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Faculty of Social Sciences
Institute of Economic Studies

Master Thesis

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Master Thesis:

The estimation of country – level production function aimed at understanding the role of human capital

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Declaration of Authorship

The author hereby declares that she compiled this thesis independently, using only listed resources and the literature. This thesis has not been used to obtain a different or the same degree.

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In Prague, May 16, 2013

Signature

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Abstract

Our goal is the estimation of country – level production function aimed at understanding the role of human capital. We analyze the effect of education, especially the effect of the share of college graduates in prime-age population (between 25 – 54 years) on the European Union (EU) countries' labor productivity. Here, an important issue is efficiency of tertiary education institutions. We split the ratio of human capital to observe it from different aspects. We compare an effect of lower and upper tertiary educated, by specializations and by gender. The relationship between human capital and labor productivity was found positive though not significant or significant only on 10 % confidence level. The influence of human capital on labor productivity was found very low, in some cases even negative. Assuming that one of the main reasons behind these contra-intuitive results is the problem of unobserved heterogeneity, we also run instrumental variable estimation. We found positive and significant on 5 % confidence level relationship between human capital and labor productivity. The influence of larger share of tertiary educated people on labor productivity is more evident after some period of time, in our example after two years.

Keywords: human capital, labor productivity, European Union, production function

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Abstrakt

Naším cieľom je odhad úrovne produkčnej funkcie v krajinách zamerané na pochopenie úlohy ľudského kapitálu. Analyzujeme vplyv vzdelania, najmä vplyv terciálne vzdelanej populácie v rozpätí 25 až 54 rokov, taktiež nazvané produktívny vek, na produktivitu v krajinách Európskej únie (EÚ). Dôležitou otázkou je efektívnosť inštitúcií terciárneho vzdelávania. Neskôr sme sledovali podiel ľudského kapitálu z rôznych hľadísk. Porovnávame efekt nižšieho a vyššieho terciárneho vzdelania, odlišné špecializácie a podľa pohlavia. Vzťah medzi ľudským kapitálom a produktivitou práce bol nájdený ako nevýznamný alebo významný len na 10% úrovni spoľahlivosti. Vplyv ľudského kapitálu na produktivitu práce bol nájdený ekonomicky nevýrazný, v niektorých prípadoch dokonca negatívny. Za predpokladu, že jedna z hlavných príčin týchto proti-intuitívnych výsledkov je problém spôsobený nepozorovanou heterogenitou, riešenie hľadíme pomocou odhadu inštrumentálnej premennej. Zistili sme pozitívny a významný na 5% hladine spoľahlivosti vplyv ľudského kapitálu na produktivitu práce. Vplyv vysokoškolsky vzdelaných ľudí na produktivitu práce bol zreteľný po určitom období, v našom prípade po dvoch rokoch.

Kľúčové slová: ľudský kapitál, produktivita práce, Európska únia, produkčná funkcia

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Acronyms

EU – European Union

OECD –The Organisation for Economic Co-operation and Development

GDP – gross domestic product

Master Thesis Proposal

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Proposed Topic:

Trends in college enrolment analyzed by gender and its economic consequences to members of European Union

Topic Characteristics:

My thesis will follow theoretical arguments, which proved that education plays positive role in the growth productivity, supporting quality and brings benefits on the labour market. Educational attainment is viewed as a reproducible factor of production. I will emphasize on the human capital theory, neoclassical growth model, knowledge spillovers and watch the sheepskin effect. These theories described that higher educational level will raise the transitional growth rate; will bring greater prosperity, increase welfare, competitiveness and should experience higher rates of economic growth. This paper will also focus on measurement of effectiveness between men and women and will compare differences in gender in the labour market and gain from productivity. I am studying European integration, so disparities will be monitoring in European Union, especially in 108 NUTS II regions of the EU. Firstly, I am going to collect data from Eurostat, UNESCO, World Bank and OECD and statistically analyze the development of regions. Economies with higher levels of educational attainment should bring higher rates of productivity efficiency. Secondly, this work will observe the differences in gender from life-time productivity, their economic activity and awards. Thirdly, I will verify results with endogenous econometric growth model; find the positive relationship between education and labour productivity and find the ratio of economic effectiveness in gender. I will run a multiple regression analysis to get better results and to avoid measurement errors in the regressions and analyse growth effect of human capital.

Hypotheses:

1. Positive relationship between education and labor productivity
2. There are pronounced differences among European Union
3. The southern European regions are less productive than the northern one
4. The estimated productivity effects of education did not change over time
5. Men are more awards than women in EU
6. There is deepening gap in trends in college enrolment by gender

Methodology:

Firstly I'm going to collect data from the sources mentioned above and compare results in EU regions. Educational level will be monitored generally, by type of degree (trends in the number of associate's, bachelor's, master's and doctorate's) and by gender. Then I will compare the differences in sexes by number of degrees awarded, their labour productivity and their value brought to the total GDP. I will use simple statistical methods, graphs and tables. Lastly, I will linkage theoretical arguments with my assumptions and verify the results with econometric model. With the purpose of undertaking a balanced and sustained analysis of European regions, will be analyzed between 1993 and 2010, which will allow us to estimate panel data. I will run multiple regressions to get better results and to avoid heteroskedasticity, using both OLS and instrumental variables to control each other. I will confirm results by sigma convergence; this type is measured by the standard deviation of the variable transformed into natural logarithms. I will estimate educational structure of population and compare with situation on the labour market of college graduates in individual countries. I will measure differences between countries and investigate indicator of college graduates on the labour market in European Union members.

Outline:

1. Theoretical linkages between educational level and productivity growth
2. Statistical analysis on development of disparities in EU regions
   1. Educational level
   2. Trends in gender
3. Observation of economic efficiency by gender
   1. Life – time productivity
   2. Economic activity
   3. Awards
4. Analysis of data in econometric model
   1. Description of empirical design
   2. Relationship between education and labor productivity
   3. Ratio of economic effectiveness in gender
   4. Interpretation of estimated results
5. Conclusion
   1. Explanation of results
   2. Concluding remarks

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Author

Supervisor

1 Introduction

Our goal is the estimation of country – level production function aimed at understanding the role of human capital. We analyze the effect of education, especially the effect of the share of college graduates in prime-age population (between 25 – 54 years) on the European Union (EU) countries' labor productivity. We want to find out whether countries should invest more to tertiary education. The topic concerning comparison between people with tertiary education and unskilled ones and their benefits to economy is controversial. Here, the important issue is efficiency. We estimate how strong the link is presented in states of EU (27) and we compare differences across EU. Similar studies have been made in US, in OECD countries, but our contribution will be in observing an effect directly across European members. We observe tertiary education divided by upper and lower educational level. In other words, we estimate if additional years of tertiary education matter, and the extent of its influence to economic productivity. The importance of tertiary education and its effect to economic productivity of countries is much debated.

We want to observe the effect of variables concerning tertiary education to labor productivity and propose policy implications and suggest future tools for decision makers. We compare our results with proposed and confirmed Lisbon Strategy – Europe 2020. The proposal is to increase tertiary education to 40 % across EU. Important question here is comparison of quality represented by efficiency and quantity represented by increasing capacity and easier access to universities.

In section 1 we describe theoretical base and we explain individual expressions. Then we go through proposed estimation to set our model correctly and to have a better overview. We compare opinions which support or contradict to our hypothesis. Then we specify a way of estimation and which effects we should include into our model. This is included in section 2. In section 3 is explained methology, we use augmented Solow model. Section 4 describes used data, variables and goes step by step through all regressions. This part consists of discussion and comments of the results as well. Section 5 is conclusion, followed by Bibliography in section 6 and Appendix.

1.1 Hypotheses

We decided to write our thesis based on the following primary hypotheses:

1. Labor productivity is influenced also by education
2. Educated labor force represents creative and innovative thinking, best-usage of technology, higher competitiveness, and demand for labor force from outside, which directly or indirectly have pattern on labor productivity
3. There is a significant positive relationship between tertiary educated and labor productivity
4. They are significant differences in correlation between tertiary education and labor productivity among EU members
5. The effect of tertiary education is changing over time
6. There is a significant difference between genders in college graduated. We suppose that women are less flexible on the labor market than men.

1.2 Tertiary education

Tertiary education builds on secondary education, providing learning activities in specialised fields of education. It aims at learning at a high level of complexity and specialisation of particular field. Tertiary education includes what is commonly understood as academic education, but is broader than that, because it also includes advanced vocational or professional education. Tertiary education comprises ISCED levels 5 and 6 (UNESCO, Institute for Statistics, 2011).

1.2.1 Tertiary education across European Union

We will describe the chosen subgroup (the population with tertiary education between 25 and 54 years old) in section 4, but for general overview and for future policy implications we would like to describe the actual situation on the market of tertiary educated people.Total number of students enrolled in tertiary education in EU 27 in 2010 was 19 846 700 (Eurostat, 2010). A median age in EU 27 was 22.1 year. The comparison of gender between tertiary obtained populations between 30 – 34 years old was 38.5 % of women and 30.8 % of men. The highest ratio of obtaining tertiary enrolment was shown in United Kingdom (UK), Norway, Ireland and Luxembourg. Almost in all countries, female to male ratio is relatively higher. On average, in EU 27, 124 women were enrolled for every 100 men in tertiary education. The total number of graduates in EU 27 was 4 477 000 students in 2010. But during the period 2000 – 2009, the rate of tertiary educated people increased about 22% (See Graph 1, in Appendix). There are approximately 3 300 higher education establishments in European Union (Key data on education, 2012).

1.3 Human capital

Human capital represents ‘activities that influence future real income though the imbedding of resources in people.’ (Becker, 1962). It is the most valuable asset held by individuals on the labor market.

1.4 Definition of productivity

Productivity is commonly defined as a ratio of a volume measure of output to a measure of input use (OECD, 2001). Then the labor productivity, describing the relationship between production and factors of production, is defined as output per unit of labor input. The driving forces behind improvements in labour productivity are the accumulation of machinery and equipment, improvements in organisation as well as physical and institutional infrastructures, improved health and skills of workers (“human capital”) and the generation of new technology (Key indicators of the Labor market, 2002). Labor productivity reflects the economic level in the given state. In our case, the ratio is measured by volume of output, which is represented by the gross domestic product in real terms (GDP) and input is presented by total population in productive age. We chose total population to measure education variables for the same set of people. Education should be providing under reasonable costs as a fair value of share of total government expenditures and output. The topic if education is valuable to society and if individuals and whole society are receiving back expected benefits is much debated. Here, an important issue is efficiency understood as obtained quality of service from the given amount of resources and effectiveness.

1.5 The level of importance of education and relationship between technology and tertiary education

We assumed that highly educated people are connected with an access to new tehnologies more than uneducated ones. From the private point of view, education increases productivity, entrepreneurship, specialization in different fields, and support a variety of jobs. From the public point of view, education is connected with increase in R&D, governance, safety and social development issues. All these effects help to economic growth of the country through reducing poverty. But, on the other hand, the disadvantages are in increased spending into education, time dedicated to education, lower tax revenues, for instance. These both sides should be at least equal.

Related to human capital theory, an income in countries is distributed by the level of education of workers. Individuals can gain more, because of obtained education. We expect the better results on the labor market from skilled ones. Higher ratio of efficiency is expected. The mentioned microeconomic assumptions are implemented into our model as they were estimated by many authors. For example, benefits of educated people are showed by social returns to higher education by Acemoglu, Angrist 2000, Moretti 2004. The positive productivity spillovers are proved by Moretti (2004). He observed a positive relationship between wages and education in cities. Steven Yamarik and Randall King (2001) found that social return of 4-years college degree is 0.099 % per year. They also confirmed the positive relationship between higher education and labor productivity.

Barro and Sala-i-Martin (1994) found that increase in tertiary education of 0.09 years raised an annual economic growth by 0.5 % per year. They proved a positive correlation between gross domestic product (GDP) and human capital. In other words, the higher ratio of human capital brought higher economic growth. An increase of productivity is supported by 4-years college attention, no by additional years of schooling, as Schultz (1961) pointed out, the social return of 4-years college is decreasing over time. The research by Stoyanov & Zubanov (2011) in Danish companies showed that the effect of productivity spillovers by educated workers or more skilled workers is positively correlated. Moretti (2004) in his paper work stated that spillovers are all around us. All these estimations are in favour of hypothesis, that productivity is increased by educational level of workers. The results of paper ran by Vieira Elvira, Vazques-Rozas Emilia & Neira Isabel (2008) were in favour of poorer companies, where the productivity effect had been presented stronger than in richer companies. They showed that investments in education and R&D are more profitable in less developed countries.

Human capital is crucial for successful adoption of technology (Acemoglu, and Zilibotti, 2001). Human capital intensity causes an indirect effect to technology and it improves the circle of economic output. Countries can reach a similar access to same set of technologies thanks to process of globalization. But, because of accumulation of technology-skill mismatch, there will be a significant difference. An increase of one unit of R&D expenditures over GDP can increase the productivity growth by 0.85 units (Hector Sala, José I.Silva, 2011). A strong relationship between producing and accepting new technology is also discussed in paper by Schultz (1967) or Nelson and Phelps (1966). The presence of the link between economic growth and human capital via knowledge spillovers was found in work of Lucas (1988). Romer (1990) stated that society with more educated workers can achieve better ideas and can grow faster. An opinion of focusing more on innovation, exchange of learning process and learning by doing not on the differences in prices was presented by Daron Acemoglu & Joshua Angrist (2000). Generally, on average in G8 members (Canada, France, Germany, Italy, Japan, Russia, United Kingdom and United States) spending of GDP to education is between 4 – 7% (OECD, 2006). The government spending on tertiary institutions discusses an adequate quality given to these institutions. Here, an important issue is securing an adequate financing of universities. In 2008, the EU has spent 5% of GDP on education in general and 1.3% of GDP on tertiary education. The share is quiet inconsistent, if we compare costs of primary and tertiary education which are almost twice as high (Key data on education, 2012).

As we mentioned, technology goes hand in hand with highly skilled workers. An innovative country can attract more investors and more capital, which leads to an increase in labor productivity. More skilled human capital is more attractive to foreign investors. It can be presented as a circle. Educated people are producing innovative and creative thinking, which will secure best-usage of technology and higher ratio of accumulation of knowledge, followed by knowledge spillovers with a positive contribution to labor productivity, which can lead to reducing inefficiency (Couto, Vieria, Tiago and Natario, 2006).

1.6 Lisbon strategy 2020

One of the main principles of EU is to secure a free movement of labor across members. The assumption behind supports the idea that more qualified labor force will increase the economic growth in EU countries simultaneously. Lisbon strategy for the education and training 2020 agreed on modernization of the education system. The main aim is focused on constructing Europe as the most competitive and dynamic knowledge economy in the world, in other words to secure sustainable, smart and inclusive growth notably by equipping citizens with the skills and competences (Luce Pepin, 2011). One of the medium how to reach these aims is the increase of the percentage of higher educated people to 40 %. Actual percentage of this ratio across EU is showed in Appendix (Table 13). Currently, one of three people holds diploma between 25 and 34 years old. Here, an important question is if this proposed massification of tertiary education does not go into the conflict with quality of education. On the one hand, we have an increase of investment into education to fight unemployment and poverty. On the other hand, we deal with an increasing ratio of overqualified people and massification of institutions. There are significant share of tertiary students, who are overqualified for future positions. Currently, more than one of fifth students are overqualified for his position and this rate has been increasing since 2000. The specialization of tertiary educated is changing in the opposite direction than is desirable. There is a decreasing number of a student enrolled in sciences, mathematics and computing studies and increasing number of students enrolled in business (Key data on education, 2012).

Higher education is limited, in other words it is not available for all people. The topic if we should increase the number of college graduates and increase a capacity of universities to make them more available for population or we should focus more on quality of education, increase efficiency and prefer less people higher educated but more skilled is controversial.

2 Literature review

This section is dedicated to similar papers and works done to observe the methods of estimation of relationship between human capital and labor productivity from different points of view.

2.1 Demand for tertiary educated

Higher education with adequate quality is considered to fulfil two main strategies as generating additional revenues and increasing productivity (Philip Stevens and Martin Weale, 2003). Bassanini (2001) came to conclusion, that there is a possible increase in labor productivity affected by human capital.

Poelhekke (2007) by estimating German metropolitan areas pointed out, that aggregate productivity growth is in the large extent caused by share of college graduates. Similar studies done on American MSAs concluded the same results, that the higher share of college graduates increased aggregate productivity. Especially in Germany the amount of vocational training students was in a positive relationship with economic growth. For every 10% increase in share of college educated workers, the size of the skill-growth effect for American cities was 0.8% as recently shown by Shapiro (2006). By using the method of instrumental variables estimation, there were found an evidence of relationship between college graduates and employment growth. Around 60% of the employment growth effect of college graduates is due to enhanced productivity growth, but there is no evidence between high school graduates and employment growth. In this paper was also shown that higher education can support productivity directly as well indirectly by improving quality of life and adding other positive externalities (Jesse M. Shapiro, 2006). However, we need to mention, that a larger percentage of human capital can bring more benefits in quality of life rather than in economic productivity. The externalities can be observed in different utilities of consumption, less crime and less pollution. This effect was observed in cities, but it can be a good direction to follow. We can transform microeconomic level into macroeconomic one and include this assumption into our regression. The size of the city or the size of state member can have a significant influence and can be correlated with employment growth. A larger labor market or agglomerations are more attractive for skilled workers. A positive productivity shocks attract higher share of college graduates and the workers are available to bring more benefits. We can find a positive correlation between the size of the cities and the share of tertiary educated people and we will discuss it later in section 4.

Here, we deal with the issue, why we consider only tertiary education to be significant trough European members. Basically, primary and secondary education is expected and obligatory through members, so we expect that it will not have a significant correlation to labor productivity. Anyway to confirm the hypothesis, we include the ratio of primary and secondary graduated students into our regression. Jenkins (1995) by observing data in United Kingdom compared the index of total factor productivity and its relationship to different levels of education. He confirmed that one percent of increase in education qualifications will increase an annual growth by 0.42 units. Bacolod, Blum& Strange (2007) in their paper work showed, that cognitive skills, which are supposed to be possessed by college graduates, are more productivity enhancing than motor skills. They confirmed the theory, that the best indicator of local productivity can be the share of college graduates. Usage of college skills and share of college graduates in population were estimated by Barbara Gebicka and Anna Lovasz, 2011. Their results based on worker-level data in the Czech Republic, Hungary and Slovakia confirmed the positive influence of the number of skilled workers on the demand for them (Barbara Gebicka and Anna Lovasz, 2011).

Another interesting point is that younger skilled workers can be more productive than the older ones. It is derived from changing technology, younger can adapt more rapidly and are more familiar with concept of new technologies. Especially information technologies are connected with new methods used in organization and better access to new technologies which are in favour of younger ones (Bresnahan, Brynjolfsson, Hitt, 2002). High–years educated can better secure catch-up because of best-practice technology. The attraction between college graduates and advanced technology is deeper. We will consider this assumption in our estimations and we observe an effect trough European Union in section 4.

2.2 Contradiction to our hypothesis

We assumed that there is a positive relationship between tertiary educated and labor productivity. Productivity is significantly conditional on education. Here, we would like to mention an opposite opinions to our hypothesis. The research by Barro in 1997 showed that one extra year of education for men can raise growth rate by 1.2% per year. But from his studies we can conclude that growth of education is conditionally given by initial level of output of country. Those with lower incomes try to catch up those with higher incomes. In his results, an increase in education will end up not in faster growth, but in higher output. In long-term it can reduce the return of education. Studies made by Krueger & Lindahl (2001) showed, that a positive and significant relationship was proved only in countries with the lowest level of education. They estimated the relationship between years of education and economic growth. Higher levels of education were brought a decreasing rate of growth as was pointed by Barro. Edwards Terence Huw showed that the increase in technological spillovers or the rise of educational productivity can be found, but not both. Studies made by Jean–Luc De Meulemeester & Denis Rochat in 1995 supported the idea of importance of higher education, but it was not sufficient for growth. They found a strong positive relationship in US, Japan, UK, France and Sweden, but not in Australia and Italy. Another contradiction to our hypothesis was found in Fortin (2006) and Bound (2004) through estimation in US states. They found the positive correlation between economic growth and high-school educated workers variable not for college graduates. Here, the main problem was a significant influence of migration.

2.4 Empirical research – how to estimate the effect of human capital

Sheepskin effect or credential effect, introduced by Spence (1974) is defined as the wage gap between credential and non- credential workers conditional on years of schooling. It raised the issue of signalling theory. In other words, person holding degree should be more productive on the labor market. It specifies a relationship of the increase in labor market earnings associated with the completion with diploma or degree gained in high school or university. Skills vary through different fields of studies. To identify a sheepskin effect properly as authors argued, we should include in regression both, years of schooling and degree status, because these two measures can obtain different results. The regression showed an important difference in skill between individuals holding the same degree status (Alfonso Flores-Lagunes, Audrey Light, 2007). Many studies explained that only years of study can be relevant to measure for human capital. In estimation done by Mincer (1974) was shown a positive correlation between human capital and individual earnings. Estimation was done between years of schooling and outcome on the labor market, earnings. In this model only years of education mattered, not the degree status. But the main limitations behind model are just a little relevance for policy makers, because the lack of interpretation. On the other hand, pure credentials theory believed, that only diploma matters, and years of schooling have no impact to economic growth. This theory thinks of degree as an independent variable of return of investing to education. Alternatively we can observe years of schooling with degree status, which is directly an observation of sheepskin effect. But in our estimation we will focus mostly on degree status.

More ways to estimate education were proposed by Dean (2002). These are direct pricing output, which means a direct collection of data for detailed services (Sergueev,1998), direct measurement of output, borrowed price parities approach, which means an adoption of price parities for market and non market services, labor productivity indicator, which means an output ratio by adjusting labor inputs, wage equation approach, where outputs are followed by estimation of wages, the compensation weights approach, which means a labor compensation of output ratios (OECD).

Lucas (1988) described human capital as a fraction of physical capital determined by total factor productivity. Human and physical capital is assumed to increase the returns of scale. Output can grow without limit, because in this model it depends only on production factors (Philip Stevens, Martin Weale, 2003). Here, we assumed human capital as a share of worker time devoted to market production, time devoted to education and saving rate to be endogenous. Given our goal to explain cross-country differences in human capital formation, this method cannot be used because of the macroeconomic characteristics of our data.

The lack of education is one of the reasons, why countries cannot get advantage of available technologies, followed by mismanagement of economy. Kneller and Stevens (2002) tried to solve this problem by using stochastic frontier analysis. They set output as a main variable and capital stock, labor input (hours worked per week), human capital, random disturbances and economic inefficiency were on the right side of the equation.

3 Methodology

In this section we will go through augmented Solow model, which is used as a theoretical base for our hypothesis and estimation. Then we will explain the fixed effects model – the estimation method applied in our analysis.

3.1 The augmented Solow model including Human capital and R&D

Solow model or exogenous growth model explains a long run economic growth, considering the following factors: labor productivity, capital stock, population growth and technological progress. This model exhibits diminishing returns to labor and capital separately and constant returns to both factors jointly (Todaro & Smith, 2006). The growth rate of capital and labor are weighted by respective income share. Since weights add up to one output will grow by one unit, if both, capital and labor grow by an extra one unit, which is the definition of constant returns to scale (CRS). The main problem of Solow model is that it considers all production factors to be exogenous, in other words, to be independent of economic growth. But if we follow our hypothesis, there is a two-way correlation between education and economic growth. Mankiw, Romer and Weil (1992) first came with the statement, that not only capital and labor cause economic growth, but also human capital. Mankiw (1992) uses a secondary school enrolment as a proxy for human capital and assumes that it influences labor productivity. With his approach he finds a better fitting of data than in Solow model, because he observes an income convergence by adding school enrolment into regression. While in endogenous growth model steady-state is driven by reproducible factors of production, an educational attainment can lead to permanent differences in steady-state growth in output per worker (Steven Yamarik and Randall King (2001).

Education is viewed as a reproducible factor of production at the macroeconomic level. The aggregate production function shows a relationship between inputs, i.e. production factors and output. We will follow the direction of the above mentioned economists when formulating the aggregate production function. The variable representing output is gross domestic product (GDP). Among the factors of production we will not include enrolment rates, but total number of graduated people with tertiary education to observe human capital and its effect more precisely. We will also add a variable R, which is the stock of know-how created by R&D in year t (Ben S. Bernanke, Refet S. Gurkaynak, 2002). So we set our basic model as follows:

$$Y = Af\ (K, H, L, R) \tag{3.1}$$

Where *Y* stands for aggregate output (GDP). By input we mean capital stock *K*, human capital intensity *H*, labor *L*, R&D stocks *R* and technology parameter *A*. The parameter A represents the level of technology or multifactor productivity. An increase in technology level will cause an increase in output for any given level of inputs. By transforming the equation (3.1) into Cobb-Douglas production function, we receive the following relationship:

$$Y_t = K_t{}^{\alpha} H_t{}^{\beta} R_t{}^{\gamma} (A_t L_t)^{\delta} \tag{3.2}$$

$$\alpha + \beta + \gamma < 1 \tag{3.3}$$

Where α stands for the portion of capital income, β is a share of human capital in output, γ is a share of R&D in output, $\alpha + \beta + \gamma < 1$ shows a hypothesis of decreasing returns of scale for investments into labor productivity and δ is the portion of labor income (Solow, 1956). Under the assumption of the constant returns to scale with respect to all factors, we can deduce another relationship, $\alpha + \beta + \gamma + \delta = 1$. We will test this hypothesis in the empirical part. Dividing both sides of this equation by *L*, we will derive the model in per capita terms. Under the assumption of constant returns to scale it looks as follows:

$$.\frac{Y}{L} = (\frac{K}{L})^{\alpha} (\frac{H}{L})^{\beta} (\frac{R}{L})^{\gamma} A^{\delta} \tag{3.4}$$

If we define output, stock of capital, human capital intensity and R&D stock as quantities per effective unit of labor, then y = *Y/L*, *k=K/L*, *h=H/L* and *r=R/L*. There is no L on the right-side as long as $\delta = 1 - \alpha - \beta - \gamma$.

Then we substitute the equation (3.4) and we transform it into the logarithmic form. As the result we receive the equation for a steady state per capita income:

$$\ln y_{i,t} = \alpha \ln k_{i,t} + \beta \ln h_{i,t} + \gamma\, ln\, r_{i,t} + \delta \ln A_{i,t} \qquad (3.5)$$

This equation is different from Solow's model as income per capita depends on labor and accumulation of physical and human capital as well as R&D stock expressed in per capita terms.

Considering that there are diminishing returns to scale, i.e. if $1 < \alpha + \beta + \gamma + \delta$, the equation looks as follows:

$$\ln y_{i,t} = \delta \ln A_{i,t} + \alpha \ln k_{i,t} + \beta \ln h_{i,t} + \gamma \ln r_{i,t} + \lambda \ln L_{i,t} \qquad (3.6)$$

We will estimate both equations in section 4 to compare the influence of human capital intensity to labor productivity.

3.2. Estimation methods

We will estimate our model using fixed effects (FE) estimation method. We assumed that FE model is more appropriate for our regressions than simple OLS, because it can help us to solve the issue of endogeneity of human capital by constructing dummy variable. The base equation for the model is:

$$y_{it} = \alpha + X_{it}^T\beta + \sum_{i=1}^{N} \mu_i D_i + v_{it} \qquad (3.7)$$

Where μ_i is assumed as fixed parameters to be estimated. It works as an appropriate specification if we focus on specific set of N individuals or countries or firms, etc.... D_i is a dummy variable for the i-th country. There is a restriction to avoid dummy variable trap given on μ_i by $\sum_{i=1}^{N} \mu_i = 0$. The v_{it} is the reminder of disturbance term that varies over individual countries and time. All are classical idiosyncratic independent distributed (iid) random variables with 0 mean and varianceσ_v^2. OLS estimation of equation 3.5 is supposed to be BLUE, but in the case when we estimate N+K parameters, the first problem is the loss of degrees of freedom. The second one is that larger number of dummies can lead to multicollinearity and we will have a large $X^T X$ matrix to invert (Baltagi, 2008). We propose to use the FE approach, because we assume to reach better results. Fixed effects model controls for, or partials out, the effects of time- invariant variables with time-invariant effects (Allison, 2009). It can help us with the problem of endogeneity of human capital. We cannot confirm this assumption, because there is insufficient number of degree of freedom to estimate random effects.

4 Empirical part

In this section, we describe data, methods of estimation and regressions. We compare different techniques of estimation to make an appropriate conclusion. We make comments and analysis of results. This part is concluded by short discussion.

4.1 Data, Description of variables

Our dataset is composed of data between year 1995 and 2010. All variables are observed for 27 European Union state members. Data has been collected from Eurostat, UNESCO, WORLDBANK and OECD[1]. For the purpose of estimation we used statistical software Stata. Firstly, we changed the structure of our dataset from cross-country data into panel data, because we want to estimate the effect of tertiary education over time for many individual countries. It was important to organize them well. Otherwise it would have a significant effect to our results. We have 27 cross-sectional units and 16 time – periods. The panel used is not balanced, because of missing values, especially in less developed countries across EU and in earlier periods, which is followed with problem of using OLS. OLS is still unbiased and consistent, but its standard errors are biased. We started with the estimation of one panel model, and with simple OLS estimation to confirm this statement.

In table 1 we can see summary statistics of our basic variables. Detailed description of all variables with exact source is shown in Appendix part, Table 1.1 and 1.2.

[1] http://www.oecd.org/, http://epp.eurostat.ec.europa.eu/portal/page/portal/eurostat/home/, http://www.worldbank.org/, http://www.unesco.org/new/en/

Table 1. Summary statistics

Variable	Mean	Minimum	Maximum	Std. Dev.
L	7753660	158494	36284700	9635890
y	285501	4608	5275910	867349
k	419895	3666	8208920	1207870
r	778.66	12.05	3412.23	831.32
h	0.23	0.06	0.46	0.09

For better overview we describe a situation on EU labor market from descriptive statistics mentioned in table 1. Where y represents labor productivity, in other words output per capita, its minimum value between period 1995 and 2010 in EU members is 4608 Eur and maximum value is 5 275 910 Eur. It means that maximum value is 1145 times higher than minimum value. We need to state, that we divided all variables by total population between age 25 and 54, not all population is included. That explains such a high numbers. Total population (L) of productive age (25-54 years) oscillates between values 158 494 and 36 284 700. Here, the difference is 229 times. Minimum value of capital stock expressed in per capita terms (k) is 3666 Eur, which is 2239 times lower than maximum value. R&D expenditures per capita (r) oscillates between 12 Eur and 3412 Eur. Minimum share of tertiary graduated students in productive age (h) expressed in per capita is 0.06 which is 7.5 times lower than maximum value. As we can see, differences across EU are huge. This can cause quite high standard errors in our estimation. The other thing is, that we can not apply same rules and policy implications for all members as it states in Lisbon strategy 2020. But this discussion leads to another topic.

4.2. Regressions, results and analysis

Our challenge is an estimation of country-level production function aimed at understanding the role of human capital in GDP formation. There were suggested a lot of different methods how to estimate human capital as pupils hours adjusted for quality (Eurostat, 2001), number of pupils hours (Konijn and Gallais, 2006), hours of pupil attendance (Lequiller, 2006), real earnings growth (Atkinson, 2005) or student's years of education (Fraumeni, 2008). We measure human capital as the total number of people with tertiary education in productive age. This subgroup is already active on the market, which allows us to observe the relationship between labor productivity and human capital better. Firstly, we consider the share of tertiary graduated as a whole to see the aggregate effect of tertiary education on income. Then we split the ratio into specific groups as lower and upper tertiary education, by different fields of study and by gender. Departing from the theoretical base of augmented Solow model, we set the empirical model as follows:

$$\ln y_{i,t} = \delta \ln A_{i,t} + \alpha \ln k_{i,t} + \beta \ln h_{i,t} + \gamma \ln r_{i,t} + \lambda \ln L_{i,t} + \varepsilon_{i,t} \quad (4.1)$$

Where y represents labor productivity in country i and year t, which is output measured by GDP in real terms produced in country divided by total population between 25 – 54 years, also called productive age (L). Including total population in labor productivity relationship will secure having the education variable for the same set of people. As we need to measure human capital for the same set of people and tertiary graduated people can be productive mostly after finishing their tertiary institution, we assumed this part of population as the most appropriate variable. The constant term (A) is the labor augmenting Solow residual expressed in country i and year t. Human capital intensity (h) in country i and year t is measured by total number of tertiary educated people in productive age divided by total population in productive age. Using the share of college graduates in population as a proxy for human capital stock increases the possibility of reverse causality, in other words higher GDP per capita leads to higher participation in college education and endogeneity in general has to be considered. This argument concludes, that regression coefficient in OLS will be biased and not an appropriate method to our regression. We will discuss this problem more in the next section. Capital stock (k) in country i and year t, exactly capital deepening, which means a real net capital stock divided by total population in productive age. The last one to be observed is r variable, exactly expenditures on research and development (R&D) in country i and year t divided by total population in productive age. The variable r should theoretically represent the R&D stocks as it is claimed in section 3, but the empirical counterparts of this variable is hard to measure or obtain across European countries. Expenditures on research and development are used widely as a measure of innovation input and are good indicators of country's level investment into new knowledge, so we consider them to be a good empirical proxy for the estimation. $\varepsilon_{i,t}$ is an error component, which represents random disturbances of the model. This part is very important, because there are more factors which influence output, as minor or major economic or political shocks. All variables are measured relative to total population in productive age to express them in per capita terms to solve the problem of different size of European members. Moreover, all variables are expressed in logarithmic form to avoid heteroscedasticity, easier interpretation of relationship between variables and to obtain symmetric distribution. The estimated coefficients will correspond to elasticity between variables.

4.2.1 Problems of panel data, limitations and assumptions behind the model

As in every model, in our case there are some imperfections as well. Firstly we assumed perfectly immobile market. Glaeser (2002) and Simon (1998) by estimating labor mobility concluded that perfectly immobile labor would lead to increase of wages and disconnect productivity from employment growth. They estimated human capital as a single variable as an average of share of workers with college degree. To secure perfect labor mobility, we should have at least similar wages across countries. Otherwise it can cause migration of more educated population to places, where they will be paid better. High concentration of skilled workers in one region can affect neighbouring members. Then, as we confirmed a huge difference across European Union members, it can be a sign of problem with endogeneity, in other words, the presence of correlation between explanatory variables and disturbances term. We can deal with this topic by using different estimation methods such as GMM techniques or dynamic panel model data. Including more variables into our regressions can improve model as well, but it can reduce effect of some explanatory variables. Especially, we assume a correlation between human capital intensity and R&D expenditures. This problem can be solved by using instrumental variable, uncorrelated with disturbance term, but highly correlated with the problematic explanatory variable. This method is called instrumental variable estimation (IV).

Here, different techniques of estimation will be presented to compare the performance of parameters. We already mentioned that OLS regression coefficients will be probably biased because of endogeneity and correlation between variables. But we would like to show it and confirm our hypothesis, equation 4.1. is estimated by OLS to obtain the following results:

\

Table 2.: OLS estimation	
Dependent Variable: log y (real value added/L), 1995-2010	
Sample	European Union (27)
Obs.	372
Constant	- 1.6687 (0.4845)***
l_k	0.9945 (0.0310)***
l_L	0.0393 (0.0256)
l_h	- 0.4115 (0.0974)***
l_r	- 0.0138 (0.0340)
$\overline{R}^2$	0.7991
F – statistics	369.9128***

Note: * denotes significance at the 10%level, ** at the 5% level, and *** at the 1% level
Standard error in parenthesis.

As we can see, these results are inconsistent with the theoretical part. We expected a positive correlation between labor productivity and human capital, thus the strong and negative relationship is contra intuitive. Before we go through explanation, is necessary to run test the model and run White's test for heteroscedasticity. With p – value = 7.1786e-008, we can reject the null hypothesis, which means that heteroscedasticity is presented and OLS is not BLUE anymore. It means that there exists another, more efficient estimator, the robust one. Heteroscedasticity is not the only reason to exclude OLS, the main reasons are potential endogeneity of human resource variable and biased standard errors as we mentioned in previous part. So we exclude OLS as an appropriate estimator for our data. To deal with this problem we can use two alternative approaches as fixed effects model or instrumental variable estimation. We focus on fixed effects model estimation and set an equation as follows:

$$\ln y_{i,t} = \beta_0 + \alpha \ln k_{i,t} + \beta \ln h_{i,t} + \gamma \ln r_{i,t} + \lambda \ln L_{i,t} + \theta_i + \varepsilon_{i,t} \qquad (4.2)$$

The variable θ_i represents country fixed effects in our model and $\varepsilon_{i,t}$ are random disturbances of the model. Firstly, the model is estimated with non-constant returns to scale, in other words, population is included in the per-capita production function. Adding log (L) to the right-hand-side of this equation is just a test whether this condition $\delta = 1 - \alpha - \beta - \gamma$ holds.

Table 3.: (4.2) model, Fixed effects	
Dependent Variable: log y (real value added/L), 1995-2010	
Sample	European Union (27)
Obs.	372
Constant	14.8241 (3.4150)***
l_k	0.2937 (0.0346)***
l_L	-0.5265 (0.2211)***
l_h	0.0921 (0.0469)*
l_r	0.1522 (0.0317)***
$\overline{R}^2$	0.8686
F – statistics	134.60***

Note: * denotes significance at the 10%level, ** at the 5% level, and *** at the 1% level
Standard error in parenthesis.

There is a positive, but statistically significant only on 10 % confidence level correlation between human capital and labor productivity. It means that 1 % increase in human capital will cause a 0.1% increase in labor productivity, which is not an economically significant influence. The positive and significant relationship between variable r and y confirmed our assumptions of influence of technology on labor productivity. A 1 % increase in R&D expenditure expressed in per capita terms will cause a 0.15% increase in labor productivity. Capital stock is affecting labor productivity positively; the 1 % increase in capital stock will cause a 0.29 % increase in labor productivity. This model explained around 86.86% of variation in labor productivity. We clustered standard errors by member's states and we received much lower value of F-statistics than under OLS, which is a good sign.

Then, we provide the estimation results for the constant returns to scale model, population is not included in per-capita production function in order to clarify possible differences in significance of human capital and as a robustness check. The model and results are follows:

$$\ln y_{i,t} = \beta_0 + \alpha \ln k_{i,t} + \beta \ln h_{i,t} + \gamma \ln r_{i,t} + \theta_i + \varepsilon_{i,t} \quad (4.3)$$

And results are follows:

.

Table 4 .: (4.3) model, Fixed effects	
Dependent Variable: log y (real value added/L), 1995-2010	
Sample	European Union (27)
Obs.	372
Constant	6.7237 (0.3197)***
l_k	0.3065 (0.0385)***
l_h	0.0483 (0.0468)
l_r	0.1361 (0.0373)***
$\overline{R}^2$	0.8471
F – statistics	185.14***

Note: * denotes significance at the 10%level, ** at the 5% level, and *** at the 1% level Standard error in parenthesis.

The similar results as in table 3 we can observe from table 4. The relationship between tertiary educated and labor productivity stayed non significant. The reasons behind these contra intuitive results will be discussed in the last part of this section. The influence of other variables to main variable stayed similar as in the table 3. What we can see from table 3, that parameter L, which represents total population in productive age, is negative, which means that there are decreasing returns to scale. We decided to include L into our regressions, followed by assumption, that removing L from the model will bring biased results.

Then, we run the instrumental variable estimation (IV) to check the problem of inside correlation. We use 2-years lagged l_h as an instrument for current l_h, which means that we will lose two years of observations for each country. The results as follows:

Table 5.: IV with Fixed effects	
Dependent Variable: log y (real value added/L), 1995-2010, Instrumented: l_h Instruments: l_L l_k l_r l_lag2h	
Sample	European Union (27)
Obs.	345
Constant	15.9496 (1.7806)***
l_k	0. 2943 (0. 0202)***
l_L	-0. 5744 (0. 1010)***
l_h	0. 1890 (0. 0947)**
l_r	0. 1120 (0. 0324)***
$\overline{R}^2$	0.8499
F – statistics	2281.40***

Note: * denotes significance at the 10%level, ** at the 5% level, and *** at the 1% level
Standard error in parenthesis.

The results from table 5 are more in favour with our hypothesis as in previous cases (table 3 or table 4). We found positive and significant on 5 % confidence level correlation between human capital and labor productivity. In other words, the influence of tertiary educated people to labor productivity is more evident after some years, in our example after two years. A 1 % increase in human capital will cause a 0.19% increase in labor productivity. The influence of other parameters stayed similar as in previous models, this model explained around 84.99% of variation in labor productivity.

4.2.2 The influence of human capital intensity to labor productivity over time

From the previous model (4.2) we observe a weak correlation between tertiary educated population and labor productivity. Here, we want to see if this correlation is persistent, in other words, if it is stable over time. We compare the influence of human capital stock in periods between 1995 - 1997, 2000 - 2002 and 2008 - 2010 separately to test if the effect of human capital differs over time. We run the next models:

$$\ln y_{i,1995-1997} = \beta_0 + \alpha \ln k_{i,1995-1997} + \lambda \ln L_{i,1995-1997} + \beta \ln h_{i,1995-1997} + \gamma \ln r_{i,1995-1997} + \theta_i + \varepsilon_{i,1995-1997} \quad (4.4)$$

$$\ln y_{i,2000-2002} = \beta_0 + \alpha \ln k_{i,2000-2002} + \lambda \ln L_{i,2000-2002} + \beta \ln h_{i,2000-2002} + \gamma \ln r_{i,2000-2002} + \theta_i + \varepsilon_{i,2000-2002} \quad (4.5)$$

$$\ln y_{i,2008-2010} = \beta_0 + \alpha \ln k_{i,2008-2010} + \lambda \ln L_{i,2008-2010} + \beta \ln h_{i,2008-2010} + \gamma \ln r_{i,2008-2010} + \theta_i + \varepsilon_{i,2008-2010} \quad (4.6)$$

Results are in Table 6:

Table 6 - Comparison between periods 1995-1997 and 2008-2010, fixed effects			
Dependent Variable: log y (real value added/L)			
Sample	Model (4.4) – 1995 - 1997	Model (4.5) – 2000-2002	Model (4.6) – 2008 - 2010
Obs.	44	73	78
Constant	3.4473 (8.1941)	10.9517 (3.8430)***	17.9884 (10.2012)
l_k	0.2313 (0.1443)	0.2567 (0.0689)***	0.1704 (0.0199)***
l_L	0. 2334 (0. 5829)	-0.2405 (0.2537)	-0. 6598 (0. 6706)
l_h	-0. 0186 (0. 0726)	-0.0004 (0.0223)	-0. 1858 (0. 1075)
l_r	0.1999 (0. 0882)**	0.1135 (0.0330)***	0. 1270 (0. 0281)***
$\overline{R}^2$	0.7807	0.7850	0.7162
F – statistics	22.85***	39.23***	45.25***

Note: * denotes significance at the 10%level, ** at the 5% level, and *** at the 1% level
Standard error in parenthesis.

We can see the similar results in the both periods, main problem are missing data during the period 1995 and 1997. This was the main reason why we decided to include one more period (2000 and 2002) to observe the relationship between variables over time. Correlation between human capital and labor productivity in all periods stayed non significant and even negative.

4.2.3 Division of human capital

In this part, we will observe the human capital differently. Firstly, we include two more variables into model as total number of graduated students of primary and secondary education. We mentioned that share of primary or secondary educated students will not have a significant effect on labor productivity. This hypothesis needs to be confirmed, also on the one hand, it is not informative to include all levels of graduated, because everybody who plans to go to college has to go through primary and secondary school first. On the other hand, someone, whose highest completed education level is secondary school, has not gone to college. Output is explained by six indicators of education L, k, r, rates of primary, secondary and tertiary graduated, measured as fractions of total population in productive age. Later on, as we can see in table 6, we divided tertiary educated people into three groups: level 5A, level 5B and level 6. Level 5A covers more generally information, more theoretically – based programs. Basically it represents a step behind level 6. Level 6 represents advanced research qualifications and professions with high skills requirements. Level 5B is dedicated to occupationally specific programs, which provide a relevant qualification or are more practically oriented. In other words, level 5 is dedicated do Master's degree and level 6 is for PhD. studies (OECD). Firstly we set a model as follows:

$$\ln y_{i,t} = \beta_0 + \alpha \ln k + \lambda \ln L_{i,t} + \gamma \ln r_{i,t} + \beta_1 \mathrm{Pri}_{i,t} + \beta_2 Sec_{i,t} + \beta_3 TER + \theta_i + \varepsilon_{i,t}$$

(4.7)

Variable l_Pri is a logarithm of a total number of pre-primary, primary and lower secondary educated (levels 0-2) of population in productive age (25 - 54), l_Sec is a log of total number of upper secondary and post-secondary non-tertiary educated (levels 3 and 4) of the same group and l_TER is a log of total number of upper and lower tertiary educated (levels 5 and 6) of the same group.

Table 7.: (4.7) model, Fixed effects	
Dependent Variable: log y (real value added/L), 1995-2010	
Sample	European Union (27)
Obs.	372
Constant	- 5.1927 (0.6935)***
l_k	0.2723 (0.0234)***
l_L	-0.5177 (0.1525)***
l_r	0.1528 (0.0235)***
l_Pri	-0.2380 (0.0520)***
l_Sec	-0.1480 (0.0809)**
l_TER	-0.0667 (0.0505)
$\overline{R}^2$	0.8993
F – statistics	159.17***

Note: * denotes significance at the 10%level, ** at the 5% level, and *** at the 1% level. Standard error in parenthesis.

Human capital intensity was divided into three groups as total number of graduates of primary, secondary and tertiary students in productive age. We assumed that primary and secondary education is obligatory in EU 27, so we expected positive and not significant correlation. But as we can see from the table 7 there is a strong and negative correlation between primary educated and labor productivity, an increase of 1% of ratio of primary educated people will cause a decrease of 0.24% of main variable. Also negative, but less significant (on 5% confidence level) correlation is observed between secondary educated and labor productivity. A 1% of increase of secondary educated people will cause a decrease of 0.15% of y. The influence of tertiary educated population on labor productivity stayed non significant. We decided to include primary and secondary educated people into our regressions to specify the relationship between human capital and labor productivity more precisely. Here, we deal with a negative although not significant correlation between labor productivity and tertiary educated, which can lead to problem of massification and over education. These are current problems in European countries. As we mentioned, there is a significant share of tertiary students, who are overqualified for future positions. Currently, more than one of five students is overqualified and this rate has been increasing from 2000 (Key data on education, 2012). In other words, the share of educated people is increasing, but also the share of unemployment of the same group is going up. Another question is to find a boundary of balance between education's input and output and its impact on labor productivity.

In the next model is included the primary and secondary educated, also three levels of tertiary educated 5A, 5B and 6:

$$\ln y_{i,t} = \beta_0 + \alpha \ln k_{i,t} + \lambda \ln L_{i,t} + \gamma \ln r_{i,t} + \\ + \beta_1 \,\mathrm{Pri}_{i,t} + \beta_2 \,\mathrm{Sec}_{i,t} + \beta_3 \ln 5A_{i,t} + \beta_4 \ln 5B_{i,t} + \beta_5 \ln 6_{i,t} + \theta_i + \varepsilon_{i,t} \tag{4.8}$$

Variable l_5A is a logarithm form of total number of graduates of the first stage of tertiary education, programmes that are theoretically based/research preparatory or giving access to professions with high skills requirements, l_5B is log of total number of graduates of the first stage of tertiary education, programmes which are practically oriented and occupationally specific enrolment and l_6 is log of total number of graduates of the second stage of tertiary education leading to an advanced research qualification. All variables explaining tertiary education are in per capita terms, it means divided by variable L.

The results are follows:

Table 8. (4.8) model, Fixed effects	
Dependent Variable: log y (real value added/L), 1995-2010	
Sample	All European countries together (27)
Obs.	285
Constant	19.7944 (1.7401)***
l_k	0.2494 (0.0157)***
l_L	-0.8334 (0.1240)***
l_Pri	-0. 1414 (0. 0508)*
l_Sec	-0. 1041 (0. 0888)
l_r	0.1439 (0.0251)***
l_5A	0. 0226 (0. 0241)
l_5B	0. 0055 (0. 0066)
l_6	0. 0144 (0. 0173)
$\overline{R}^2$	0.9038
F – statistics	87.22***

Note: * denotes significance at the 10%level, ** at the 5% level, and *** at the 1% level
Standard error in parenthesis.

Research done in Canada proved that workers with univeristy education earn 54% more than high school graduates. Regression showed that individuals with bachelor diploma degree, which in our case is represented by 5A, had 20% increase in wages in Canada compared with those who did not obtain a diploma. Master degree has very little or not significant effect in that paper. These results depend on field of study, some jobs are almost impossible to do without degree as medicine or professions in technical fields. But, for example the bachelor in business can have a significant difference (Ferrer Ana, Ridell W.Craig, 2001). In our case (Table 8), all variables explaining education are non significant to labor productivity. We split the tertiary education into three levels and we confirmed the persistent non significant correlation between human capital stocks and the main variable.

4.2.4 Different fields of study across European Union

In this part, we do not give importance only maintaining the tertiary education or not, we would like to focus on specialization and different fields in this sector. The topic of which combination of skills is beneficial and if is more productive to be specializing in one field or is preferred to have complex of skills across state is controversial. Heterogeneity, on the one hand will have a positive impact for policy makers, because they can focus on particular subgroups, on the other hand it will affect the individual's choice of education. Arcidiacono (2004) found that a large difference in earnings of individuals depends on the field of study, for example they are larger earning in natural sciences or business rather than in social sciences. His paper, investigating the employment structure of the EU regions and its evolution over time showed that productive structure is related to convergence in per-capita incomes. There were proved greater differences inside of country than between countries. He also discussed the importance of specialization of country to reach higher economic growth. But, these differences can be changed only in long term period, which is why the disparities across EU regions are persistent. Otherwise, similarity can increase competitiveness and flexibility on the labor market through EU. Different fields of study can bring faster adaptability of graduated workers on the markets and secure free movement of human capital as pointed Enrico Marelli in 2004.

The situation on the European market is described next. Total number of people in productive age with completed tertiary education in EU 27 was 697 986 900 (Eurostat, 2010). The proportion of students in 2010 was divided as follows, in field of education was 11.56% of student graduates, in humanities and arts was 9.99%, in social sciences, business and law it was 35.10%, in science, mathematics and computing it was 8.35%, in agriculture and veterinary field it was 2.02%, in health and welfare it was 14.11%, in engineering, manufacturing and construction was 13.41% and in services was 5.02% of student graduates. Data have been collected from World Bank and percentage was calculated as an average across members.

Here, we want to observe the effect of different fields of study, different specializations of tertiary educated people and its influence on the main variable, aggregate output. We found the ratio of different fields of study of tertiary graduated people and transformed it into model:

$$\ln y_{i,t} = \beta_0 + \alpha \ln k_{i,t} + \lambda \ln L_{i,t} + \gamma \ln r + \beta_1 \text{Pri}_{i,t} + \beta_2 \text{Sec}_{i,t} + \beta_3 \ln \text{EDU}_{i,t} + \beta_4 \ln \text{HUM}_{i,t} + \beta_5 \ln \text{SOC}_{i,t} + \beta_6 \ln \text{Scien}_{i,t} + \beta_7 \ln \text{IN}_{i,t} + \beta_8 \ln \text{AGR}_{i,t} + \beta_9 \ln \text{Health}_{i,t} + \beta_{10} \ln \text{Service}_{i,t} + \theta_i + \varepsilon_{i,t} \quad (4.9)$$

Where l_EDU is logarithm of total number of tertiary educated students (ISCED 5-6) graduated in education field, l_HUM is logarithm of students graduated in humanities and art field, l_SOC is log of students graduated in social science, business and law field, l_Scien is log of students graduated in science, mathematics and computing field, l_IN is log of students graduated in engineering, manufacturing and construction field, l_AGR is log of students graduated in agriculture and veterinary field, l_Health is log of students graduated in health and welfare field and l_Service is log of students graduated in services field. We did not find the exact share of specializations of graduated students in productive age, because of the unavailability of data, but the share of graduated students in each field is a good proxy of situation on the market.

Table 9. (4.9)model, Fixed effects	
Dependent Variable: log y (real value added/L), 1995-2010	
Sample	All European countries together (27)
Obs.	256
Constant	- 7.2085 (1.5141)***
l_k	0.2245 (0. 0139)***
l_L	-0. 8931 (0. 0898)***
l_r	0. 1723 (0. 0176)***
l_Pri	-0. 1679 (0. 0597)*
l_Sec	-0. 0909 (0.0836)
l_EDU	0. 0216 (0. 0176)
l_HUM	-0. 0126 (0. 0371)
l_SOC	0. 0585 (0. 0301)**
l_SCIEN	-0. 0372 (0. 0181)**
l_IN	-0. 0515 (0. 0240)***
l_AGR	-0. 0056 (0. 0129)
l_HEALTH	0. 0248 (0. 0168)
l_SERVICE	-0. 0118 (0. 0097)
$\overline{R}^2$	0.9202
F – statistics	137.17***

Note: * denotes significance at the 10%level, ** at the 5% level, and *** at the 1% level
Standard error in parenthesis.

The overall explanatory power of the model measured by the coefficient of the determination is 92.02%. The share of population graduated in social sciences, business and law has a significant (on 5% confidence level) and positive, but not really strong influence to labor productivity. A 1% increase in this variable will cause an increase 0.06% in labor productivity. Also positive, but not significant correlation was found between people graduated in education, health and welfare field and labor productivity. A share of population graduated from sciences, mathematics, computing have a negative and significant (on 5 % confidence level) correlation with labor productivity with an influence of 0.04%. Negative and strong significant correlation was also shown between graduated in engineering, manufacturing and construction field and labor productivity. A 1% increase in variable IN will cause a decrease 0.05% in labor productivity. A non significant relationship was shown between independent variables as graduated in humanities, arts, agriculture, veterinary field and services and dependent variable aggregate output. We found only three of eight variables explaining education to be significant, but two of them even with negative influence on labor productivity. We cannot conclude that only some fields of tertiary education can increase labor productivity of states members. But we showed that specialization of tertiary education also matters and has the significant influence on labor productivity. These results can indicate a necessary need of specific fields and overwhelming amount of people graduated in different ones. It can also lead to further estimation and research of overeducation and massification of specific universities in European Union.

4.2.5 Gender differences and its effect to labor productivity

The next challenge was to estimate gender differences and gender inequality and its effect on labor productivity of EU countries. We divided total population in productive age and total number of graduated in tertiary education by gender to estimate if the ratio varies across EU. We assumed different outputs from both gender, because the proportion of specialization of gender on the labor market is also different.

In appendix, in graph 2, we can see that women significantly overwhelmed men in social sciences, business, law, health and welfare and education. There is an interesting point, if we consider results from previous regression (4.9), especially between population graduated in social sciences, business and law and labor productivity was proved a significant and positive correlation. On the other hand, there are more percentage of men graduated in scientific fields and engineering, where have been shown a negative correlation with labor productivity. The model is set as follows:

$$\ln y_{i,t} = \beta_0 + \alpha \ln k_{i,t} + \lambda_1 \ln LW_{i,t} + \lambda_2 \ln LM_{i,t} + \gamma \ln r_{i,t} + \beta_1 \mathrm{Pri}_{i,t} + \beta_2 \mathrm{Sec}_{i,t} + \beta_3 \ln WTER_{i,t} + \beta_4 \ln MTER_{i,t} + \theta_i + \varepsilon_{i,t} \qquad (4.10)$$

Independent variables l_LW and l_LM are total number of population in productive age of women and men on the labor market. The female share' data comes from Eurostat, the rest of numbers are own calculations. Variables l_WTER and l_MTER stand for total number of women and men graduated in tertiary education in productive age expressed in per capita terms.

The results are follows:

Table 10. (4.10)model, Fixed effects	
Dependent Variable: log y (real value added/L), 1995-2010	
Sample	All European countries together (27)
Obs.	366
Constant	6.8500 (0. 3421)***
l_k	0.2461 (0. 0215)***
l_LW	0. 1620 (0. 0761)**
l_LM	0. 3894 (0. 1484)**
l_r	0. 1618 (0. 0290)***
l_Pri	-0. 2081 (0. 0560)***
l_Sec	-0. 2564 (0. 0767)***
l_WTer	0. 0292 (0. 0805)
l_MTer	-0. 1423 (0. 0742)*
$\overline{R}^2$	0.8947
F – statistics	129.22***

Note: * denotes significance at the 10%level, ** at the 5% level, and *** at the 1% level
Standard error in parenthesis.

We estimated the influence of gender differences to the labor productivity on the European states' market. We can see from graph 3 (Appendix) that almost in all countries of EU, the ratio of female with tertiary education to male is visible higher. This ratio is visible increasing from 1995 on average it was 115% female to male and in 2010, it reached 139%. Here, it is also important to show a proportion of share between men and women on the labor market. From graph 4 (Appendix) we can observe, that there are not big differences between men and women. On average in EU 27, there is 55.8 % share of female to male. Coming back to our results, there is a negative but significant only on 10% confidence level correlation between tertiary educated man and labor productivity. An increase 1 % in independent variable will cause a decrease of 0.14% in dependent variable. A not significant correlation was found between women with tertiary education and labor productivity. Model (4.10) explains 89.47% of original variation.

4.3 Discussion

Our estimated results came to contradiction with the hypothesis and described theoretical part. We mostly confirmed not significant relationship between human capital and labor productivity. In table 3, in the basic model, the relationship between mentioned variables was found very low and significant only on 10 % confidence level. By dividing human capital intensity into different subgroups, we lost the significance of the correlation between human capital and labor productivity. It could be caused by few observations, why when adding many explanatory variables is followed by loosing significance of the model. We found only primary and secondary education to be significant in the aggregate production function, while tertiary education is not. We assumed that the reason to explain not significant and in some cases even negative coefficient associated with human capital in augmented Solow regressions can be as mentioned not too many observations, low variability of human capital, measurement error or unobserved heterogeneity caused.

To solve the problem of unobserved heterogeneity we run IV. We found positive and significant on 5 % confidence level relationship between human capital and labor productivity. The influence of tertiary educated people on labor productivity is more evident after some years, in our example after two years.

The research done by Arcandy and d'Hombres in 2007 showed, that measurement in the human capital, additional source of unobserved heterogeneity stemming from country-specific rates of labor-augmenting technological change and the lack of variability in the human capital can result in non significant relationship between human capital and labor productivity. Unobserved country – specific heterogeneity and data containing the measurement error are problems connected with estimation of human capital in production function. As Benhabib and Spiegel (1994) or Islam (1995) pointed out that the coefficient of human capital is neither statistically insignificant nor indistinguishable from zero. Angel and Doménech (2000) faced to the same problem. Poor data quality in relationship between human capital and labor productivity caused the opposite direction in growth regression as have been expected. Existing data on educational attainment contain a considerable amount of noise.

The low variability of human capital intensity in our case is not the problem as we can see from graph 5 and 6 (Appendix). The values oscillate between 0.1 and 0.35 across European members in 2000 and these values are increasing to 0.15 and 0.4 in 2010. We can see that there are high cross-country differences, but within countries we observe uniform growth.

Logarithmic form of the same variable is reaching negative values and oscillates between -2 and -1 in 2010.

5 Conclusion

We estimate the macroeconomic production function of EU countries modified so as to account for the role of human capital. The relationship between human capital and labor productivity almost in all cases was proved to be not significant. The coefficient of human capital intensity oscillated between low positive and negative values in all regressions. The main reasons behind these contra-intuitive results are measurement error, low number of observations and unobserved heterogeneity. To solve these problems we run instrumental variable estimation and we confirm positive and significant on 5 % confidence level correlation between human capital and labor productivity. The influence of human capital is more evident after some period of time. We also found the evidence of the correlation between primary and secondary education and labor productivity. We showed that different fields of tertiary education have different relationships with labor productivity. In other words, also specialization of tertiary education matters.

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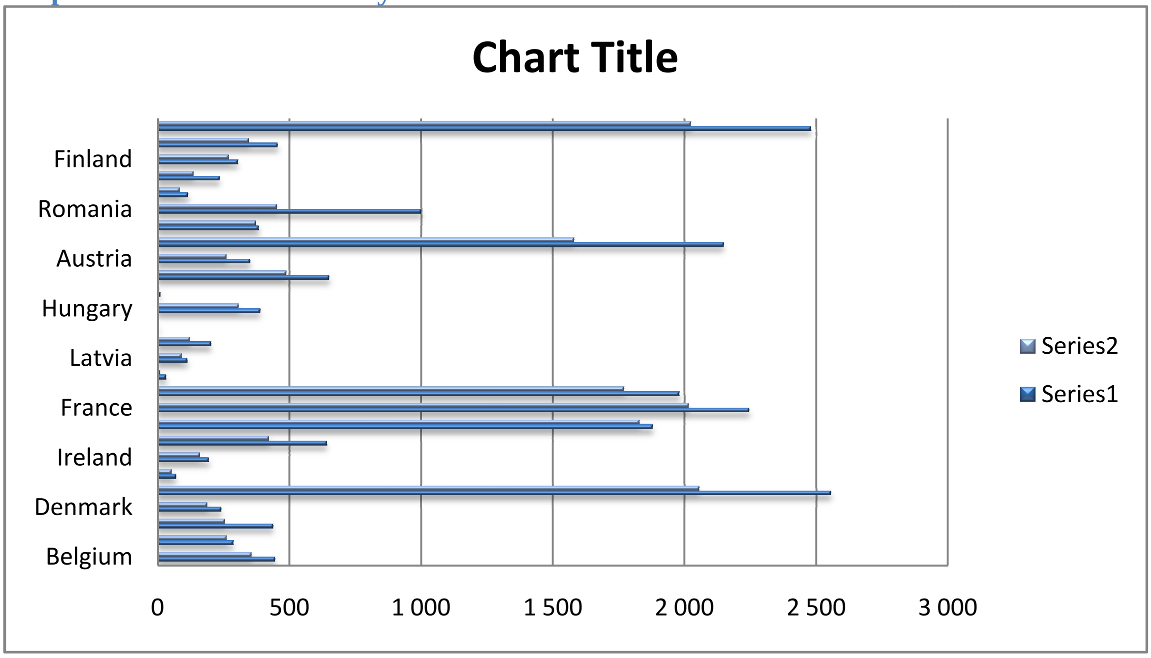
7 Appendix

Graph 1 - The rate of tertiary educated in 2000 and 2010



Source: Eurostat, Series 2 represents 2000, Series 1 – 2010

Table 11– Definition of variables

Table 1. Definition of variables

Variable	Definition	Source
y	Labor productivity = Gross domestic product in real terms/L	Eurostat
L	Total population in productive age between 25 – 54 years	Eurostat
k	Capital stock (capital deepening = real net capital stock/ L)	Eurostat
r	R&D expenditures/L	Eurostat
h	First and second stage of tertiary education (levels 5 and 6) in productive age (25-54 years)/L	Eurostat
Pri	Total number of pre-primary, primary and lower secondary education (levels 0-2) in productive age (25-54 years) / L	Eurostat
Sec	Total number of upper secondary and post-secondary non-tertiary education (levels 3 and 4)) in productive age (25-54 years) / L	Eurostat
Ter	Total number of upper and lower tertiary education (levels 5 and 6) in productive age (25-54 years) / L	Eurostat
5A	Total number of graduated of first	Eurostat

	stage of tertiary education, programmes that are theoretically based/research preparatory or giving access to professions with high skills requirements – level 5A /L	
5B	Total number of graduated of first stage of tertiary education, programmes which are practically oriented and occupationally specific-5B	Eurostat
6	Total number of graduated of second stage of tertiary education leading to an advanced research qualification-level 6 /L	Eurostat
EDU	Total number of tertiary educated (ISCED 5-6) graduated in education field / L	World Bank
HUM	Total number of tertiary educated graduated in humanities and art field / L	World Bank
SOC	Total number of tertiary educated graduated in social science, business and law field / L	World Bank
SCIEN	Total number of tertiary educated graduated in science, mathematics and computing field / L	World Bank
IN	Total number of tertiary educated graduated in engineering, manufacturing and construction field / L	World Bank
AGR	Total number of tertiary educated graduated in agriculture and veterinary field / L	World Bank
HEALTH	Total number of tertiary educated graduated in health and welfare field/ L	World Bank
SERVICE	Total number of tertiary educated graduated in services field / L	World Bank
LW	Total number of women from population in productive age (25 - 54 years) / L	Eurostat
LM	Total number of men from population in productive age (25 - 54 years) / L	Eurostat
WTER	Total number of women of upper and lower tertiary education (levels 5 and 6) in productive age (25-54 years) / L	Eurostat

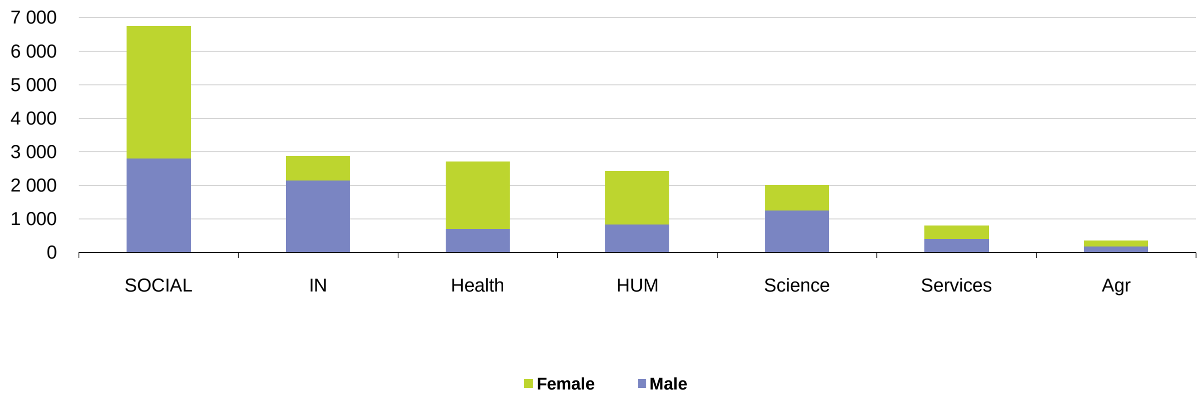
MTER	Total number of women of upper and lower tertiary education (levels 5 and 6) in productive age (25-54 years) / L	Eurostat

Table 12 – Summary statistics

Variable	Mean	Median	Minimum	Maximum
L	7753660,00	3668930,00	158494,00	36284700,00
LW	0,58	0,58	0,25	0,98
LM	0,44	0,44	0,33	0,60
y	285501,00	53062,30	4607,63	5275910,00
k	419895,00	89828,80	3666,02	8208920,00
r	778,66	423,97	12,05	3412,23
PRI	0,27	0,23	0,06	0,82
SEC	0,48	0,47	0,11	0,79
5A	0,01	0,01	0,00	0,04
5B	0,00	0,00	0,00	0,02
6	0,00	0,00	0,00	0,00
h	0,23	0,23	0,06	0,46
WTER	0,12	0,12	0,02	0,27
MTER	0,11	0,11	0,04	0,19
EDU	0,03	0,03	0,00	0,08
HUM	0,03	0,02	0,01	0,09
SOC	0,08	0,08	0,03	0,19
SCIEN	0,02	0,02	0,00	0,08
IN	0,03	0,03	0,01	0,10
AGR	0,00	0,00	0,00	0,02
HEALTH	0,04	0,03	0,00	0,09
SERVICE	0,01	0,01	0,00	0,07
Variable	**Std. Dev.**	**C.V.**	**Skewness**	**Ex. kurtosis**
L	9635890,00	1,24	1,53	1,11
LW	0,15	0,26	0,14	-0,51
LM	0,05	0,12	0,50	0,42
Y	867349,00	3,04	4,57	20,46
k	1207870,00	2,88	4,56	21,44

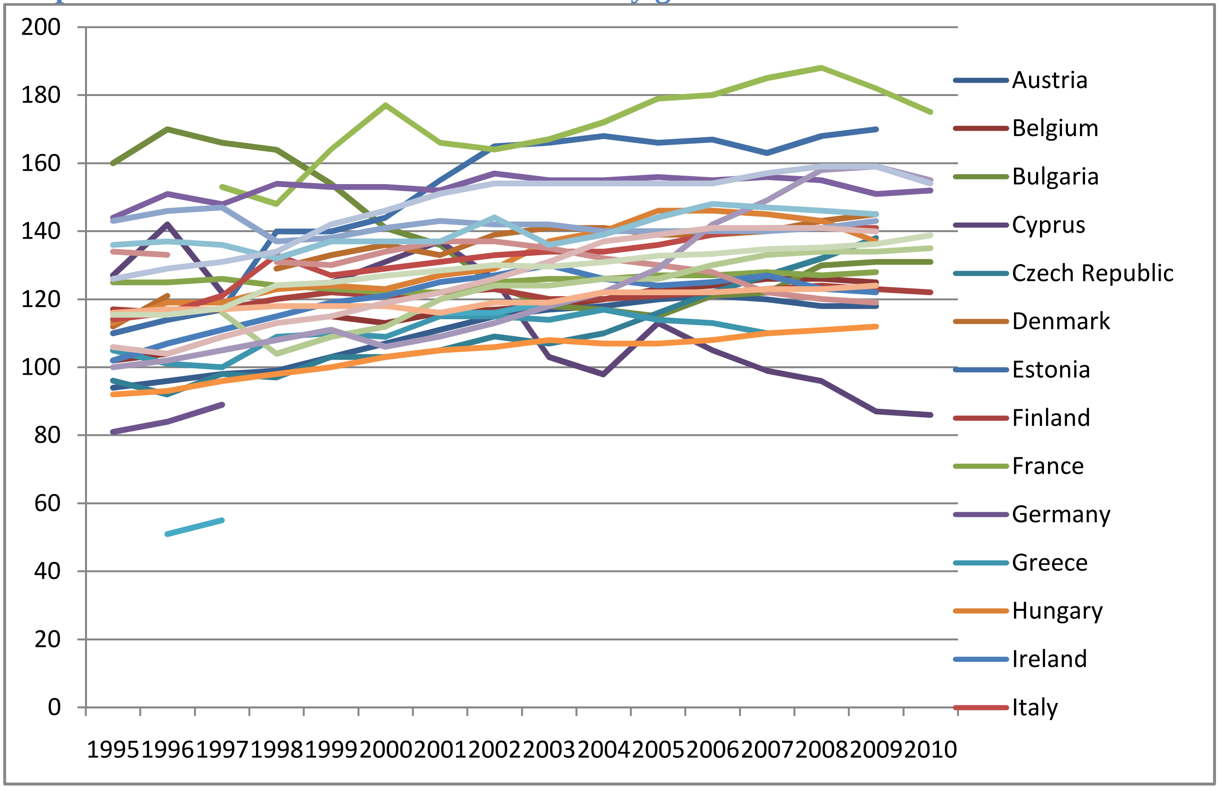
r	831,32	1,07	1,23	0,80
PRI	0,17	0,63	1,30	1,14
SEC	0,17	0,35	-0,26	-0,56
5A	0,01	0,52	0,99	1,19
5B	0,00	0,86	0,85	-0,11
6	0,00	0,61	0,79	0,45
h	0,09	0,37	0,15	-0,87
WTER	0,05	0,41	0,37	-0,59
MTER	0,04	0,36	0,05	-1,15
EDU	0,01	0,48	0,36	0,08
HUM	0,01	0,56	1,18	1,62
SOC	0,03	0,39	0,39	-0,21
SCIEN	0,01	0,58	1,01	1,56
IN	0,02	0,49	1,35	2,32
AGR	0,00	0,50	1,41	5,52
HEALTH	0,02	0,63	0,72	-0,73
SERVICE	0,01	0,82	2,86	11,80

Graph 2 Comparison of gender in different fields of tertiary education



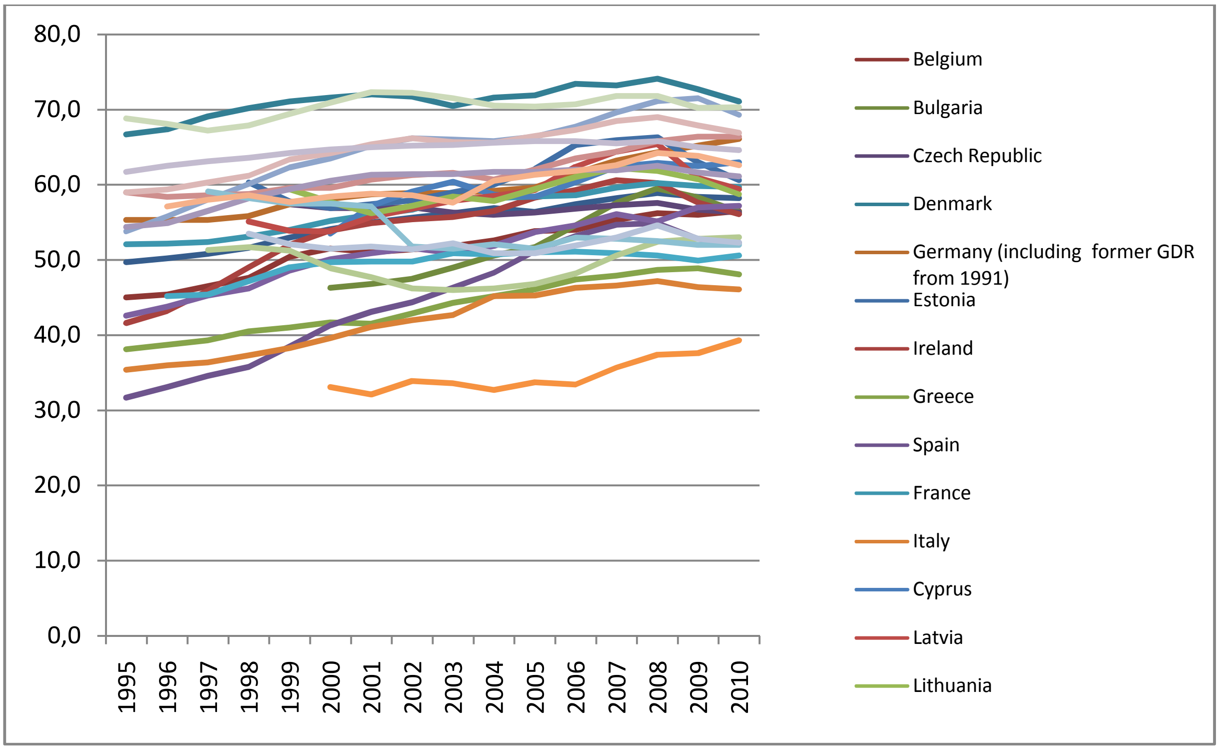
Source: Eurostat, Graduates from tertiary education, by field of education and gender, EU-27, 2010

Graph 3 – The ration of female to male tertiary graduated across EU



Source: Eurostat, graph based on own calculations

Graph 4 – The proportion of share between men and women on the labor market in EU



Source: Eurostat, graph based on own calculations

Table 13 – Lisbon strategy's targets

Europe 2020 targets[1]

EU/Member States targets	Employment rate (in %)	R&D in % of GDP	CO_2 emission reduction targets[2]	Renewable energy	Energy efficiency – reduction of energy consumption in Mtoe	Early school leaving in %	Tertiary education in %	Reduction of population at risk of poverty or social exclusion in number of persons
EU headline target	75%	3%	-20% (compared to 1990 levels)	20%	20% increase in energy efficiency equalling 368 Mtoe	10%	40%	20,000,000
Estimated EU[3]	73.70-74%	2.65-2.72%	-20% (compared to 1990 levels)	20%	206.9 Mtoe	10.30-10.50%	37.50-38.0%	Result cannot be calculated because of differences in national methodologies
AT	77-78%	3.76%	-16%	34%	7.16	9.5%	38%	235,000
BE	73.2%	3.0%	-15%	13%	9.80	9.5%	47%	380,000
BG	76%	1.5%	20%	16%	3.20	11%	36%	260,000
CY	75-77%	0.5%	-5%	13%	0.46	10%	46%	27,000
CZ	75%	1% (public sector only)	9%	13%	n.a.	5.5%	32%	Maintaining the number of persons at risk of poverty or social exclusion at the level of 2008 (15.3% of total population) with efforts to reduce it by 30,000
DE	77%	3%	-14%	18%	38.30	<10%	42%	330,000 (long-term unemployed)
DK	80%	3%	-20%	30%	0.83	<10%	At least 40%	22,000 (household with low work intensity)
EE	76%	3%	11%	25%	0.71	9.5%	40%	Reduce the at risk of poverty rate (after social transfers) to 15% (from 17.5% in 2010)
EL	70%	to be revised	-4%	18%	2.70	9.7%	32%	450,000
ES	74%	3%	-10%	20%	25.20	15%	44%	1,400,000-1,500,000
FI	78%	4%	-16%	38%	4.21	8%	42% (narrow national definition)	150,000

[1] As set by Member States in their National Reform Programmes in April 2011

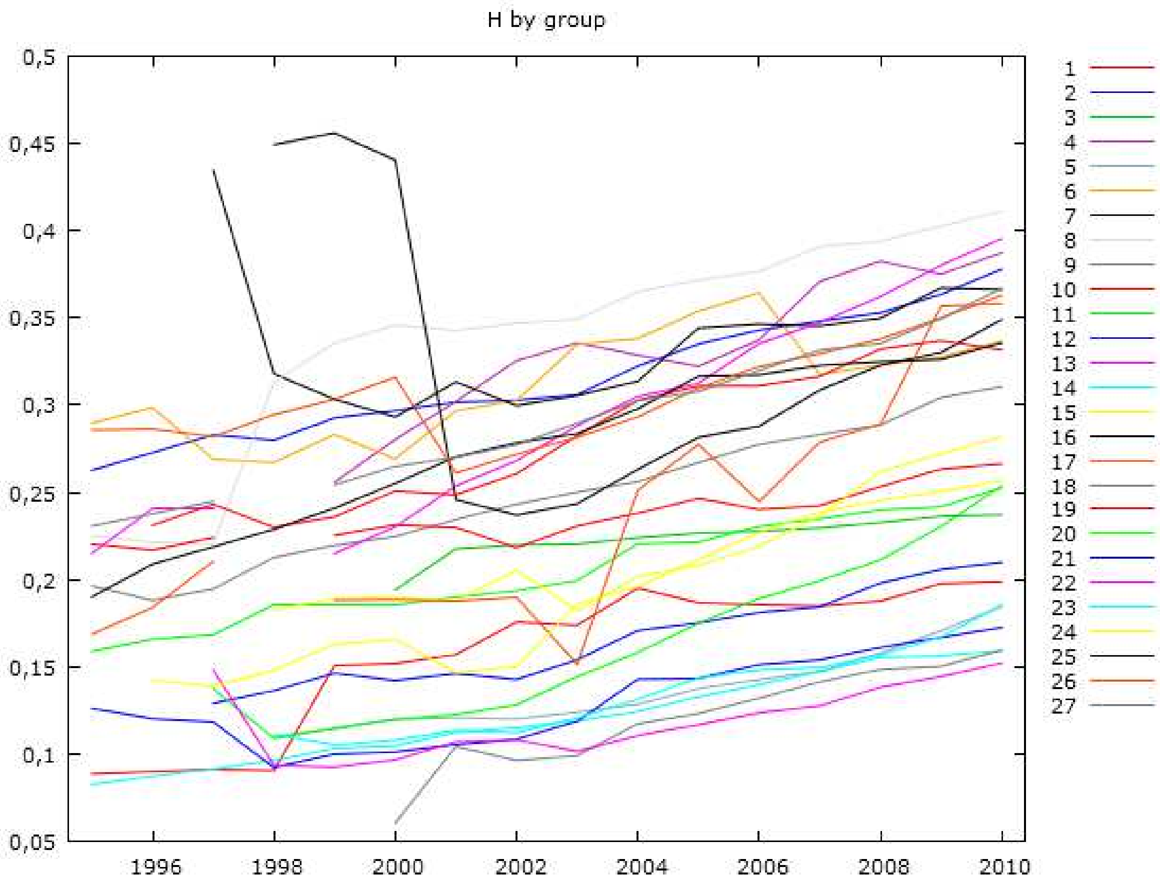
[2] The national emissions reduction targets defined in Decision 2009/406/EC (or "Effort Sharing Decision") concerns the emissions not covered by the Emissions Trading System. The emissions covered by the Emissions Trading System will be reduced by 21% compared to 2005 levels. The corresponding overall emission reduction will be -20% compared to 1990 levels.

[3] Addition of national targets

Europe 2020 targets

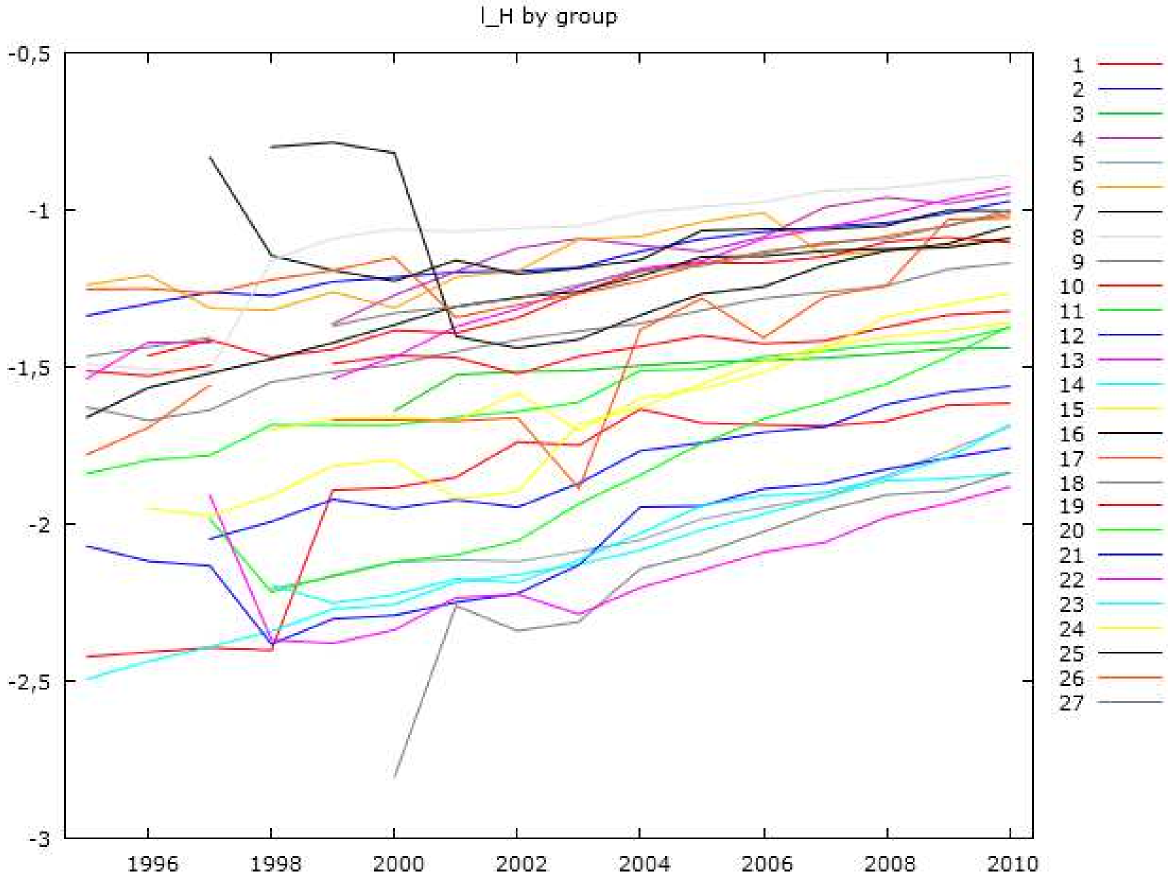
Member States targets	Employment rate (in %)	R&D in % of GDP	CO_2 emission reduction targets	Renewable energy	Energy efficiency – reduction of energy consumption in Mtoe	Early school leaving in %	Tertiary education in %	Reduction of population at risk of poverty or social exclusion in number of persons
FR	75%	3%	-14%	23%	34.00	9.5%	50%	Reduction of the anchored at risk of poverty rate by one third for the period 2007-2012 or by 1,600 000 people
HU	75%	1.8%	10%	14.65%	2.96	10%	30.3%	450,000
IE	69-71%	approx.2% (2.5% GNP)	-20%	16%	2.75	8%	60%	186,000 by 2016
IT	67-69%	1.53%	-13%	17%	27.90	15-16%	26-27%	2,200,000
LT	72.8%	1.9%	15%	23%	1.14	<9%	40%	170,000
LU	73%	2.3-2.6%	-20%	11%	0.20	<10%	40%	No target
LV	73%	1.5%	17%	40%	0.67	13.4%	34-36%	121,000
MT	62.9%	0.67%	5%	10%	0.24	29%	33%	6,560
NL	80 %	2,5 %	-16%	14%	n.a.	<8 %	>40% 45% expected in 2020	100,000
PL	71%	1.7%	14%	15.48%	14.00	4.5%	45%	1,500,000
PT	75%	2.7-3.3%	1%	31%	6.00	10%	40%	200,000
RO	70%	2%	19%	24%	10.00	11.3%	26.7%	580,000
SE	Well over 80%	4%	-17%	49%	12.80	<10%	40-45%	Reduction of the % of women and men who are not in the labour force (except full-time students), the long-term unemployed or those on long-term sick leave to well under 14% by 2020
SI	75%	3%	4%	25%	n.a.	5%	40%	40,000
SK	72%	1%	13%	14%	1.65	6%	40%	170,000
UK	No target in NRP	No target in NRP	-16%	15%	n.a.	No target in NRP	No target in NRP	Existing numerical targets of the 2010 Child Poverty Act

Graph 5 – Variability in human capital intensity in 27 European state members.



Source: Eurostat

Graph 6 – Variability in logarithm of human capital intensity in 27 European state members.



Source: Eurostat