization framework. The new growth theory highlights the roles of research and development (R&D) activities and accumulation of human capital to explain the per capita income differences, productivity growth and welfare. Improvement of technological innovations will have eventually a positive impact on the final goods (also on productivity and competitiveness) hence, improves economic growth. In addition, the new approach does not ignore the distortions associated with the R&D activities such as monopoly pricing, intertemporal knowledge spillovers, congestion externalities, and creative destruction. In this thesis, regarding technological improvements and formation of human capital as the engine of growth, I try to investigate public policy whose objective is to enhance total factor productivity through investments in innovation for US and EU economies[1]. US and EU constituted approximately 40% of world's GDP in 2010. Since the GDP is the total value of all goods and services produced within that country in a year, it is mostly regarded as a measure of the economic power of a country. US and EU are the largest and dominating economies in the world. In terms of economic development both are ahead of the others and they are also leaders in investing in R&D activities. After examining the sectoral decomposition of both countries, it is shown that there are structural differences in the industries of those countries causing a quantitative difference in investing in R&D activities. As I shall discuss in Chapter 5, each country responds differently to the R&D subsidization policy.

Outline of the thesis is as follows; Chapter 2 is review of the theoretical and empirical literature mainly based on neoclassical and endogenous growth theories. In Chapter 3, I try to document and compare the data of R&D and human capital expenditures of US and EU. Chapter 4 consists of methodology including the Social Accounting Matrix (SAM) framework. In Chapter 5, I present the results of R&D subsidization policy and Chapter 6 is the conclusion part.

[1] European Union with 27 countries

CHAPTER 2

LITERATURE REVIEW

In last two decades there were significant contributions to the R&D based growth models in order to explain income per capita, growth rate and productivity differences across countries. Romer (1990) constructed a model with endogenized, non-rival and partially excludable technology which is the engine of growth. Unlike Solow (1956), market incentives have an important role in the translation process where new knowledge is turned into goods with economic value. Grossman and Helpman (1991) analyses the role of intentional industrial innovations on growth. Main aim of R&D is expanding the set of variety of products. Each product follows a stochastic progression up to a quality ladder. In other words, it is a model of horizontal innovations. However, equilibrium is determined by aggregate rate of innovations which is constant and determinate in the steady state. The welfare properties of the model where the growth rate responds to profit incentives in the R&D sector were studied. Whereas in Aghion and Howitt (1992) uncertain research activities leads a random sequence of quality improving innovation that lies in the heart of the growth. This is a vertical innovation model which has a property of obsolescence that directly implies creative destruction, thus the Schumpeterian nature. In all approaches described above have the same nature in driving economic growth by innovations, and accumulation of knowledge is the source of innovative growth.

In the literature there are many theoretical models of growth indicating the crucial role played by human capital in the form of education. Nelson and Phelps (1966) and Lucas (1988) are the pioneering works that highlights the emphasis of human capital. Although their work is emphasizing the same concept, there is a dichotomy that growth is driven by stock of human capital (Nelson and Phelps (1966)) vs. human capital accumulation (Lucas (1988)). Also King and Rebelo (1993) and Barro and Sala-i-Martin (1995) treated human capital as a central concept to economic growth. There are also empirical exercises with wide range of countries such as Romer (1990a) and Barro (1991).

Funke and Strulink (2000) proposed a model that combines Uzawa Lucas framework (where human capital has a positive external effect on goods sector) and Grossman and Helpman (1991) model, and studied its convergence. They set up an endogenous growth model with physical capital, human capital and blueprints for intermediate goods. Their model emphasizes the role of physical capital which allows an analysis that encompasses the development process towards an innovating economy characterized by extensive growth and accumulation of skills. In their economy, physical capital contributes in large parts to income per capita growth. However long-run growth is generated by incentives to innovate and this long-run growth surpasses growth through factor accumulation and quality improvement. Since innovations require knowledge accumulation, cruciality of education and training is reflected in their work. They assume output of new ideas is merely determined by the aggregate knowledge employed in R&D sector and exclude decreasing returns as well as scale effects in varieties.

As well as the positive impact of human capital on economic growth and welfare, it is known that externalities driven by R&D activities have an impact on economic growth and welfare, too. The sign of this impact is related to whether there is an overinvestment or underinvestment in R&D in decentralized equilibrium. Since R&D is a key determinant of long run productivity and welfare, many studies in the literature deal with the question that whether a decentralized economy undertakes too little or too much R&D. In the literature, empirical evidence shows that decentralized equilibrium typically underinvests in R&D relative to what is socially optimal. Jones and Williams (2000) shed light on this issue by arguing that a conservative estimate indicates that optimal investment in research is more than two to four times actual investment. Thus, conventional wisdom requires a subsidization policy. In 2002, The Barcelona European Council has reached an agreement on increasing the average research investment expenditures from 1.9% of GDP to 3% of GDP by 2010, of 2/3 should be funded by the private sector. Also the Council had showed the incentives to support the private firms financially by arguing public support is justified by the recognized failure of the market to induce business investment in research to attain optimal level (COM 2003).

Sequeira (2008) made a numerical analysis to compare the quantitative effects of R&D policy with the quantitative effects of human capital policy in wealth and welfare. On the other hand, Sequeira (2008) argued the skills may also be accumulated through the contact to aggregated technological knowledge of economy and this contact with technologies is made using the stock of individual human capital. Also the presumption on accumulation of human capital is enhanced by the new effect called 'learning with varieties' besides schooling. His conclusion indicates that although R&D subsidy influences growth, wealth and welfare, subsidies to schooling proved to be more income and welfare enhancing. Most recently, Voyvoda and Yeldan (2011) analyses the Turkish economy to examine the interaction between accumulation of human capital, knowledge driven growth and the effect of public policy. They studied the subsidization of human capital through skill accumulation against subsidization of R&D activities. Their results shows that education subsidy yields more favorable results than R&D subsidy with respect to steady-state growth rates, both in terms of output and the knowledge stock of the economy.

I will be on the path of these types of most recent applied pure policy analysis calibration exercises by following the footprints of Voyvoda and Yeldan (2011) and my purpose of this study is a general equilibrium investigation of R&D policy across the Atlantic.

CHAPTER 3

R&D AND HUMAN CAPITAL EXPENDITURES

The Gross Domestic Expenditure on R&D (GERD) is the total intramural expenditure on R&D performed on the national territory during a given period. GERD takes into account R&D performed within the country and funded from abroad but it excludes payments made abroad for R&D. GERD is usually stated in terms of purchasing power parity (PPP). However despite the measurement in PPP, the absolute value of the GERD is based on the size of the country. Thus, to eliminate the size effect GERD per GDP is a good candidate.

Empirical evidence shows that GDP and GERD are positively correlated in years. Growth of R&D expenditure pursues the business cycle, and growth of GERD shows larger fluctuations than growth of GDP and a time lag of one to two years. Funds devoted by private sector have the largest fluctuations indicating the big impact of business cycle. On the other hand, publicly financed R&D tends to be more countercyclical and displays fluctuations smaller in magnitude than private sector. As a result, during the economic crisis a large drop is observed in private funds. According to the

EU Industrial R&D Investment Scoreboard (Scoreboard) 2009 crisis has a different impact on the companies than 2001 crisis. After 2009 crisis, there was a worldwide tremendous decrease in sales and profits about 10.1% and 21% respectively. However in nominal terms R&D investment decreased by 1.9%. According to the deduction of Innovation Union Competitiveness Report (IUCR) (2011) this indicates the strategic significance that large spending companies in R&D continued to devote their funds to R&D, which they regard as a priority. Thus some companies continued to increase R&D investment even during the crisis for the purpose of competitiveness in preparation for the recovery.

Besides the research activities, there is no doubt that educational investments are seemed as an engine of economic growth by many countries, especially by developed ones. Data on education expenditures shows that devotion of funds to education have been increasing in years. Predominantly, allotted expenditures to education have a remarkable percentage share in both public expenditures and GDP in many developed and developing countries.

3.1 R&D Expenditures in US and EU

It is apparent from the fig.2 that EU's expenditure on R&D neither exceeds nor catches up the US expenditures. In 2002 and 2004 there is a slight decrease in the difference but after 2004 the gap started to rise and in 2008 it attained its maximum level. Between 2001 and 2005 one can observe a fall for both EU and US. This might be caused by cuts in the R&D expenditures due to the recovery after the 2001 crisis. EU has an average of R&D expenditures 1.8% of GDP between 1995 and 2008. In both 2009 and 2010 this average increased approximately to 2%. However this rise is not attributable to the increase in GERD but it is due to the rapid fall in GDP caused by 2008-2009 financial crisis.

Through 2000 to 2005, EU's R&D expenditure growth rate is -0.005 and between 2005 and 2009 growth rate is 0.081. Besides the recovery of 2001 financial crisis, Lisbon Strategy[2] in 2005 for reaching the target of devoting 3% of GDP to R&D by 2010, influenced this increment. Since the EU could not have achieved the objective set in the 2002 Lisbon Strategy, in 2010 the target has been revised as devoting close to 3% of GDP to R&D by 2020. Also each of the Member States announced their own national 2020 objective. As stated in IUCR (2011), if those objectives are reached, R&D share of EU in GDP will be between 2.7-2.8%.

For the whole time period indicated in fig.2 growth rate of GERD in EU is 0.1 and in US it is nearly 0.06. In 1995, EU has a world share of 24% in investing R&D and US has 38%. Also between 1995-2008 World's real GERD virtually duplicated, meantime in EU it rose approximately 50% and in US increment was about 60%. However the increase in R&D expenses was

[2]The Lisbon Strategy, also known as the Lisbon Agenda or Lisbon Process is a development plan effectuated in 2000 by the European Council in Lisbon in March 2000 for the economy of the EU between 2000 and 2010. The objective is to make the EU the most competitive and dynamic knowledge-based economy in the world capable of sustainable economic growth.

worldwide that Asian economies and BRIS countries (Brazil, Russia, India, South Africa) have devoted more percentage share of GDP to R&D. As a result, in 2008, EU share of world has decreased to 24% and US share has decreased to 33%.

France, Germany, Italy and United Kingdom (UK) have a larger share of GDP devoted to R&D among the countries in EU. It can be shown in the fig.3 that in 2004, Germany has a slight difference from US. Germany is always above the EU level. In addition, expenditures in R&D in France exceeds the R&D intensity level of EU for years. On the other hand UK shows a similar trend with the EU level but there is a remarkable fall in 2010. Although Italy has a higher share than other countries in EU, it's share is always under the average EU level.

For a detailed investigation, GERD can be broken into subparts: R&D conducted by business enterprise sector (BERD), higher education sector (HERD), research institutes owned by the government sector (GOVERD) and non-profit organizations (OTHER). Among the mentioned indicators BERD is the most important one to roughly identify the standing point in R&D activities. In other words, it clarifies whether a country's expenses in R&D is more committed by industry or by public sector.

Table 2 shows that the largest performers of the R&D investments is business enterprises in both EU and US. The second largest performer of the R&D is higher education sector for both. However in US the difference between HERD and GOVERD is not as high as in the EU. Although the EU industry has the largest share in GERD it is remarkably lower than the US level. As GERD can be splitted by the sectors of performance, it can be also decomposed by the sources of funds as shown in Table 3. Generally BERD is encompassed by the industry and funds given by government to R&D activities usually constitute a small part. In contrast, HERD is largely funded by government and industry has a lower share. Also GOVERD is almost completely funded by the government sector. Table 3 indicates that EU has lower share of sources of funds in private sector. The difference between two countries in R&D investment is 70 billion Euro and the private sector is responsible for the amount of 61 billion Euro. The large and growing gap in R&D spending between them is attributable to the structural difference of US and EU in R&D sector. The reason for that is the low commitment of EU private sector in R&D activities compared to US where the manufacturing industry is bigger in magnitude and more research intensive. Although the funds devoted by public sector are larger in EU, this is not enough to compensate the difference in the private funds. Thus the gap between them is mostly ascribable to the relatively less devotion of industry to research activities in EU compared to US. Hence, private sector in EU should be encouraged to invest further in R&D.

Since the effect of private sector is greater in magnitude, it is crucial to go behind the reasons that make the industries of two countries so different. According to Scoreboard in 2009, the R&D gap between US and EU can be explained by observing the sectoral composition of both countries. Also the

Scoreboard points out the impact of the young firms (created after 1975). Submission of the Scoreboard indicates that 17.8% of EU firms and 54.4% of US firms are young as indicated in fig.4. In other words, while more than half of the US companies are young, EU industry mostly composed of old firms. This difference plays a significant role because young firms of EU have a research intensitivity of 4.4%, on the other hand young companies of US has 11.8%. If the sectoral decomposition of both countries is taken into consideration, evidently the industrial structure of EU is the main source of the gap. According to the Global R&D Funding Forecast (2011), part of the problem lies in the high labor costs in EU. Recent study shows that more than 70% of R&D cost represents labor costs. In contrast, in US labor costs forms nearly 45% of R&D budget.

Patent applications are correlated with the investments of business enterprise sector in R&D.[3] Concerning the technological output produced by EU and US patents generated by the United States Patent and Trademark Office (USPTO) and applications to the European Patent Office (EPO) are indicated in fig.6 and fig.7. To reduce the size effects, data is indicated by per million inhabitants. In 2007, US constitutes 24% of papent applications in EPO and 47% of patents are invented in EU. US share in USPTO applications has always been larger than EU for indicated years.

Public funds of R&D are under direct control of governments. Mostly,

[3]This is an approximation by IUCR (2011). Factors such as country's degree of specialization in technology areas which are intensive in patents may influence this.

share of public sector is larger in R&D expenses in less research intensive countries.[4] Also, from fig.5 percentage of GOVERD in GERD by source of funds is larger in EU for years. Contemporaneously, the European Commission is an important contributor from abroad to the public funds in EU. The data is not presented in here but through the medium of Research Framework Programme and Structural Funds, the European Commission plays a significant role in the public fundings.

Besides GERD, government expenses in R&D are indicated by Government Budget Appropriations or Outlays for Research and Development (GBAORD). From fig.1 their contribution channel can be identified. From GBAORD Eurostat report in 2005, GBAORD in the EU exceeded EUR 80 billion at current prices. The major contributors are Germany, France, the United Kingdom, Italy and Spain.[5] Between the time indicated in table 5 and table 6, R&D appropriations and educational appropriations in GBAORD increased in magnitude for both EU and US. However it is evident that appropriations devoted to education is larger in EU and R&D appropriations are larger in US for all years. In table 7, funds dedicated to R&D in GBAORD indicated as % of GDP to eliminate the size effects. Since educational appropriations in GBAORD are small relative to GDP, table 8 represents educational funds in euro per inhabitant. GBAORD as a percentage of total general government expenditures is decreased in US after 2004 as shown in fig.9. On the other hand EU is maintained at the same level

[4] Case of EU and US is a good example for this generalization.

[5] Besides the major contributors, as a percentage of GDP Finland was the only Member State that exceeded 1%.

around 1.5% after 2004.

Also it is important to note that R&D financed by government is comprised by grants, loans and procurements which are given to the companies. Indirect government funding through R&D tax incentives such as R&D tax credits, R&D allowances, reduction in R&D workers' wage taxes and social security is not recorded in the government financed R&D. Unfortunately data is not available to compare the direct and indirect government funding in EU and US.

3.2 Human Capital Expenditures in US and EU

Public funds of education is under control of goverments like public funds of R&D. IUCR (2011) indicates that in 2007 EU governments invested approximately eight times more in education than R&D. In 2007, government expenditure on education constitutes 5.06% of GDP in EU. On the other hand, R&D expenses of government forms 0.63% of GDP. In 2007, private funding in education receives a share of 0.7% of GDP averaged over EU countries.[6] In US, this share is remarkably higher than the EU average by 2.6% of GDP. Public and private expenditures on education as a percentage of GDP are illustrated in fig.8. From fig.8, it can be seen that EU public expenditure on education is remarkably higher only in 2005 and 2008. However as indicated in table 9, US public expenditure on education as a % of GDP is larger than EU for all years. In 2008 public expenditure of EU on

[6] UK and Cyrups are remarkable exceptions with share of private funding 1.7% and 1.3% of GDP

education was increased approximately by 31% with respect to 2001 level. Funds devoted to education perpetually have risen over years even during the time of economic crisis. This endorses the importance of education and shows the concern of EU where education is regarded as a top priority. Also, Lisbon Strategy in 2005 encourages EU to invest more in human capital.

In EU more than 895 000 students have a tertiary degree in Science and Engineering in 2008. EU generates a massive amount of source for R&D in terms of human capital. In magnitude, human capital produced for R&D is more than two times produced in US. Also in 2008, count of doctorates awarded is nearly 111 000. This number is again more than two times of doctorates awarded in US. In table 4 graduation from tertiary education is represented for the years between 2000 and 2009. The average growth rate for EU in the time interval indicated in table 4 is approximately 5% and for US it is nearly 3%. Although EU had negative growth rates in 2006 and 2009, EU commitment to tertiary education is always higher compared to US. However US has larger share of researchers in the business enterprise sector compared to EU as indicated in fig.6. It is not a suprising result because in the previous section we have already demonstrated the low R&D intensity in the industry structure of EU. According to the recordings of IUCR (2011), if the 3% target is reached in EU by 2020, together with the expected increase of GDP there will be a need of more than one million additional researchers by 2020, especially in the private sector.

Besides devoting the human resources domestically, researchers of US and

EU are also jointly participating in some international research projects. European Center of Nuclear Research (CERN) is a good example illustrating the co-work of researchers. Also US government is a financial contributor to this research center. There are some state-of-the-art facilities constructed by CERN such as Large Hydran Collider (LHC) and the European Synchrotron Research Facility. US participation in LHC is supported by US Department of Energy's Office of Science and the National Science Foundation. European and American researchers are also co-working in the Human Genome Project (HGP) coordinated by the U.S. Department of Energy and the National Institutes of Health. European Commission has educational initiatives such as ERASMUS and SOCRATES programmes. These programs mainly concerns research collaboration through educational exchanges. EU teachers stayed abroad (ERASMUS Programme) as a percentage of academic staff has an average of 1.7% between 2001 and 2006. Also, recently 33.4% of the world's total scientific publications is produced by EU but the capacity of EU to produce high-impact scientific publications (a proxy for scientific quality) is lower than the US.

CHAPTER 4

METHODOLOGY

The broad tradition of the human capital and R&D driven endogenous growth literature will be followed. Diao, Roe and Yeldan (1999) and Voyvoda and Yeldan (2011) are my benchmarks where the growth is endogenized through technological innovations and human capital formation. The model that I studied on is an overview of Lucas (1998), Romer (1990), Grossman and Helpman (1991) and their extension by Funke and Strulink (2000) and Sequiera (2008). Besides the abstract investigations about patterns of steady state growth, Japanese data is calibrated and solved to obtain both transitional dynamics and steady state equilibrium by Diao, Roe and Yeldan (1999). Recently, the model is solved for the Turkish economy by Voyvoda and Yeldan (2011).

4.1 Model

A small open economy is considered with three sectors: final goods, intermediate goods and R&D production sector. Final good is produced with the following production function which exhibits constant returns to scale and diminishing marginal product of capital. Wages of unskilled labor and skilled labor embodied in final goods sector are distributed according to the marginal product rule. The production function depends on unskilled labor, skilled labor and capital varieties instead of capital which is indirectly comes out through capital varieties.

$$Y_t = A_Y {L_t^Y}^{\alpha} {H_t^Y}^{\beta} \sum_{i=0}^{A_t} k_t(i)^{\gamma} \tag{1}$$

$$\alpha + \beta + \gamma = 1 \tag{2}$$

A_Y is a shift parameter in the production function and where {A} is the index of varieties of capital inputs. L_t^Y and H_t^Y denotes the labor and human capital embodied in the final good sector. Each capital variety is produced by a monopolistic firm and in this sector all firms are identical in the sense that,

$$\sum_{i=0}^{A_t} k_t(i)^{\gamma} = A_t {k_t}^{\gamma} \tag{3}$$

We assume there is no depreciation for simplicity. Thus the economy's resource constraint becomes:

$$Y_t = C_t + \sum_{i=0}^{A_t} k_t(i)^{\gamma} \tag{4}$$

As in Romer (1990), A represents the index of building new investment opportunities and it expands with the new research resulted in creation of new blueprints. Romer (1990) stated the accumulation of knowledge depends on the human capital and the existing stock of knowledge with constant returns. Jones (1995) argues that this formulation of knowledge accumulation is not consistent with the fact that knowledge does not accumulate directly proportional to the stock of knowledge. It is easy to see that structural changes such as immigrations, increase in schooling, increase in women participation in labor force also expand A. Then, Jones (1995) introduces decreasing returns to both human capital embodied in R&D and stock of knowledge to dampen the scale effects by assigning elasticity to each component. In this study, I followed a track in which new blueprints are only determined by the aggregate knowledge embodied in R&D as in Funke and Strulink (2000), Sequiera (2008) and Voyvoda and Yeldan (2011). Thus new research is generated by the following equation:

$$A_{t+1} - A_t = \varphi H_t^A \tag{5}$$

where H_t^A represents human resources devoted to R&D sector, namely research personnel. By construction of equation 4, H_t^A does not include the decreasing returns and scale effects. φ represents the productivity of each researcher.

The other main source of growth is the human capital accumulation and is constructed as follows,

$$H_{t+1} - H_t = \xi H_t^H + \chi H_t^{\varepsilon} A_t^{1-\varepsilon} \tag{6}$$

where H_t^H is human capital devoted to education and ξ is the productivity of schooling. The last term of equation 6 represents the effect called 'learning with varieties' because it is a combination of stock of human capital and the ideas that are already in the economy. χ is the productivity of this term[7] and

[7] All productivity parameters are presumed to be greter than zero.

ε captures the intensity of human capital required to cover existing knowledge[8].

Intermediate monopolistic firm buys the new knowledge created in R&D sector and manufactures the capital variety. To produce one unit of $k_t(i)$ firm uses a ratio η of $k_t(i)$ where η is an input-output coefficient. Also defining r as rental rate and P_t^A as the price of blueprint and $p_t^k(i)$ as the price that final good producer buys capital variety, the intermediate firm profit maximization problem becomes:

$$\max_{k_t(i)} \pi_t(i) = p_t^k(i)k_t(i) - \eta r k_t(i) - P_t^A \Delta A_t \tag{7}$$

The first term in the maximization problem stands for the revenue of the firm, second term is the variable cost and the last term is fixed cost of producing $k_t(i)$. Households are endowed with human capital H_t at each time t and it will be distributed across final good sector, production of new blueprints and further human capital without any waste. Households' utility maximization yields consumption savings decision stated as follows:

$$\max U_0 = \sum_{t=0}^{\infty} \beta^t \frac{c_t^{1-\theta} - 1}{1-\theta} \tag{8}$$

subject to

$$\sum_{t=0}^{\infty} R(t) P_t^C c_t = TW_0 \tag{9}$$

$$H_{t+1} - H_t = \xi H_t^H + \chi H_t^{\varepsilon} A_t^{1-\varepsilon} \tag{10}$$

[8] $0<\varepsilon<1$

where

$$R(t) = \prod_{s=0}^{\infty} (1 + r_t)^{-1} \tag{11}$$

and P_t^C is the price of consumption good and TW_0 denotes the total wealth.

4.2 Social Accounting Matrix Framework

Social accounting matrix (SAM) is a snapshot of an economy referring to a specific year. SAM is a square matrix whose columns represent expenditures and rows represent receipts. Moreover, each row sum is equal to the corresponding column sum which ensures the accounting consistency. SAM provides an organized outline for the national accounts for an economy. Thus, it can be seen as a powerful tool representing the data and setting out the logic of economic models. Since SAM captures the economic flow macroeconomic models which depend on these flows have to be internalized with SAM logic. SAM is a milestone of Computable General Equilibrium Models (CGE) where the well-stated incorporations of macro aggregates meet with the Walrasian General Equilibrium framework and input-output models developed by Leontief. As Robinson (2003) stated, SAM extends the Leontief input-output accounts with replenishing the circular flow from factor payments to household income and back to demand for products. Ultimately, Pyatt (1988), Thorbecke (1998) and Robinson (2003) have great contributions on SAM framework.

	Activities	Commodity	Factor	HH	Gov.	S-I	ROW
Activities		D					E
Commodity				C	G	I	
Factor	X						
HH			Y				
Gov.	Tx			Th			
S-I				Sh	Sg		Sf
ROW		M					

Table 1: Example of a SAM

Table 1 Definitions: D: Production sold domestically, E: Exports, X: GDP at factor cost, Tx: Indirect taxes, Th: Direct taxes on households, M: Imports, Y: Factor payments to households, C: Consumption, G: Government consumption, I: Investment demand, Sh: Household savings, Sg: Government savings, Sf: Foreign savings, S-I: Saving-investment account.

I constructed the SAM for US and EU economies in 2008. For our purposes we have extended the SAM for R&D sector by adding the corresponding rows and columns. SAM of US and EU can be seen in fig.13 and fig.14 respectively. Then, I calibrated the model for EU and US economies and I used the computer package GAMS for investigating policy analysis for those economies.

CHAPTER 5

POLICY ANALYSIS

In my analysis, R&D subsidy implemented on the input costs of production of R&D is ad valorem type. To compare the effects of results in short-run and long-run total subsidy amount is fixed to 0.5% of benchmark GDP each year. Subsidy amount is taken from government budget in a lump sum fashion. Thus, to finance subsidization costs government cuts some of its consumption expenditures. For initial value -period 1 or year 2008-, R&D expenditures are calculated as 1.95% of GDP for EU and 2.8% of GDP for US. The equilibrium interest rate is presumed as 5% for both countries. Share of differentiated capital in gross value added is 0.605, share of human capital in gross value added is 0.181 and share of labor in gross value added 0,214 and these values are again same for both countries.

In order to compare the results of the subsidization policy, I used base path values which are obtained without subsidy scheme over 60 periods. Fig.10-12 indicates transitional dynamics for some variables. Fig.10 indicates enhancement of GDP under R&D subsidy scheme. Rapid enhancement of GDP is dampened over the years but its level is always above the benchmark

GDP level. Also GDP of EU increased more than US as an expected result of the higher benchmark GDP indicating a larger economy. Fig.10 also illustrates consumption under R&D subsidy scheme and it is shown from this figure that consumption level increased over years. For US this increment is approximately 1.42% compared to base path and for EU countries it is 2.05%. From fig.11, it can be seen that price of R&D activities reduced nearly 0,97% for both countries and as time passes it ascends and at some point after subsidization policy it goes beyond the base path value. Ultimately, price of R&D remains higher in EU countries. As expected, total human capital within the economies descends over time in fig.11. It can be said that total human capital of EU countries affected less compared to US. This can be caused from EU's generation of massive amount of source for R&D in terms of human capital as stated in Chapter 3. In fig.12, for the first 30 time period R&D subsidy tends to create more favorable results for US in terms of total R&D amount. However, in the long-run total R&D amount is higher in EU. Wage rate of human capital which is the final variable examined under transitional dynamics is illustrated in fig.12. In the long-run wage rate of human capital is increased. Eventually in EU wage rate is higher both compared to benchmark value and US.

It is important to note that I observed some fluctuations over periods, especially for the variables indicating human capital. Such fluctuations are also observed by Sequeira (2008) and Voyvoda and Yeldan (2011). These fluctuations are the result of trade off impact of the most needed human capital in the economies.

CHAPTER 6

CONCLUSION

In this thesis, in the context of new growth theory I investigated public policy whose objective is to enhance Total Factor Productivity (TFP) through investments in innovation for US and EU economies. Nowadays importance of R&D is well appreciated for many developed countries, especially in the -US and EU- biggest ones because it is well known that R&D has a key role in producing new innovations, competitiveness and economic performance. Such an important key concept inspired me to this study. Ultimately, Voyvoda and Yeldan (2011) analyses the Turkish economy to examine the interaction between accumulation of human capital, knowledge driven growth and the effect of public policy. On the grounds of this work, in my study, I investigated the effects of R&D policy in US and EU.

In chapter 2, a broad literature review is presented. Starting from discussion of Solow (1956), growth literature is extended with Uzawa (1965) and Lucas (1988) where diminishing returns to capital accumulation is eliminated. Expansion of the growth theory continued with the introduction of technology as an economic good by Romer (1990). Most recent studies with

R&D driven growth along with the human capital formation through schooling found that R&D subsidies have a positive effect on growth, social wealth and welfare.

In chapter 3, data of R&D expenditures and human capital expenditures for last two decades is presented. In this part, reasons of R&D expenditure gap between US and EU is elaborately investigated. The reason for that gap is the low commitment of EU private sector in R&D activities compared to US where the manufacturing industry is bigger in magnitude and more research intensive.

In chapter 4, I present my benchmark model which is Voyvoda and Yeldan (2011) model and I give brief information about SAM framework.

In Chapter 5, I analyzed the role of public policy. I found that R&D subsidization policy enhances GDP, consumption and total amount of R&D activities. On the other hand, it dampens total human capital within both countries and increases wage rate of human capital.

To sum up, announcement of R&D subsidy policy has obviously long-run effects on economies. Sequeira (2008) and Voyvoda and Yeldan (2011) found that R&D subsidy policy directs the primary resources toward the R&D sector by offering a subsidized return and policy leads better results in terms of growth and welfare for the economy. What I have found for US and EU is consistent with this finding and I found that R&D subsidization policy enhances economic growth, social wealth and welfare in both countries. Moreover subsidization policy creates more favorable results in EU. As a future work, different kinds of subsidy schemes such as education subsidy may be investigated. Also migration effects of human capital can be considered via a migration function between US and EU. As a final remark, revealed subsidization policy results are very sensitive to the functional forms and algebraic structure of the model. Thus, my results are not immediate conclusions of real economies. Simulation results that were obtained from this study ought to be seen as rough estimations of a public policy analysis.

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APPENDIX

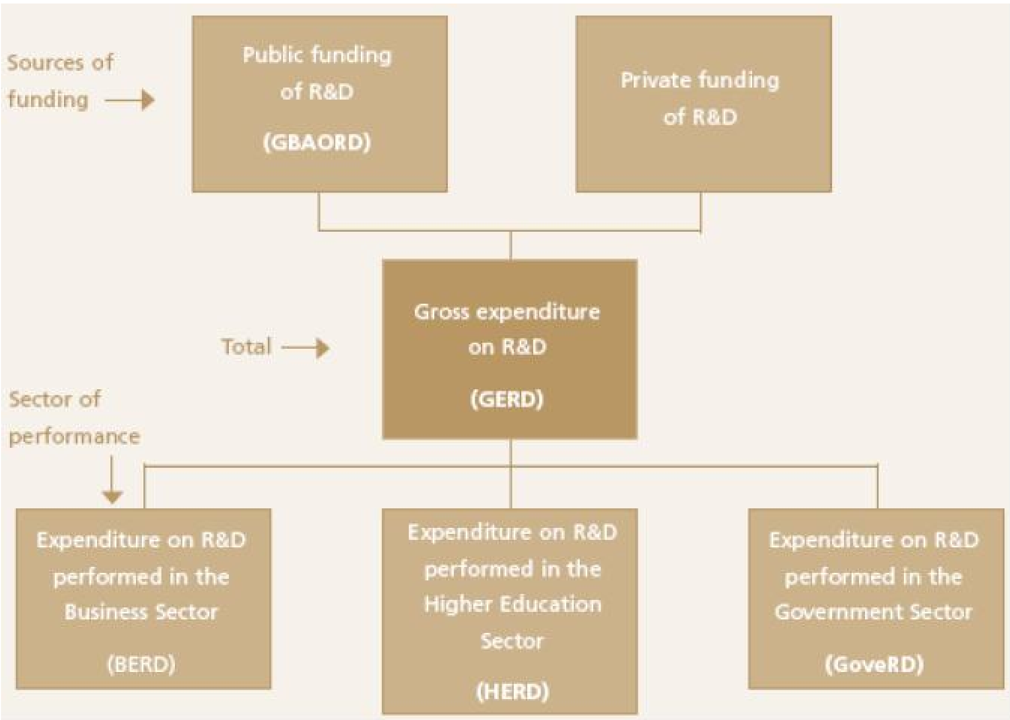


Figure 1: R&D Funding and Performance System (Table is taken from GBAORD Eurostat Report 2008)

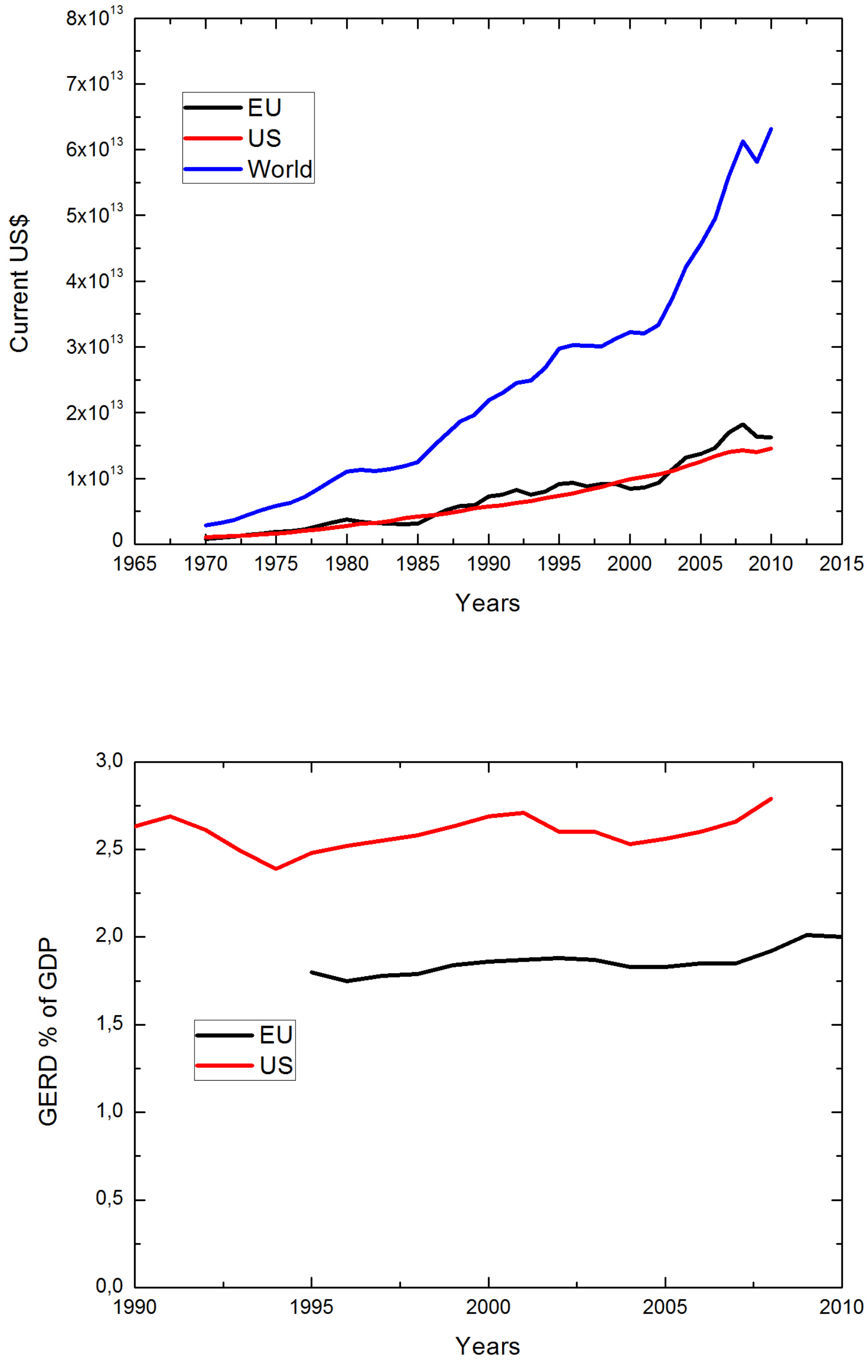


Figure 2: GDP in current US dollars and GERD as a percentage of GDP

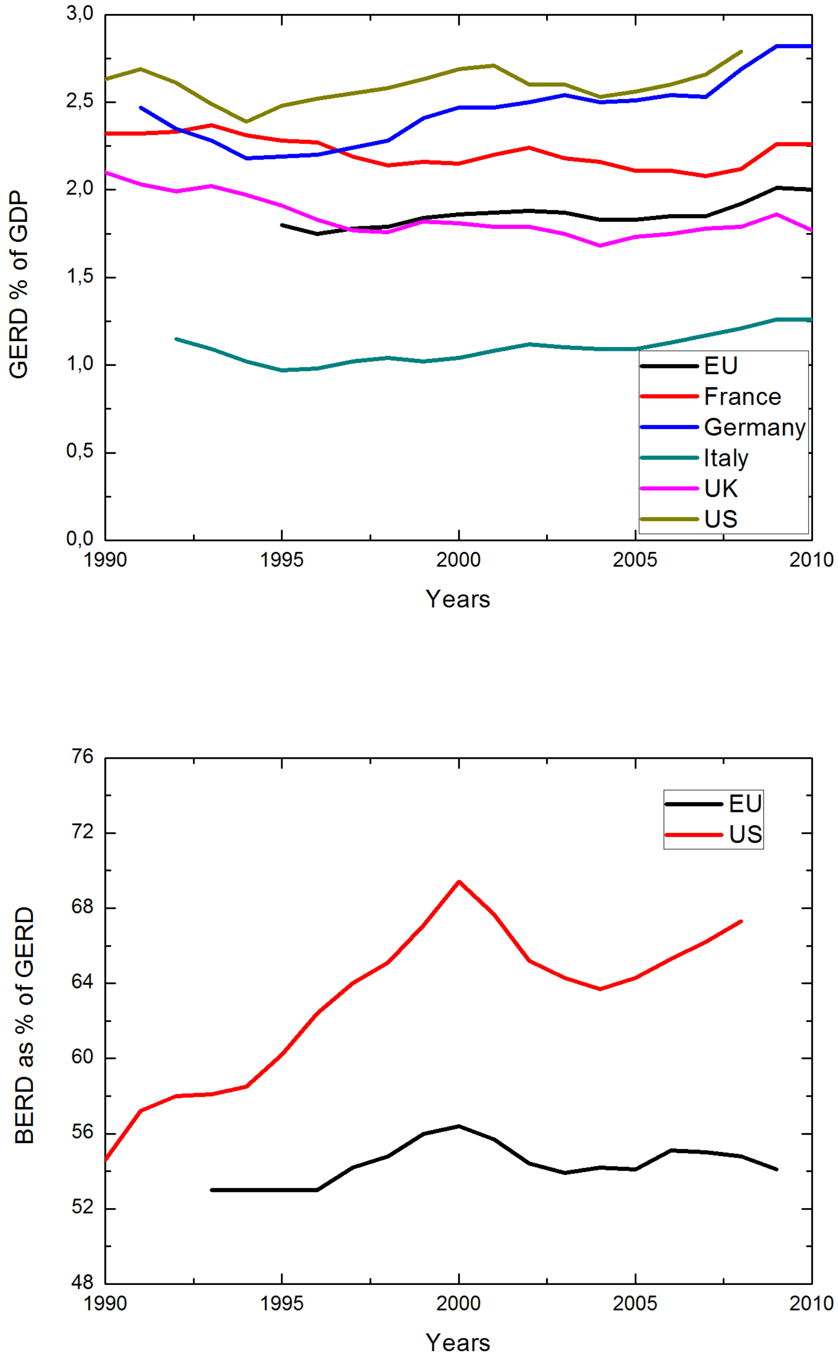


Figure 3: GERD as a percentage of GDP and % of BERD in GERD by source of funds

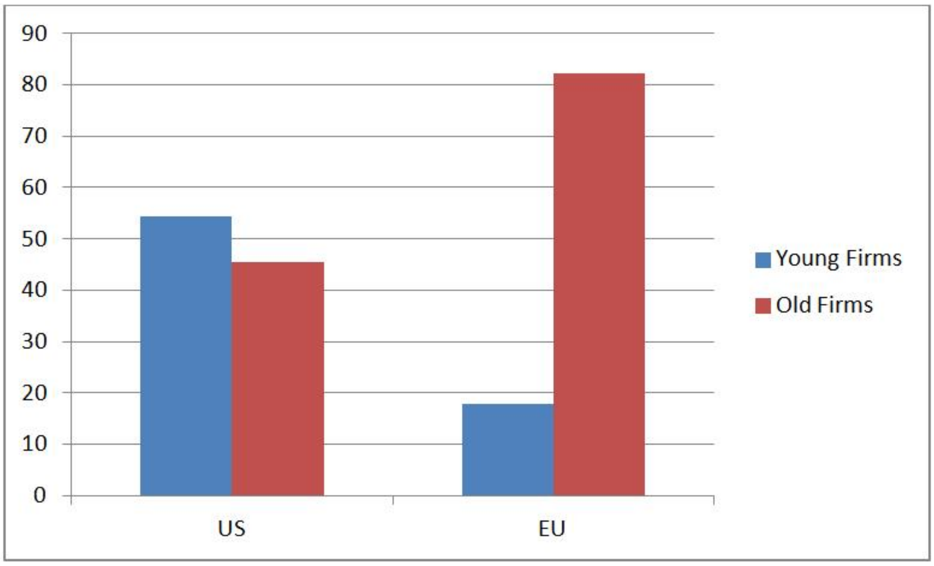


Figure 4: Share of young and old firms in EU and US

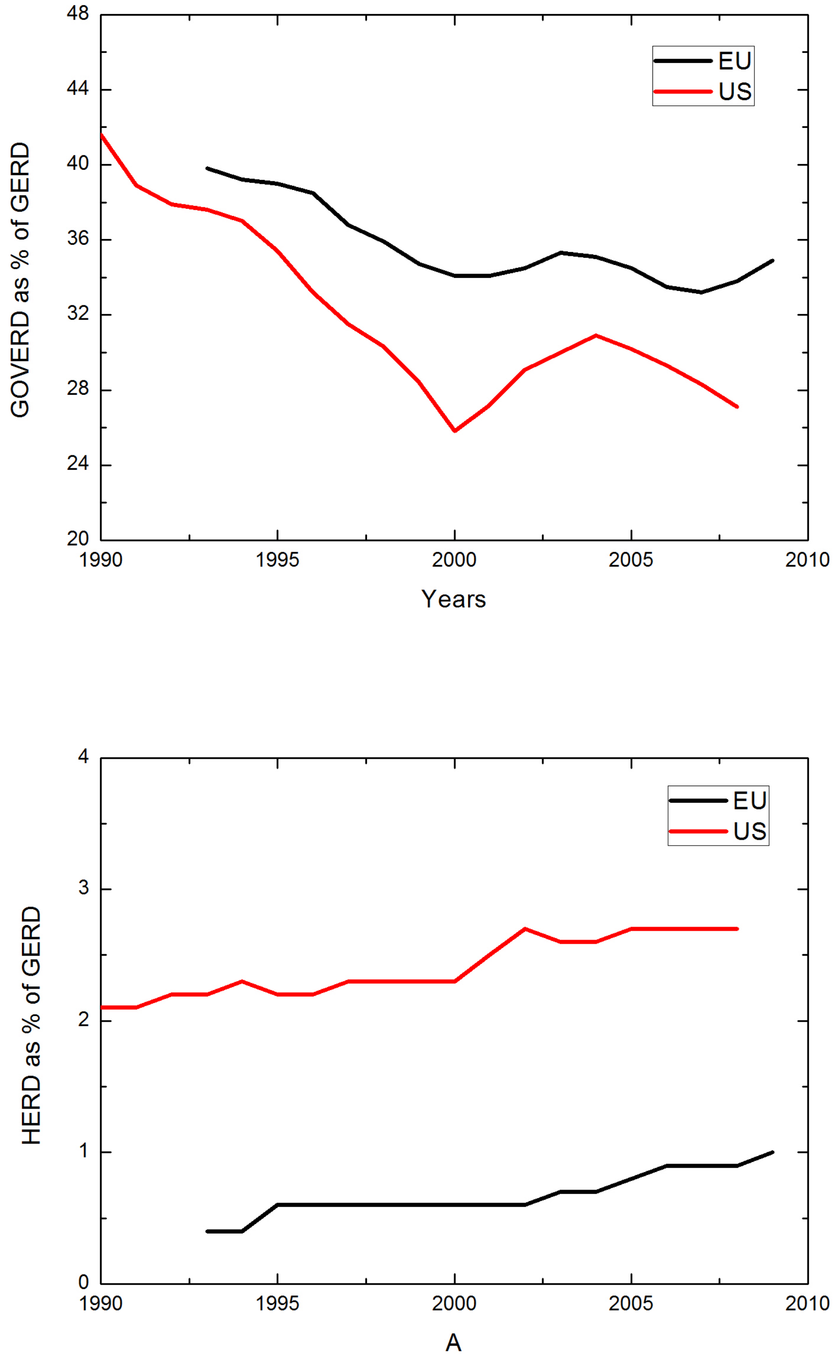
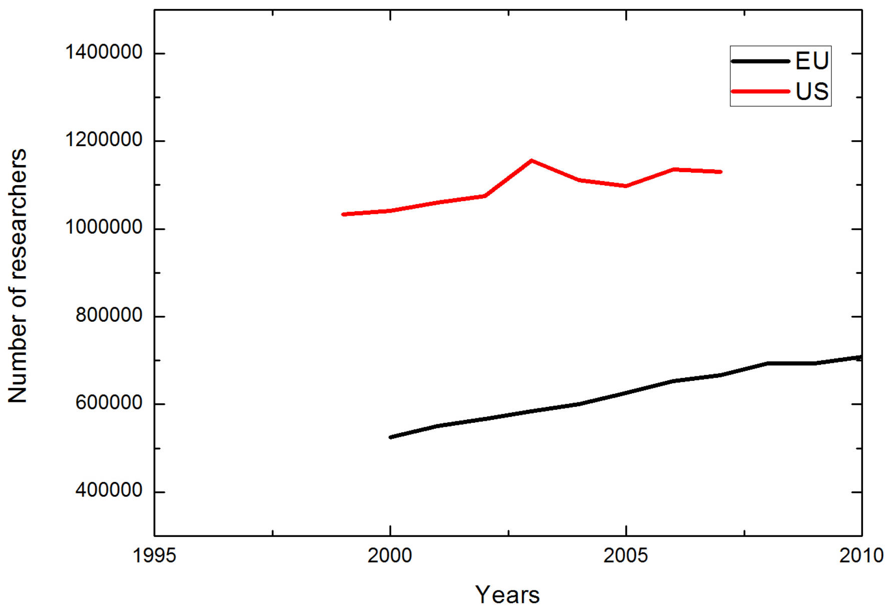


Figure 5: % of GOVERD in GERD by source of funds and % of HERD in GERD by source of funds



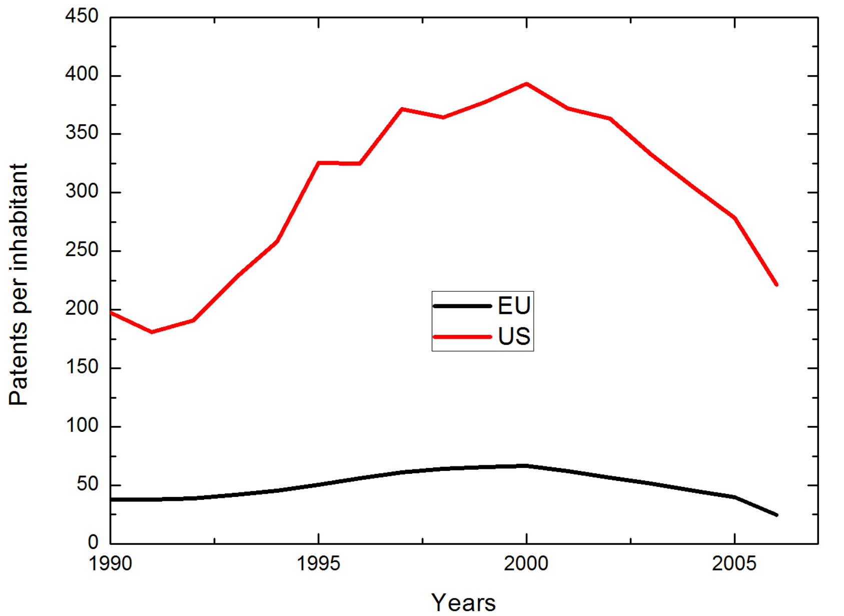
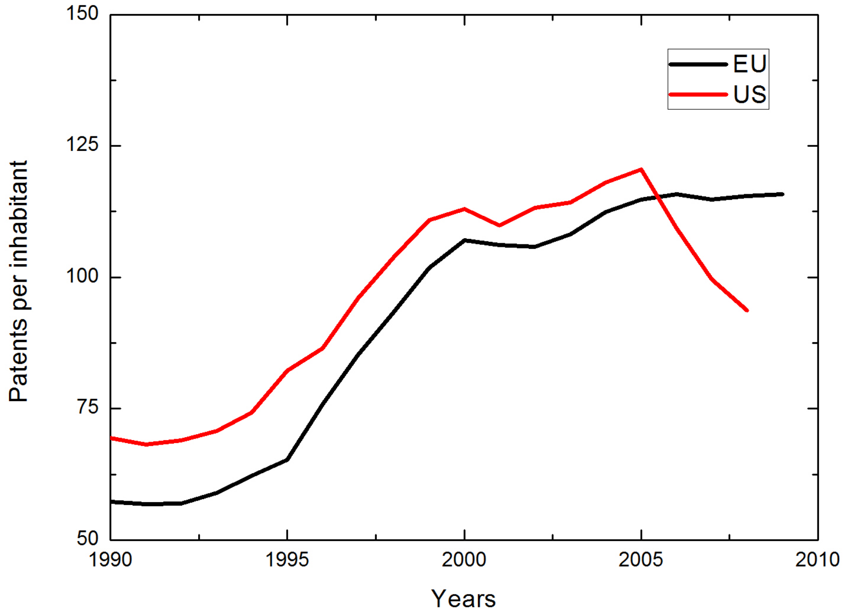


Figure 6: Total researchers (FTE) in business enterprise sector and Patents granted by the United States Patent and Trademark Office (USPTO)



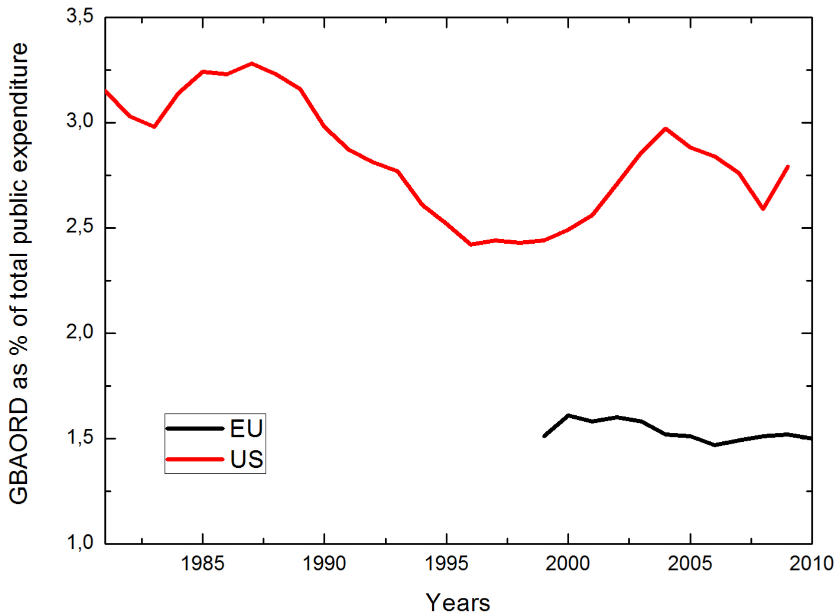


Figure 7: Patents applications to the European Patent Office (EPO) and Total GBAORD as a % of total general government expenditure

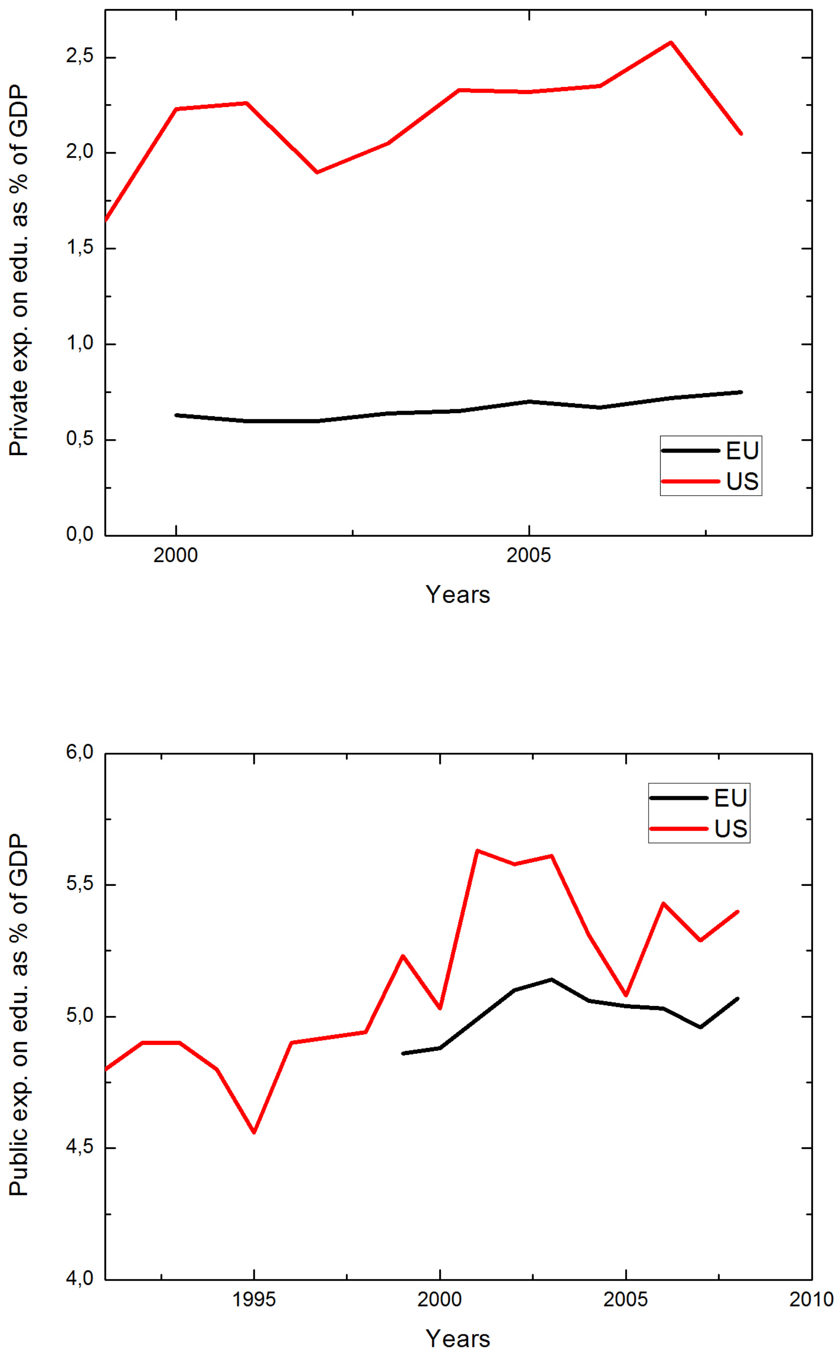


Figure 8: Private expenditure on education as % of GDP and Public expenditure on education as % of GDP

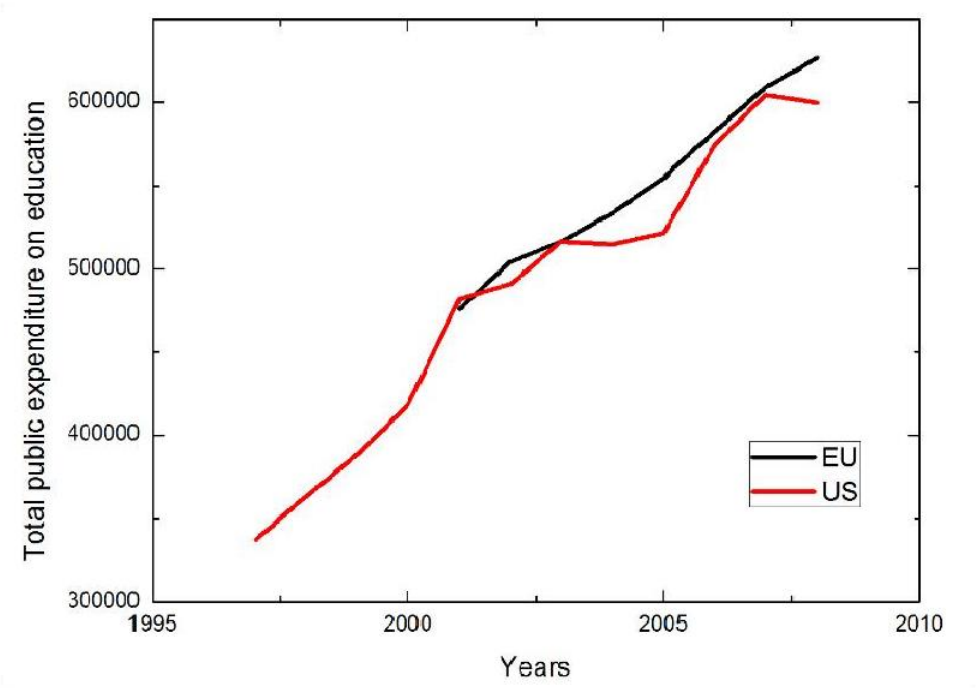


Figure 9: Total public expenditure on education Units: Millions EUR PPS

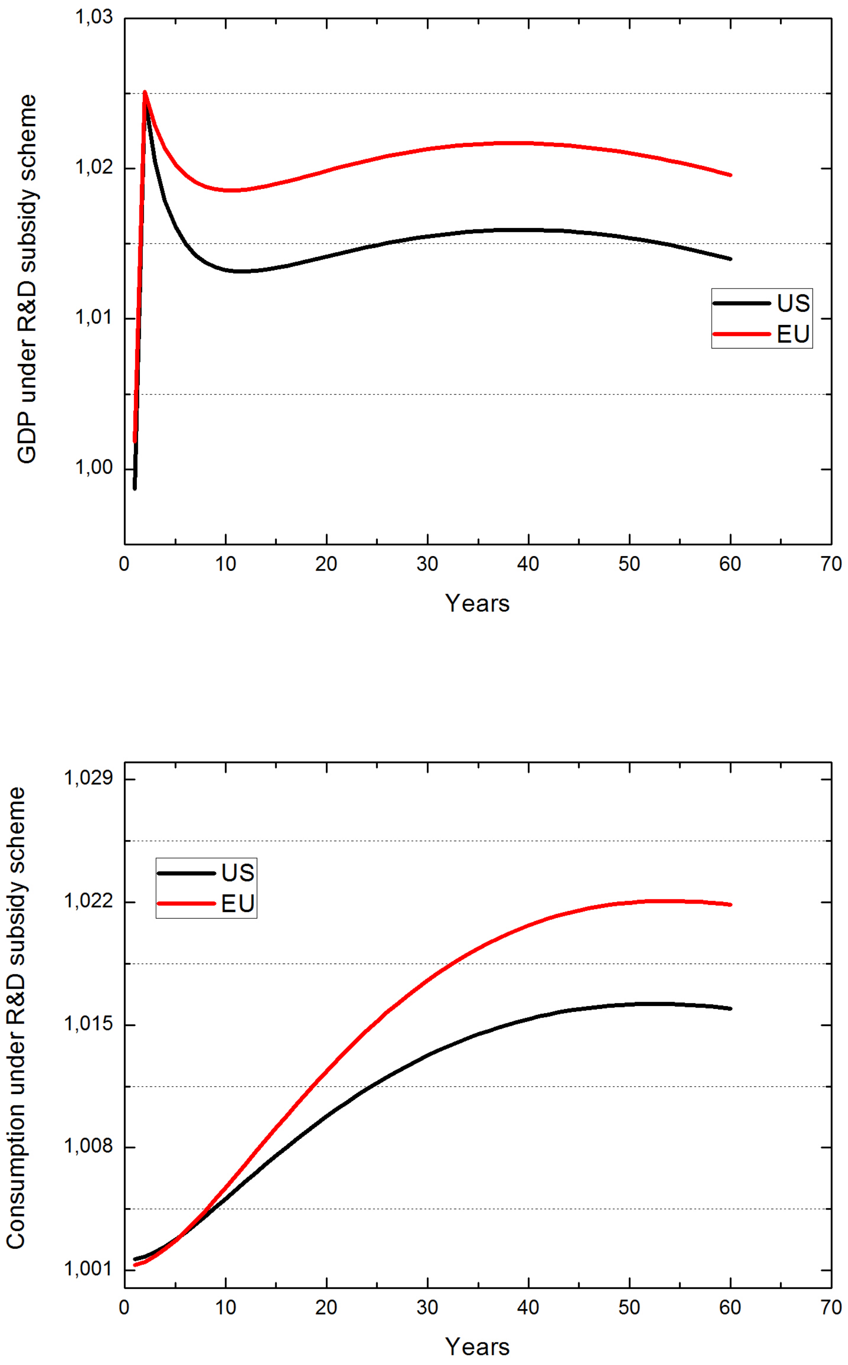


Figure 10: GDP and consumption under R&D subsidy scheme

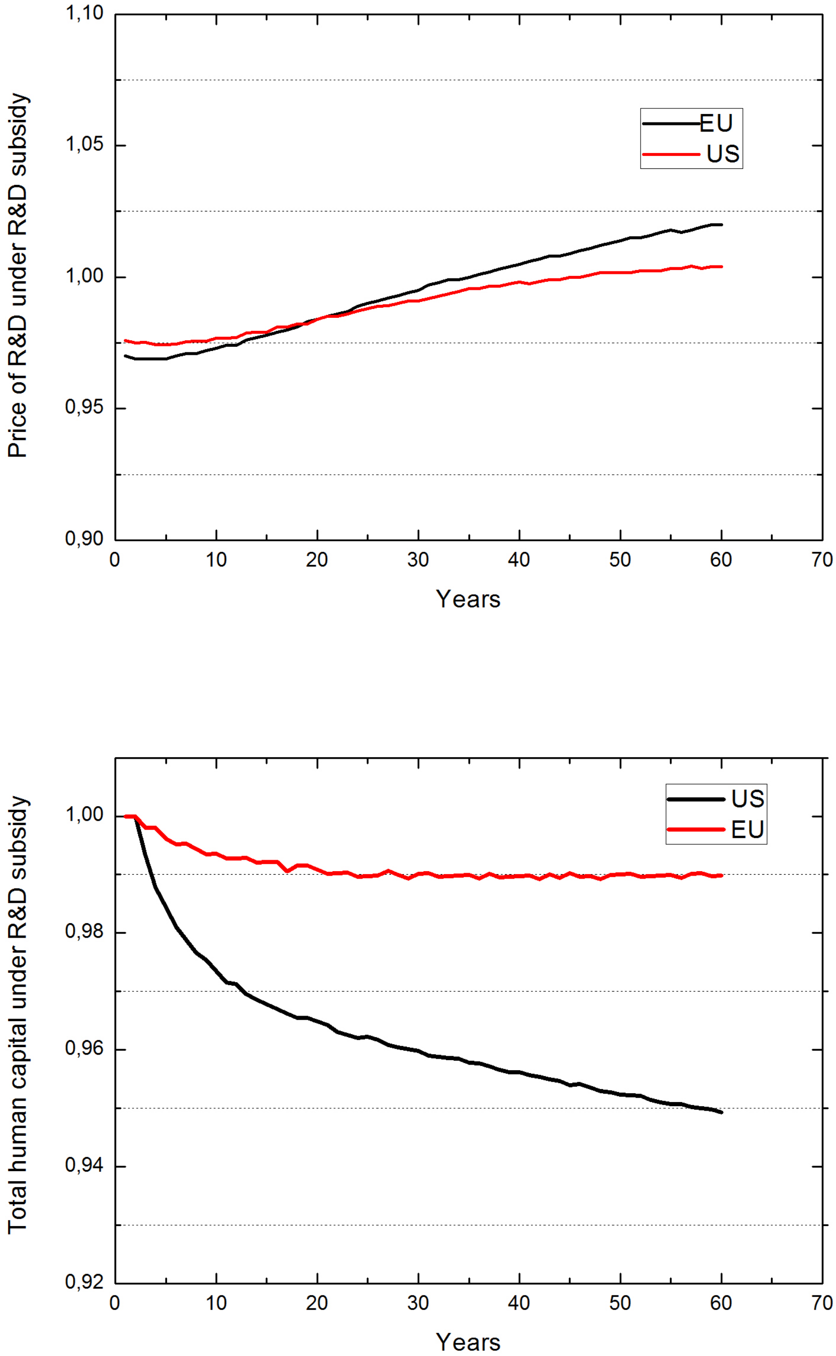
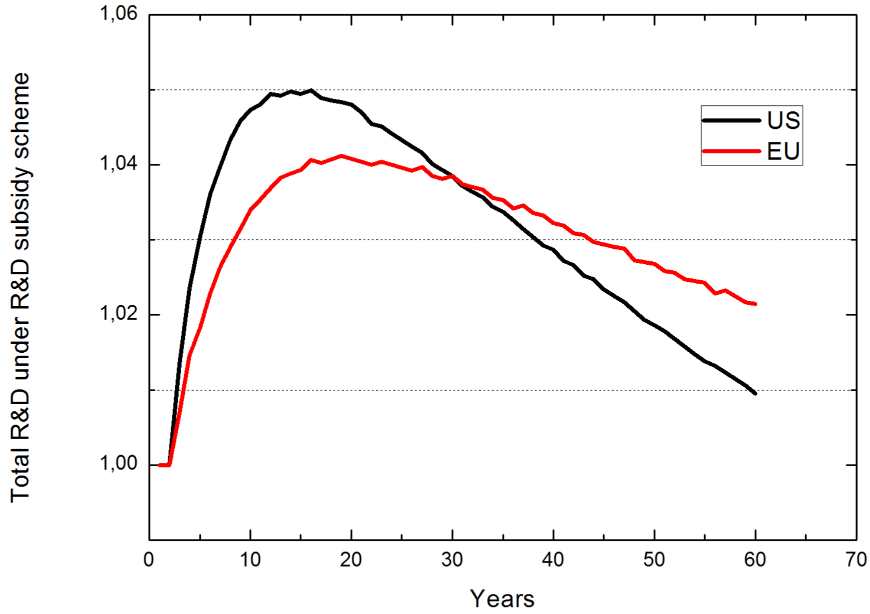


Figure 11: Price of R&D and total human capital under R&D subsidy scheme



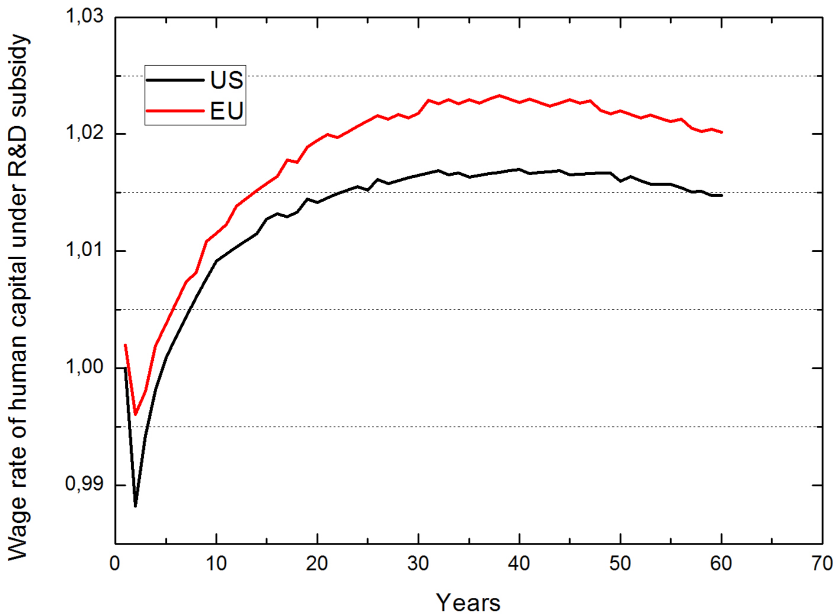


Figure 12: Total R&D and wage rate of human capital under R&D subsidy scheme

Aggregated SAM for United States with R&D (2008)		Activities		Commodities		Factors			Agents		Capital	ROW	Total
		Final Good	R&D	Final Good	R&D	Labor	Human Capital	Diff. Capital	Private HH	Gov.	Investment	Row	
Activities	Final Good			12.051.216.490.000.000								1.846.800.000.000.000	13.898.016.490.000.000
	R&D				398.883.510.000.000								398.883.510.000.000
Commodities	Final Good	7.226.968.574.800.000							3.808.531.425.200.000	1.399.800.000.000.000	1.462.716.490.000.000		13.898.016.490.000.000
	R&D										398.883.510.000.000		398.883.510.000.000
Factors	Labor	1.215.252.053.852.800											1.215.252.053.852.800
	Hum. Cap.	1.027.853.372.651.200	398.883.510.000.000										1.426.736.882.651.200
	Diff. Cap.	3.435.642.488.696.000											3.435.642.488.696.000
Agents	Private HH					1.215.252.053.852.800	1.426.736.882.651.200	3.435.642.488.696.000					6.077.631.425.200.000
	Gov.	992.300.000.000.000							407.500.000.000.000				1.399.800.000.000.000
Capital	Savings								1.861.600.000.000.000				1.861.600.000.000.000
ROW	Row			1.846.800.000.000.000									1.846.800.000.000.000
TOTAL		13.898.016.490.000.000	398.883.510.000.000	13.898.016.490.000.000	398.883.510.000.000	1.215.252.053.852.800	1.426.736.882.651.200	3.435.642.488.696.000	6.077.631.425.200.000	1.399.800.000.000.000	1.861.600.000.000.000	1.846.800.000.000.000	

Figure 13: SAM For US 2008

Aggregated SAM for European Union with R&D (2008)		Activities		Commodities		Factors			Agents		Capital	ROW	Total
		Final Good	R&D	Final Good	R&D	Labor	Human Capital	Diff. Capital	Private HH	Gov.	Investment	Row	
Activities	Final Good			10.350.000.000.000.000								7.550.000.000.000.000	17.900.000.000.000.000
	R&D				350.000.000.000.000								350.000.000.000.000
Commodities	Final Good	9.308.000.000.000.000							4.132.799.000.000.000	2.810.000.000.000.000	1.649.201.000.000.000		17.900.000.000.000.000
	R&D										350.000.000.000.000		350.000.000.000.000
Factors	Labor	1.566.715.400.000.000											1.566.715.400.000.000
	Hum. Cap.	1.325.119.100.000.000	350.000.000.000.000										1.675.119.100.000.000
	Diff. Cap.	4.429.265.500.000.000											4.429.265.500.000.000
Agents	Private HH					1.566.715.400.000.000	1.675.119.100.000.000	4.429.265.500.000.000					7.671.100.000.000.000
	Gov.	1.270.900.000.000.000							1.539.100.000.000.000				2.810.000.000.000.000
Capital	Savings								1.999.201.000.000.000				1.999.201.000.000.000
ROW	Row			7.550.000.000.000.000									7.550.000.000.000.000
TOTAL		17.900.000.000.000.000	350.000.000.000.000	17.900.000.000.000.000	350.000.000.000.000	1.566.715.400.000.000	1.675.119.100.000.000	4.429.265.500.000.000	7.671.100.000.000.000	2.810.000.000.000.000	1.999.201.000.000.000	7.550.000.000.000.000	

Figure 14: SAM For EU 2008

	EU				US			
Years	BERD	HERD	GOVERD	OTHER	BERD	HERD	GOVERD	OTHER
1999	64%	20%	14%	0.5%	74%	11%	11%	3%
2000	65%	20%	13%	0.5%	74%	11%	10%	3%
2001	64%	21%	13%	0.5%	72%	12%	11%	4%
2002	63%	22%	12%	1%	70%	13%	12%	4%
2003	63%	22%	13%	1%	69%	13%	12%	4%
2004	63%	22%	13%	1%	69%	14%	12%	3%
2005	62%	22%	13%	1%	69%	14%	12%	3%
2006	63%	22%	12%	1%	71%	13%	11%	3%
2007	63%	22%	12%	1%	72%	13%	10%	3%
2008	63%	23%	12%	1%	72%	12%	10%	3%

Table 2: Splitting GERD by the sectors of performance Data source: Eurostat

	% of GERD		In absolute PPP b€	
2003	EU	US	EU	US
GERD (total)	100%	100%	202b€	271b€
Private	55%	63%	110b€	171b€
Public	35%	31%	70b€	85b€
Other	11%	6%	22b€	15b€

Table 3: Splitting The GERD by the sources of funds Data source: Eurostat

	Graduation from tertiary education		Growth rate	
Years	EU	US	EU	US
2000	2,848.912	2,150.954	—	—
2001	3,075.560	2,174.142	0.08	0.01
2002	3,208.865	2,238.327	0.04	0.02
2003	3,466.797	2,352.271	0.08	0.05
2004	3,595.504	2,473.299	0.03	0.05
2005	3,860.042	2,557.595	0.07	0.03
2006	3,846.498	2,639.006	-0.03	0.03
2007	3,955.204	2,704.070	0.02	0.02
2008	4,368.285	2,782.270	0.1	0.02
2009	4,305.148	2,881.557	-0.01	0.03

Table 4: Annual data graduation on from tertiary education according to ISCED97 Data source: Eurostat

GBAORD - R&D Appropriations

Years	EU	US
2004	72,483.751	106,350.964
2005	75,490.621	109,803.413
2006	77,632.048	110,818.804
2007	82,358.787	115,142.66
2008	86,393.632	112,655.692
2009	87,849.862	124,550.968
2010	90,000.152	—

Table 5: GBAORD - R&D Appropriations Data source: Eurostat

GBAORD - Education

Years	EU	US
2007	759.609	364.359
2008	1,162.556	333.932
2009	1,170.754	355.609
2010	1,234.863	—

Table 6: GBAORD - Education Data source: Eurostat

R&D Appropriations Data source: Eurostat

Years	EU	US
2004	0.71	1.07
2005	0.71	1.04
2006	0.68	1.02
2007	0.68	1.01
2008	0.71	1.01
2009	0.77	1.19
2010	0.76	—

Table 7: GBAORD - R&D Appropriations as % of GDP Data source: Eurostat

	Education	
Years	EU	US
2007	1.5	1.1
2008	2.3	1.1
2009	2.3	1.1
2010	2.5	—

Table 8: GBAORD - Education Data source: Eurostat

Public Expenditure on Education

Years	EU	US
1999	4.86	5.23
2000	4.88	5.03
2001	4.99	5.63
2002	5.10	5.58
2003	5.14	5.61
2004	5.06	5.31
2005	5.04	5.08
2006	5.03	5.43
2007	4.96	5.29
2008	5.07	5.4

Table 9: Public expenditure on education as a % of GDP Data source: Eurostat