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The Role of Human Capital in Economic Growth - Evidence from OECD Countries

João António Saraiva Rocha de Almeida

Master in Economics

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ISCTE BUSINESS SCHOOL
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THANK YOU ALL!

THE ROLE OF HUMAN CAPITAL IN ECONOMIC GROWTH

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Resumo

Esta investigação pretende estimar a relação entre o capital humano e o crescimento económico de diferentes países da OCDE, com base em dados em painel recolhidos entre 2005 e 2015. Para avaliar os efeitos da tecnologia e suas repercussões no capital humano, foi efetuada uma análise exploratória para uma amostra de 12 países, com base na qual foram estimados modelos de regressão linear controlados por efeitos fixos e aleatórios.

Concluiu-se que a generalidade dos dados relacionados com o capital humano aponta para um resultado insignificante da percentagem da população com ensino superior para explicar o crescimento económico, como também demonstrado por outros autores, como Henderson (2010) e Durlauf et al. (2008). No entanto, a contribuição do ensino básico e secundário para o desenvolvimento económico é maior do que o convencionalmente percecionado.

A análise foi subdividida em dois períodos, a fim de compreender o efeito da educação sobre as economias da OCDE, quer num contexto de crise quer num de recuperação económica. Os resultados sugerem diferentes níveis de influência em relação ao abandono escolar e aos gastos públicos com educação. De um modo geral, a economia parece ser afetada negativamente por essas duas variáveis durante um período de crise, em contraste com um cenário de recuperação, onde os efeitos dessas variáveis são insignificantes. Foi ainda evidenciado o papel fulcral do comércio em ambos os ciclos económicos.

Este trabalho mostra que a conexão entre educação, tecnologia e crescimento económico continua a ser um assunto multifacetado, dependendo da abordagem e dos métodos adotados.

Códigos JEL: C23, I25 J24, O47

Palavras-chave: Educação, Capital humano, Crescimento económico, Modelos de dados em painel

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Abstract

This research aims to estimate the relationship between human capital and economic growth of different OECD countries, using panel data collected from 2005 to 2015. To assess the effects of technology and its repercussions in human capital an exploratory analysis was performed for a sample of 12 countries, from which linear regression estimations controlled by fixed and random effects were established.

It was found that matters regarding human capital point toward an insignificant outcome of tertiary education for explaining economic growth. This is in accordance with authors such as Henderson (2010) and Durlauf et al. (2008). Nevertheless, the contribution of primary and secondary schooling to economic development is greater than what has conventionally been perceived.

The analysis was subdivided into two periods, in order to perceive the education effect on the OECD economies, either in a crisis or in an economic recovery context. The results suggest different levels of influence regarding children out of school and public expenditures on education. In general, economic development appears to be negatively affected by these two variables during a crisis period, in contrast with a recovery scenario where the effects of such variables are meaningless. The important effect of trade over economic growth in every circumstance was also highlighted.

This work shows that the connection between education, technology and economic growth remains a multifaceted subject, depending on the approach and the methods adopted.

JEL Codes: C23, I25 J24, O47

Keywords: Education, Human capital, Economic growth, Panel data models

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List of abbreviations

OECD - Organization for Economic Cooperation and Development

OCDE - Organização para a Cooperação e Desenvolvimento Económico

TFP – Total Factor Productivity

GMM- Generalized Method of Moments

IMF – International Monetary Fund

log – Logarithm

MFP – Multifactor Productivity

GFC – Gross Fixed Capital formation

GDP – Gross Domestic Product

GDPppe – GDP per person employed

Log_GDPppe – Growth rate of GDPppe

FE – Fixed Effects

RE – Random Effects

OLS – Ordinary Least Squares

$R^{2.}$ – R Squared

R&D – Research and Development

ADF Test – Augmented Dickey-Fuller Test

vcov – Variance-covariance matrix for a fitted model object

HC1 – Heteroskedasticity consistent 1

1. Introduction

Can a country's economic growth benefit from education? A common answer to this question may be summarized by the following sentence:

"School education is a fundamental channel for enhancing individual and social well-being. The adequate development of cognitive and socio-emotional capabilities through quality school education leads to not only higher private financial returns in the future, but also economic growth, better health, improved nutrition and higher civic participation "(OECD, 2012).

It is widely accepted that education is a decisive object to achieve success in careers and to provide financial stability when people are involved in the labor market. This kind of statement will be the main target on this research. Thus, it becomes crucial to evaluate the effects of investing in education in order to assess whether a financial effort contributes to a better performance of an economy and if it is worth for a country to possess a greater number of qualified people and fewer not enrolled in pre-primary, primary or secondary schools.

In fact, education has long been viewed as an important determinant of economic well-being. The theoretical literature emphasizes at least three mechanisms through which education may affect economic growth. First, education can increase the human capital inherent in the labor force, which increases labor productivity and thus transitional growth toward a higher equilibrium level of output (as in augmented neoclassical growth theories, cf. Mankiw et al. (1992)). Second, education can increase the innovative capacity of the economy and the knowledge on new technologies, products, and processes, therefore promoting growth (as in theories of endogenous growth, cf., e.g., Lucas (1988) and Romer (1990)). Third, education can facilitate the diffusion and transmission of knowledge needed to understand and process new information and to successfully implement new technologies devised by others, which again promotes economic growth (cf., e.g., Nelson and Phelps (1966); Benhabib and Spiegel (1994)).

Nevertheless, the impact of education is not as obvious as empirically it may seem. Divergent opinions from different authors were encountered. Whereas some agree that schooling brings significant economic benefits, others disclaim it. Todaro and Smith (2015) pointed out the lack of skilled manpower in economies as one of the major constraints to their development. It is therefore no surprise that spending on education is regarded as a priority for many countries. However, some authors have put this assumption into question, claiming that higher education is not found to benefit economic growth in all cases (Aghion et al., 2009).

On this research, an exploratory analysis was made to identify the relationships between economic variables considered relevant to this topic and also to support the econometric approach and methodology developed. For this purpose, linear regression models were estimated using appropriate panel data methodologies, such as fixed effects (FE) and random effects (RE). Data was compiled from three major well-known data sources: World development Indicators (WDI), OECD and World Bank. The analysis covered 12 OECD countries and extended from 2005 to 2015, mainly to allow capturing the impact and evolution of modern technologies. This way, it may be more conceivable to detect synergies between education, economic growth and technological advances. The dependent variable established for all models is the growth rate of the gross domestic product per person employed (log_GDPppe), since it represents an adequate measure to monitor whether a country is on track to achieve the goal of promoting sustained, inclusive and sustainable economic growth, with full and productive employment. Since some estimations had events of serial correlation and heteroskedasticity, a robust estimator was applied to obtain more reliable and accurate results.

The outcomes suggest that human capital effects are not absolutely clear and meaningful. For instance, population with tertiary education and public expenditures on education are found to be irrelevant for explaining variations in economic growth (log_GDPppe), in opposition with children out of school which display a negative causality.

To dig further on human capital effects, a robustness check was carried out in order to perceive the behavior of the above variables in a crisis (2005-2012) and in a recovery context (2013-2015), as well as to notice if any change occurred. In such situations, children out of school and public expenditures showed different stages of significance. However tertiary education remained meaningless for explaining any variation on both scenarios.

With respect to other economic variables, it was noticed that productivity is more crucial and valuable in a crisis situation than in a context of economic recovery and it was also perceived the fundamental effect of trade over economic growth in every circumstance.

Hence, this work is focused on the instrumental role of education, mainly on building human capital, in increasing economic development, and is organized as follows. In Section 2, the literature review and the historical context of the subject is presented. Section 3 highlights some empirical evidence that motivated this work. Section 4 provides the relationship between the variables assumed and the tendencies observed in some OECD countries during the period in analysis (2005-2015). In Sections 5 and 6, the empirical approach is defined, presenting the database and the econometric methodology considered. The results for the benchmark model are also discussed. In Section 7, several robustness analyses are performed. Section 8 is focused on the results obtained using a robust estimator and also on a robustness check made to capture more information regarding the subject under study. Finally, the main conclusions are drawn in Section 9.

2. Significance of Human Capital

2.1. Concept of human capital

The concept of human capital has been interpreted in the literature in many different ways. According to Schultz (1979), human capital involves increase of investment in education and training of individuals, whose abilities can be enhanced through education and training, leading to effective changes in the performance of the jobs. In the words of Marimuthu et al. (2009), human capital refers to the processes that relate to training, education and other professional initiatives in order to increase the levels of knowledge, skills, abilities, values and social assets of an employee which will lead to the employee's job satisfaction and performance. Therefore, it can be said that not all labor is equal and there are multiple ways to improve it. Education is the foundation on which human capital is built *(*Bontis, 2000) and this research will focus on this assumption in order to apprehend the impact of education over human capital, and consequently on the growth of an economy in terms of income and social welfare.

Studies conducted by Mankiw et al. (1992) weight the crucial role of education as one of the most important production factors in increasing human capital as a determinant of economic growth, by helping individuals to acquire knowledge which encourages participation in groups, creates job opportunities, develops social interactions, makes individuals aware of their rights, improves health and reduces poverty. Human capital improves the quality of labor, increasing its productivity (Goldin, 2016).

Nelson and Phelps (1966) emphasize that education can facilitate sharing and transmission of knowledge needed for developing new technologies. Effectively, nations without enough human capital cannot manage efficiently their physical capital.

This notion has a direct effect on economic growth because individuals with more education are more productive and innovative, leading to the creation of new products and improving the productivity (Romer, 1990). Consequently, a large number of qualified people can lead to positive social externalities, such as the spillover of ideas or the performance of certain jobs that require more years of studying. For instance, in Medicine, high-intensive knowledge is a positive factor for promoting public health. Sianesi and Reenen (2003) show that human capital, specifically in its educational dimension, besides stimulating the productivity of workers, tends to improve health levels, criminal rates and social cohesion. Hence, investing on education (i.e., human capital accumulation) has an impact not only on individual returns but also on the production of social benefits.

According to OECD (2002), the concept of social rate of return is related to the costs and benefits for a society of the investment in education, which includes the opportunity cost of having people not participating actively in the production of output and the full cost of providing education. Social benefits associated with investment in education, other than increased productivity, include several non-economic aspects, such as lower criminality, better health, greater social cohesion and more informed and effective citizenship. The role of education in reducing criminal behavior is an example of this type of social benefit, which can be explained by the fact that schooling raises the opportunity cost of crime and the cost of time spent in prison, increasing the patience and the risk aversion of individuals (Lochner and Moretti, 2004).

2.2. Historical context

Until the middle of the 20th century, many nations, including some relatively rich ones, only educated people who could personally afford to attend school. However, by the end of the 20th century, all nations, even the poorest, provided elementary schooling and sometimes higher education to most of their citizens**.** More specifically, in 1900 no nation apart from the United States had more than a trivial fraction of its youth enrolled in full-time upper secondary schooling (Goldin and Katz, 2008). But, by the end of the twentieth century, all but the very poorest countries of the world had higher secondary school enrollment rates than those of the rich nations in the early twentieth century. Also, college and university enrollment rates among most OECD nations increased sharply during this century. Indeed, the modern concept of the wealth of nations emerged during the twentieth century, where the capital embodied in the people (human capital) mattered for the development (Goldin, 2001). That led the 21st century, known also as the Human Capital Century, to be characterized by the role of education in economic growth and individual productivity, where a greater level of education results in higher labor productivity as well as on fostering a higher rate of aggregate growth.

Indeed, the productive specialization of economies depends on their endowment factors. The importance of the endowment factors in an economy can be partly explained by the situation of European Southern and Nordic countries. Where Southern countries, during their tertiarization, specialized in labor-intensive services and absorbed low-skilled workers from rural migration, in contrast, Northern countries specialized in high-tech, tradable products, which require a higher level of human capital. The accumulation of human capital is a necessary condition for the increasing share of the most productive sectors (Gürbüz, 2011)**.**

Therefore, the main questions addressed here are how and why OECD countries led in education and technology and what impact this aspect had on the respective economies.

2.3. Technological and productivity weight

Rapid technological advance, measured in various ways, has characterized the 20th and 21st centuries. This means that modern technologies must be invented, innovated, put in place and maintained in order to satisfy consumer needs in an effective manner. Consequently, the competitiveness and economic growth of a country requires educated workers, managers, entrepreneurs and citizens to deal with the progress and to achieve good levels of efficiency. Presently, while the strength of arm power is being greatly reduced in production, the role of brain power and machines is rapidly increasing (Karaçor, 2015).

The framework proposed by Nelson and Phelps (1966) argued against the role of human capital as a factor input, instead suggesting that human capital serves as an aid to domestic innovation and adaption of foreign technologies. In line with this thought, a country's economic growth can be determined by the quality of its human capital, in which higher productivity can be achieved through innovation and speed of technological diffusion in the country. In fact, an increase of 1% of the capital stock leads to a 0.13% increase in the rate of growth. Also, the process of catching up the technological development of other countries is strongly influenced by the human capital stock nationwide, as highlighted by Funke and Strulik (2000). Human capital has a clear influence on the rate of internal innovation (Romer, 1989).

Thus, it may be conceivable to state that a positive correlation exists between the educated workforce of a country and the benefits of its R&D activities in terms of economic growth. Human capital promotes the absorption of new ideas and products already created by other countries. Hidalgo et al. (2007) show that the development path of a country is determined by its capacity to accumulate capabilities that are required to produce diverse and more sophisticated or complex products.

The relationship between human capital, technology and economic growth seems straightforward, unlike the empirical studies that generated mixed outcomes and in which different variables were employed as proxy to human capital for determining growth. For example, Mankiw et al. (1992) found a positive and significant relationship between human capital and growth, while Dulleck and Foster (2008), who conducted a cross-country study, found the lowest relationship between equipment investment (as proxy to human capital) and economic growth for countries with low level of human capital, the highest for countries with an intermediate range and somewhat in between for countries with the highest level of human capital. High investment in equipment can facilitate technology transfer; hence, industrialization can be achieved in countries with different levels of human capital.

From a micro perspective, firms that have employees with a high level of human capital generally adopt complementary technologies in order to achieve maximum efficiency. Hence, human capital speeds up the technological progress of countries and reduces their costs of implementation.

3. Empirical Studies

Human capital is essential due to its ability to connect and develop the attributes of a knowledge-based society. Hence, the potential of human resources should be highlighted. Smith (1776) referred to the useful abilities of all society members. The acquisition of such talents, obtained through training, study or apprenticeship, represents a real value associated to a fixed and acknowledged capital. Those skills are part of the wealth of the society. Definitely, several countries adopted this historical thinking in the sense that OECD (2010) encouraged the developed economies' governments to promote policies to increase innovation and knowledge in manufacturing and services, as a way to continue prosperity.

The issues related to the income that workers must earn in accordance with their competences were studied by classical economists, such as Adam Smith, the main pioneer of matters regarding wealth. In his famous published work "The Wealth of Nations" (Smith, 1776), he designated the labor theory of value, which in other words, denotes for the value of a commodity by the sum of the normal amounts payable for all factors used on producing it, considering also its scarcity in the market. This was one of the ancient ways to determine how much income should the labor force receive, according to its effort. With that, the link between education and earnings only emerged recently, being studied by Schultz and Mincer, among others, who used formal modeling to support their research.

Schultz (1971) based his approach in propositions like the acquisition of human skills being in essence an investment in human capital and where its contribution to output depends upon the amount of investment and the realized rate of return. The capital part rests on the proposition that certain types of expenditures create productive stocks that provide services for future periods. Schultz concluded that college graduates earn the most, high graduates earn substantially less and those with elementary schooling acquire the least. The benefits gained from an additional level of education might signalize whether an economy is on track to achieve good levels of development, not only regarding the individuals and their returns. The earnings premium suggests that productivity increases as people acquire additional qualifications, which refers to the idea of signaling where higher levels of schooling are associated with higher earnings, not only because they directly raise productivity but also because they certify that the worker is likely to be productive in a social broad context (Psacharopoulos, 2018).

There are divergent opinions regarding the influence of education in the economic development process. Barro (2013) showed that there is a direct causality relationship between education (measured by schooling rates) and economic growth. Agiomirgianakis et al. (2002) studied the relationship between human capital measured through primary, secondary and tertiary education enrollment rates and economic growth for Greece and showed that there is a direct causality between primary and secondary education and economic growth and a reverse causality for tertiary education**.** Prichett (1996) estimated the impact of growth in educational capital on growth of GDP per worker and concluded that such impact was consistently small and negative.

It is usually considered that an additional school year will increase the productivity and efficiency of workers, and consequently their income *(*Hall and Jones, 1999). Similarly, differences in the average schooling of countries are related to different economic growth rates (Benos and Zotou, 2014). For example, Easterly and Levine (1997) found that the low economic growth observed in African countries is due, in part, to their low rates of schooling.

Some discussion on the topic divides the factors influencing education spending into different categories and more specific variables, such as: socio-economic variables (GDP per capita, share of young in population), institutional variables (overall public social spending, fiscal policy authority, tax revenues, privatization levels) and partisan factors (level of rightist parties, conservative government participation). A large part of education spending on OECD countries is dedicated to primary and secondary education, since their acceptability and notice of importance make them a public expenditure not easily changed (Busemeyer, 2007).

There are several situations related with the externalities of education, as mentioned above. From the point of view of a worker it may be seen a presence of positive private returns (signaling effect) and negative social returns to education, due to the fact that more education can expand the possibilities of the individual in the job market, but it may not increase the productivity of a society (cases of skills mismatch or moral hazard, e.g) (Romanello, 2016)**.** A gap may happen between an individual's job skills and the demands of the job market, existing also the risk that a party does not enter into a contract in good faith or provides misleading information about its assets.

Both positive private and social returns on education might result mainly by the spillover of ideas and interaction with different workers (Romanello, 2016). It is realistic to think that one person's human capital is more productive when other members of society have a higher level of schooling. The benefits of such complementarities will be internalized when they occur within firms. Spillovers that go outside a company can be considered pure externalities (Braakmann, 2009). Nonetheless, the following table summarizes the estimation techniques that other investigators used to attain conclusions.[*]

[*] More studies are quoted in Table A.1 on the Appendix.

Paper	Data	Hypothesis	Main methods	Inputs/Outputs	Main results
Queirós and Teixeira (2015)	EU KLEMS Penn world table UNESCO	- Countries with a higher stock of human capital tend to grow faster than others - Countries that make changes in productive structures towards a greater share of technology/knowledge-intensive activities will tend to observe higher economic growth	- System-GMM estimation method for the dynamic panel data model - One-step system GMM for a model with few countries (10 OECD) and longer time span (50 years) - Second-step system GMM for a model with a large number of countries and a shorter time span (30 OECD countries and 22 years)	- Dependent variable: natural logarithm of real GDP per capita - Independent variable: average schooling years as a proxy of human capital	- Countries with a higher educational attainment of adults grow faster in the periods considered - Knowledge-intensive activities employ individuals with higher skills and knowledge because they are more productive and capable of enhancing the emergence of new products
Ahsan and Haque (2017)	World Development Indicators (WDI) - panel of 126 countries covering the period from 1970 to 2012	- An economy needs a certain level of development in order to acquire the capacity to use efficiently the productivity of human capital - The positive impact of human capital may not arise unless an economy is above a threshold level of development	- Fixed effects and one-step system GMM - To remove outliers, the first run one-step GMM estimation of the model is done with the application of the Hampel Identifier (HI)	- Dependent variable: growth rate of GDP per capita - Control variables: log of initial GDP per capita, gross capital formation as a percentage of GDP, population growth, trade openness (trade/GDP), financial development (M2/GDP), government expenditures	- For both GMM and fixed effects estimation, the human capital has insignificant impact for growth in developing countries. However, in developed countries, the impact is positive in case of GMM with outliers and with fixed effects estimation, unlike for GMM without outliers - Less developed countries experience little or no impact of human capital on growth whereas countries at a higher level of development experience a positive and significant impact.
Pelinescu (2015)	Annual data for the period 2000-2012 from the Eurostat database	- The role of human capital as a factor of growth means that a slow investment in human capital should retard the sustainable development of the countries	- The chosen model is with fixed effects for countries and periods, since both national and specific changes in different periods influence the relationship between indicators	- Dependent variable: GDP per capita, positively correlated with the ability of a country to develop a knowledge society - Independent variables: education expenditure in GDP, number of employees with secondary education, exports of goods and services, number of patents	- The model revealed a positive relationship, statistically significant between GDP per capita and innovative capacity of human capital (evidenced by the number of patents) and qualification of employees (secondary education), as expected according to the economic theory. - Unexpectedly, a negative relationship was found between education expenditure in GDP and GDP per capita.

Table 1. Summary of empirical findings between human capital and economic growth

4. OECD Data (2005-2015)

This section presents and discusses the cyclical relationships between human capital and economic growth of 12 OECD countries in the period from 2005 to 2015. For this purpose, a trend analysis regarding indicators such as R&D, public expenditures on education and productivity was performed. Use was made of proper indicators in order to help to analyze and answer the research question addressed in this work.

4.1. Education and economic growth

In order to evaluate the cyclical relationship between the variables, an analysis was made relating education variables and the illustrative variable of economic growth, GDPppe, during the 11 years period under study. In simple terms, it can be observed (Figure 1) that all OECD countries under consideration have experienced a slight increase of the growth rate GDPppe* during this period, with a great highlight to Ireland, which witnessed the highest growth rate between 2013 and 2015. In contrast, during this period, Portugal was always the country with the lowest growth rate (although maintaining a positive trend in every year), exhibiting a significant spread in comparison with other OECD countries in analysis.

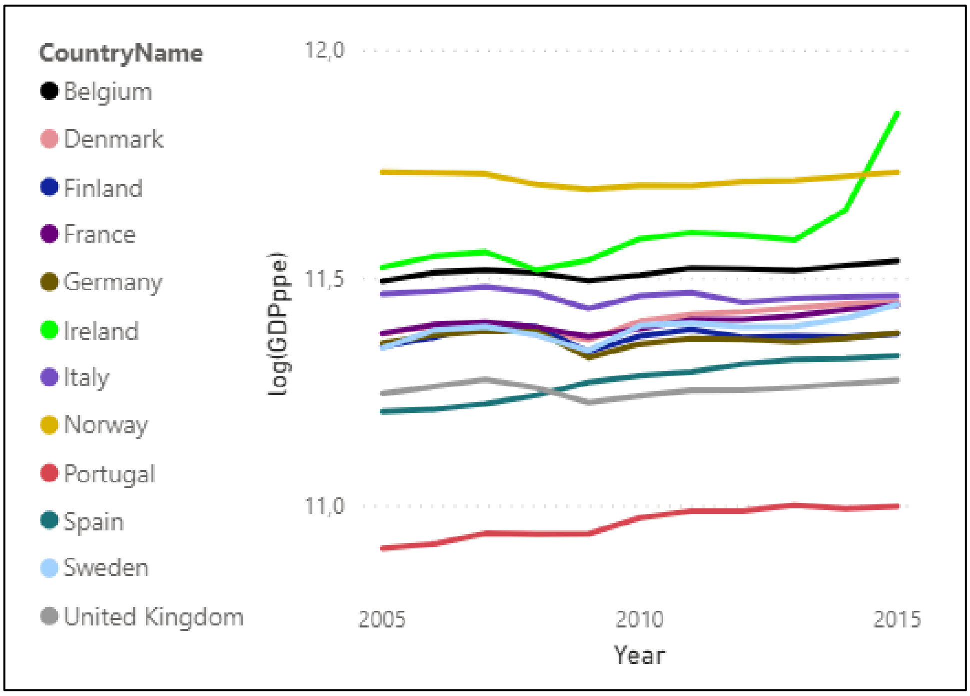

Figure 1. Growth rate of GDP per person employed – 12 OECD countries (ILOSTAT, 2018)

* GDPppe is calculated through this formula: GDP/ total employment in the economy. GDP is converted to 2011 constant international dollars using Purchasing Power Parity (PPP) rates. An international dollar has the same purchasing power over GDP that a U.S. dollar has in the United States.

Figure 2 summarizes the average GDPppe growth rate (log (GDPppe)) tendency during the period in analysis. A breakdown trend can be observed, coinciding with the beginning of the global financial crisis (2007) and extending until 2009, with negative growth rates. However, the post-crisis, particularly after 2013, was characterized by a high upward evolution until 2015, predominantly because several countries undertook exceptional and unprecedent policy measures to support their economies, combining central bank monetary policy with fiscal stimulus and financial sector operations (IMF).

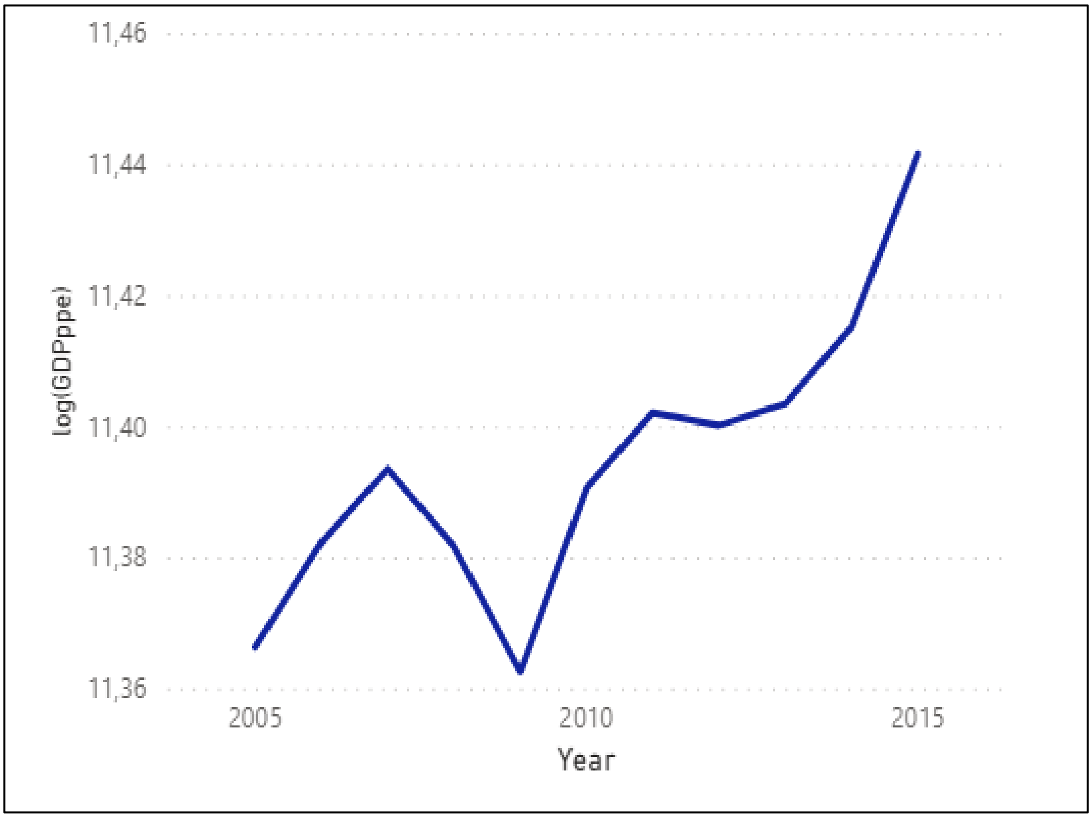

Figure 2. Average growth rate of GDP per person employed – 12 OECD countries (ILOSTAT, 2018)

With respect to investment (Figure 3), a significant drop in its values is generally registered during the crisis period, between 2007 and 2013.

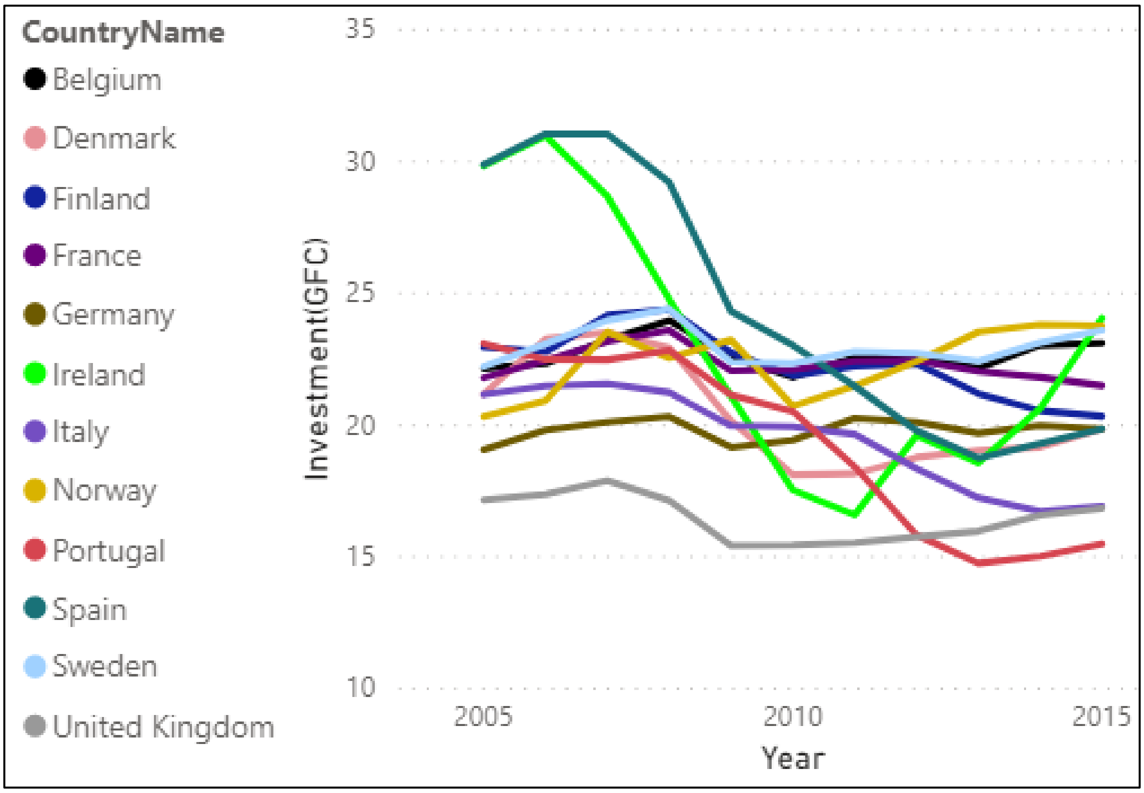

Figure 3. Investment - 12 OECD countries (World Bank and OECD national accounts data files, 2019)

To better comprehend the influence of education on the dynamics of the dependent variable (log_GDPppe), several education indicators were examined, *ceteris paribus*.

As seen in Figure 4, the population with tertiary education raised approximately by 2% from 2005 to 2015 and in contrast, children out of school had seen a dramatic decrease of 6% during the same period. That is, OECD countries became more knowledge-based since this decade.

It can be perceived that the growth rate of GDPppe started to increase when the number of children out of school went down, from 2009-2010 until the end of the time-data analysis. Also, population with tertiary education had always a positive trend along with GDPppe.

Hence the first two variables (GDPppe and children out of school) display a counter-cyclical relationship and, in contrary, GDPppe and tertiary education present a procyclical one.

Haldar and Mallik (2010) investigate the behavior of investment in human capital and output and their results suggest that this variable has significant effects in an economy.

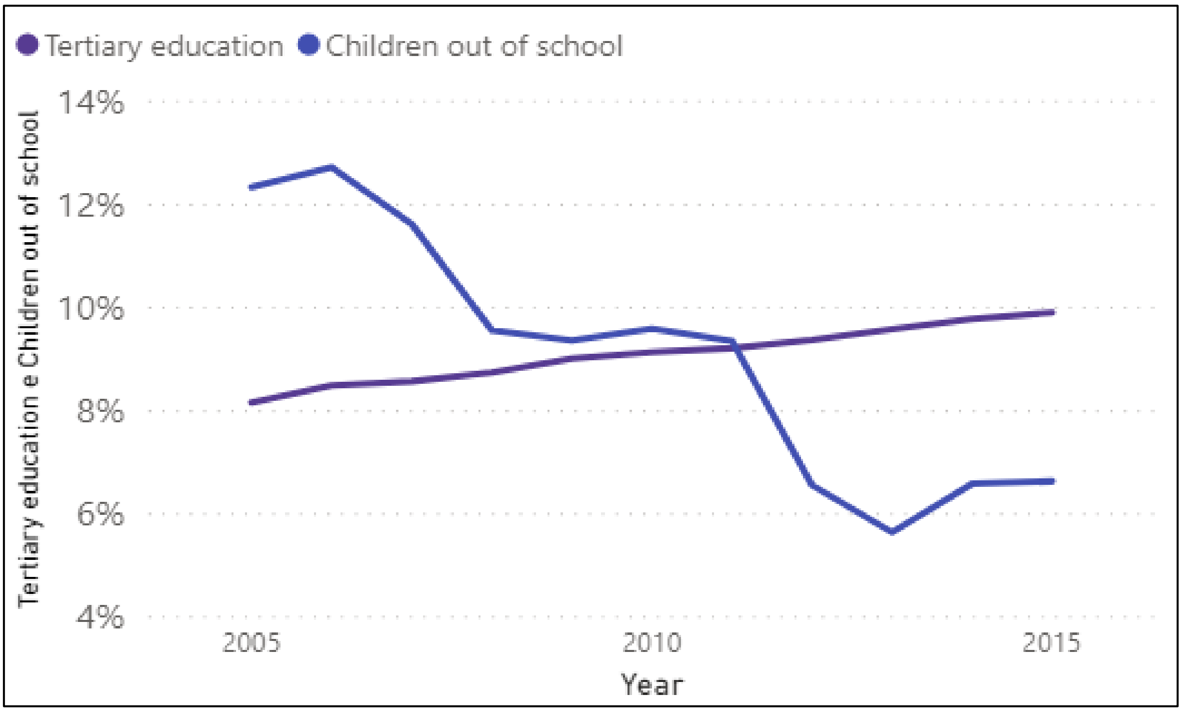

Figure 4. Average of tertiary education and children out of school* (UNESCO, 2019)

Regarding government expenditures on education, it is seen in Figure 5 that some countries such as Belgium, Finland, Germany, Norway, Sweden and United Kingdom have spent more in the recent period (2010-2015) than in the oldest one (2005-2009) of the time-data. Some other countries displayed a more volatile pattern.

Conversely, these expenditures trends cannot undertake any specific and truthful conclusions. For instance, Ireland witnessed higher levels of GDP per person employed in the last decade along with a negative trend of fiscal policy expenses. Nonetheless, it is recognized a general empowerment of government expenditures on education in a large part of countries after the financial crisis. However, as seen in Figures 5 and 6, from 2013 to 2015 this pattern was more volatile. On this research, it will be acknowledged whether these policy measures had significant effects for the respective OECD economies.

The evolution of other variables to be included in the model is presented in the Appendix (Figures A.1 to A.8).

* The units of measure are created with the percentage of total amount of population with tertiary education and children out of school.

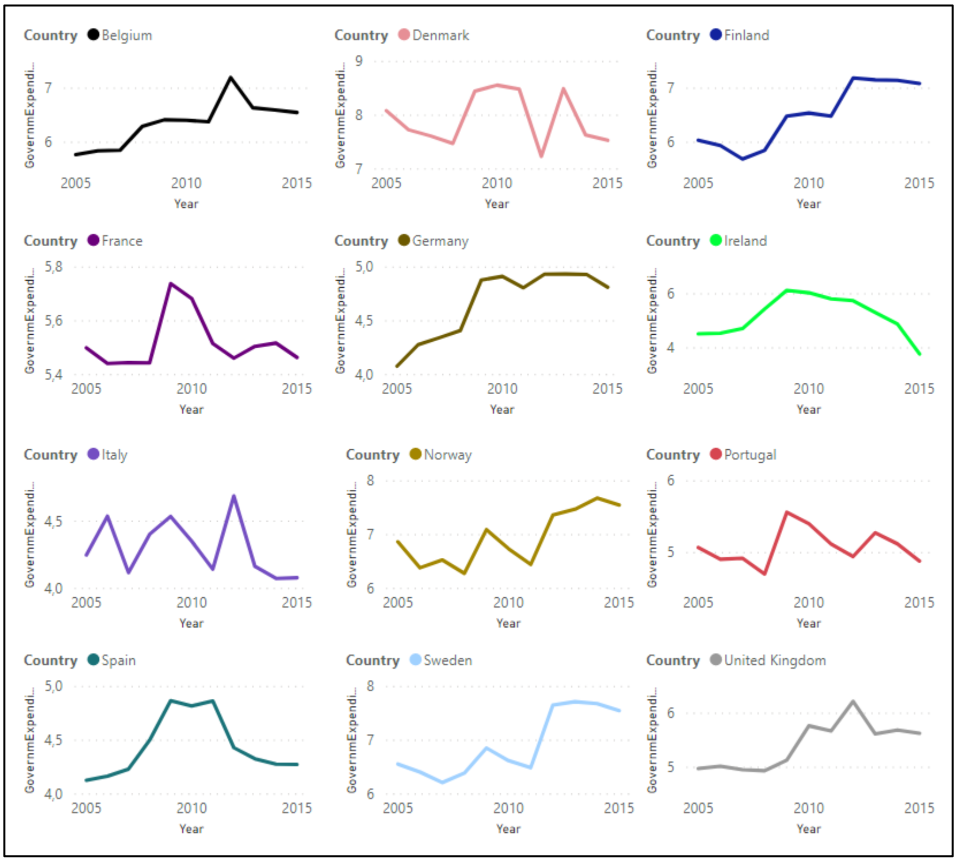

Figure 5. Government expenditures on education (UNESCO, 2019)

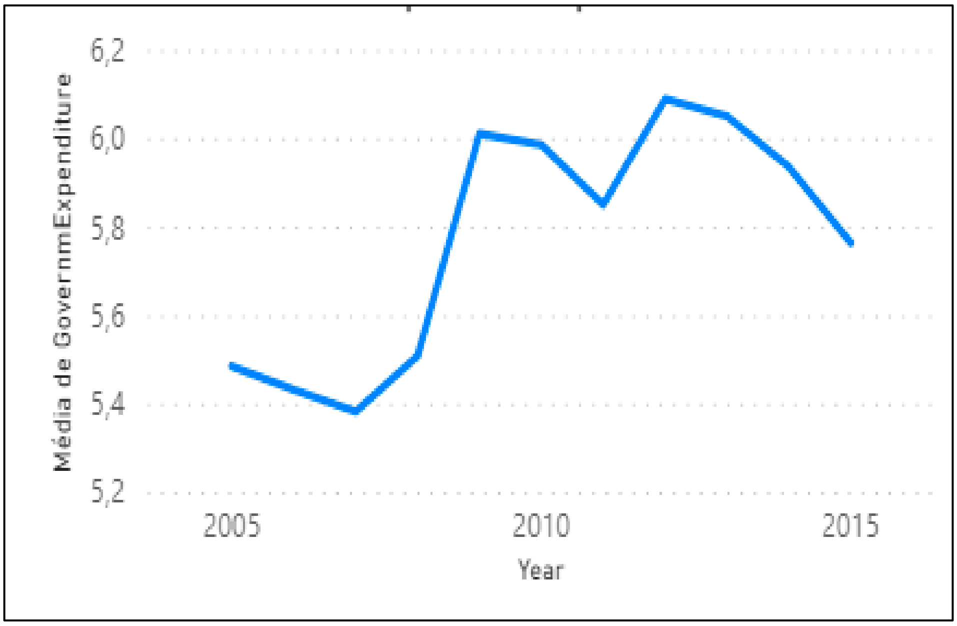

Figure 6. Average of government expenditures on education – 12 OECD countries (UNESCO, 2019)

Figure 7 denotes to the correlation between the dependent variable (log_GDPppe) and all independent variables that are going to be used in the final model, for the 12 countries under study and for the whole period of time (2005-2015). Regarding demographic indicators, the fertility rate was integrated. It is seen that as long as this index grows, log_GDPppe will rise as well. Demographics will likely affect the composition of growth by shaping aggregate consumption, saving and investment decisions (Mester, 2017). However, in Sections 8 and 9 it is perceived that such assumption is not absolutely clear for the case under study.

Population with tertiary education and government expenditures on education show positive relationships to the dependent variable, in contrast with children out of school, which presents a negative one, as mentioned before.

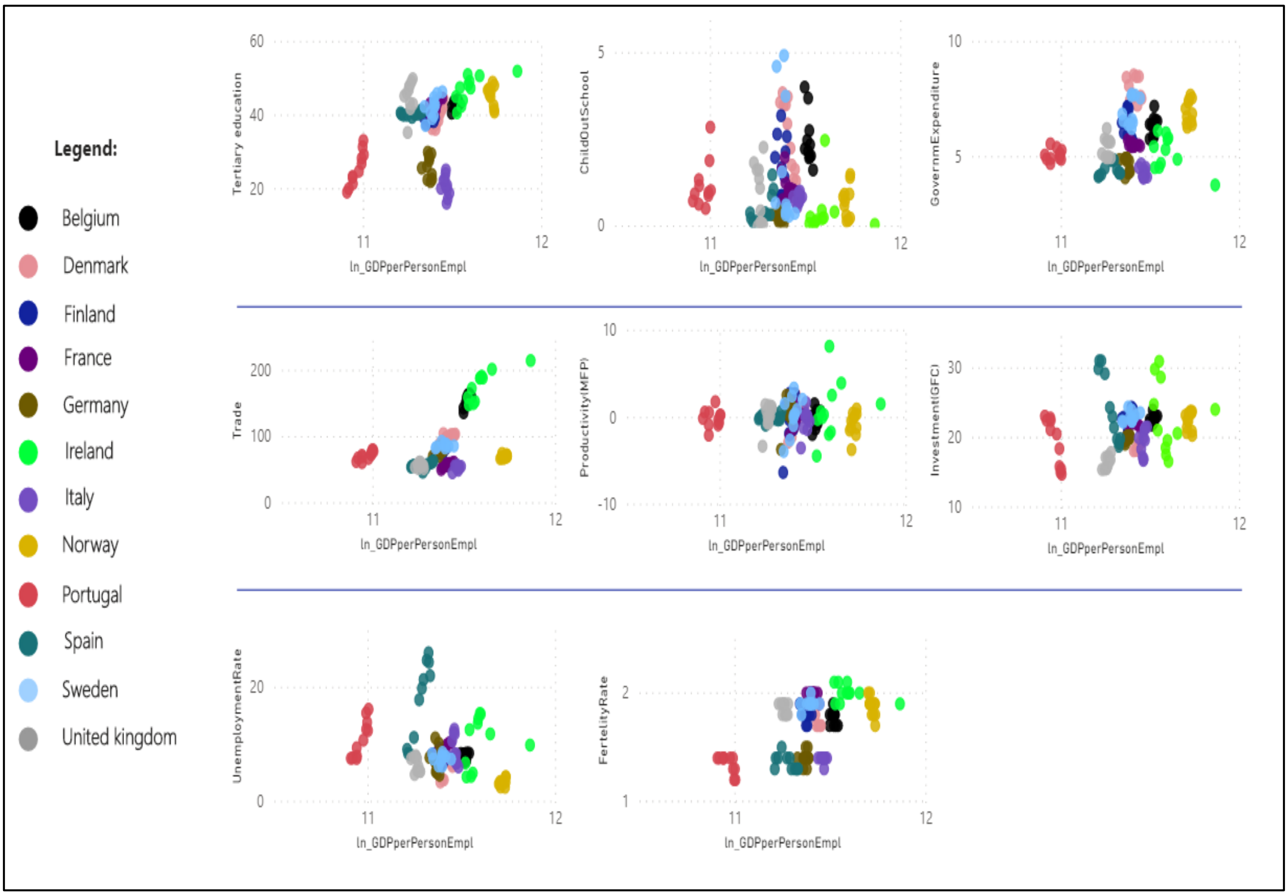

Figure 7. Overall correlations* with the growth rate of GDPppe

The following list summarizes the positive (+), negative (-) and debatable (?) interactions between the dependent variable and the following variables:

* Determined using Power BI software

1. Tertiary education (+)
2. Government expenditures on education (+)
3. Children out of school (-)
4. Trade (+)
5. Productivity (+)
6. Investment (+)
7. Unemployment rate (?)
8. Fertility rate (+)

These interactions are shown in Figure 7, which presents the scatter plot with respect to these variables. In all of them Portugal is an outlier in comparison with the other OECD countries. The overall correlations between all variables are presented in table A.2 of the Appendix.

4.2. Productivity, globalization and unemployment progression

To address this subtopic, the period under analysis was segmented. The 11 year-period studied was divided and examined into 2 groups, 2005-2009 and 2010-2015. The main reason for this approach was to perceive the technological advances between both periods, measured by the progress of R&D. It was concluded that R&D had got more force in the end of time-data (2010-2015), which means that the major part of OECD countries had put emphasis the driving of government laboratories, research institutes and universities. The following charts (Figures 8 and 9) characterize the continuous investment on R&D and also on the creation of new knowledge, products, methods and techniques. These are important mechanisms to raise labor market efficiency and productivity. In general, all the countries in analysis display a continuous positive trend in both categories except Finland, where the trend is negative in spite of having achieved the extreme absolute values.

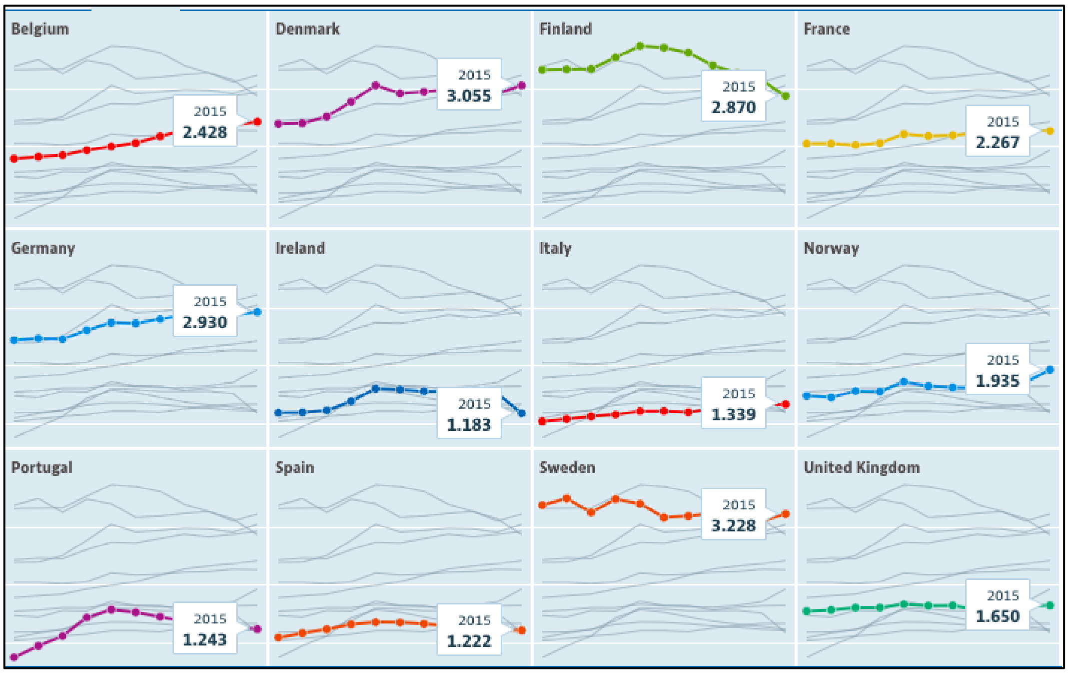

Figure 8. Gross domestic spending on R&D* (OECD, 2020)

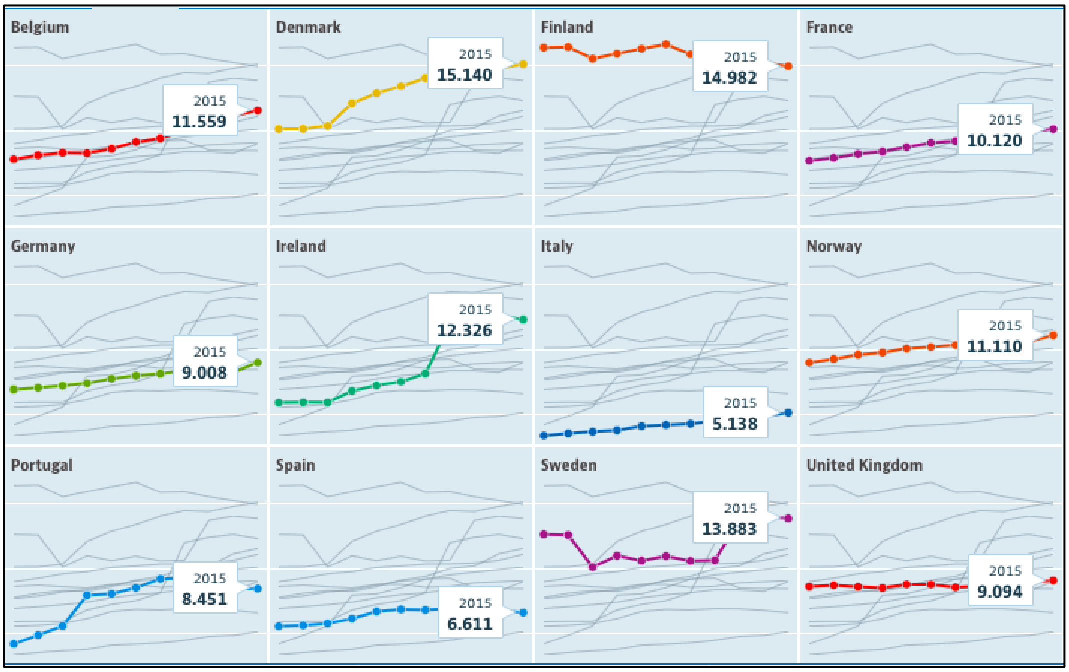

Figure 9. Number of researchers† (OECD, 2020)

* This indicator is measured in USD constant prices using 2010 as base year and Purchasing Power Parities (PPPs) as percentage of GDP.

† This indicator is measured per 1000 people employed.

On the following graph (Figure 10), the accumulation of productivity (MFP) can be observed.

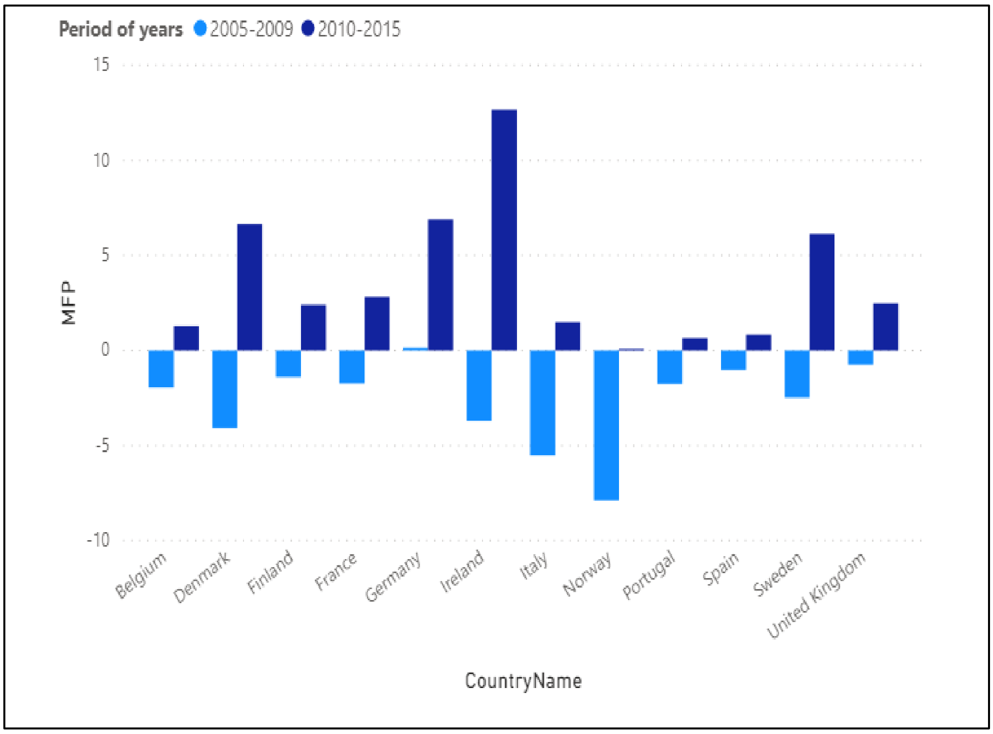

Figure 10. Total accumulation of productivity (MFP) by groups** (OECD, 2019)

In this survey, all OECD countries display positive productivity effects in the second-year group (2010-2015) in contrast with the first one (2005-2009), as shown in Figure 10. Therefore, total accumulation advanced from negative values to positive ones. Whereby, it can be observed that Ireland reached the maximum value of MFP in the second-year group and also the highest growth rate of GDPppe during the same period of time. Other countries such as Sweden and Denmark faced a similar situation. This leads to expect that great part of economic growth may come from the measure of our ignorance (Abramovitz, 1956). Rodriguez-Clare (1997) succinctly argues that is TFP* rather than capital that determines the levels and changes in international income differences, even if the concept of capital is broadened to include intangible capital such as human capital and organization capital. From a series of depression studies on nine advanced countries and a study for

** This indicator is measured as an index and in annual growth rates.

* The concept of total factor productivity (TFP) was first developed by Tinbergen (1942) and Stigler (1947) and has the same properties as MFP. Both seek to measure the efficiency with which all inputs (labor, materials, energy and capital) are being used.

the U.S mention changes in TFP are also crucial in accounting for the within-country business fluctuation (Cole and Lee, 1999; Hansen and Prescott, 2002).

Additionally, during the second-year group was also seen an empowerment of the international economy, although not very significant, as reflex of the increase in trade (Figure 11). Ireland and Belgium were the countries who got more global competitiveness in that sample, reaching the highest surplus in net exports in comparison with the other countries. The increase in the inflows of foreign exchange improves the country's capacity to import technologically advanced capital goods, which are essential to improving productivity and economic growth (McKinnon, 1964).

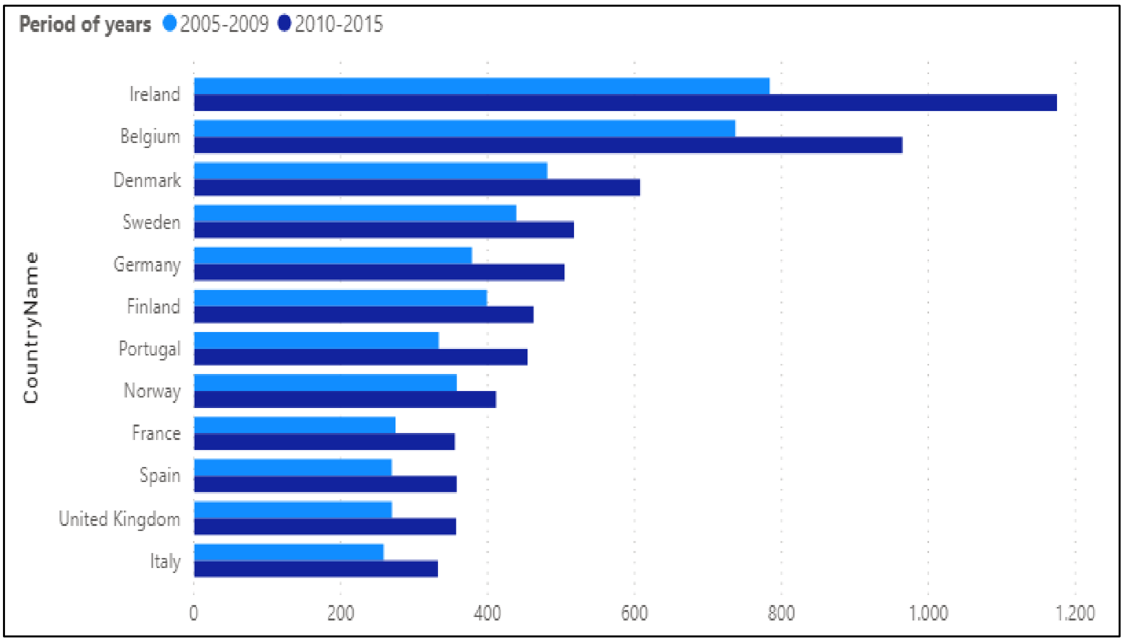

Figure 11. Variation of trade* by periods (World Bank and OECD national accounts data files, 2019)

The evolution of unemployment was also taken into account (Figure 12). Nonetheless this control variable is not a primary interest but a constant element in the research model. In general, during 2005 to 2015 a smooth grow of the unemployment rate with some fluctuations was observed, the peak being reached by Spain in 2013. Norway had always the lowest level of unemployment rate in spite of its slight increase over the last 5 years. Countries had experienced high growth levels of unemployment during 2007 to 2013, the period when the global financial crisis occurred.

According to Bräuninger and Pannenberg (2000**)**, unemployment has a negative impact on the productivity. However, in Sections 8 and 9 it is perceived that such assumption is not well-defined for the case under study.

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* % of GDP (national estimates)

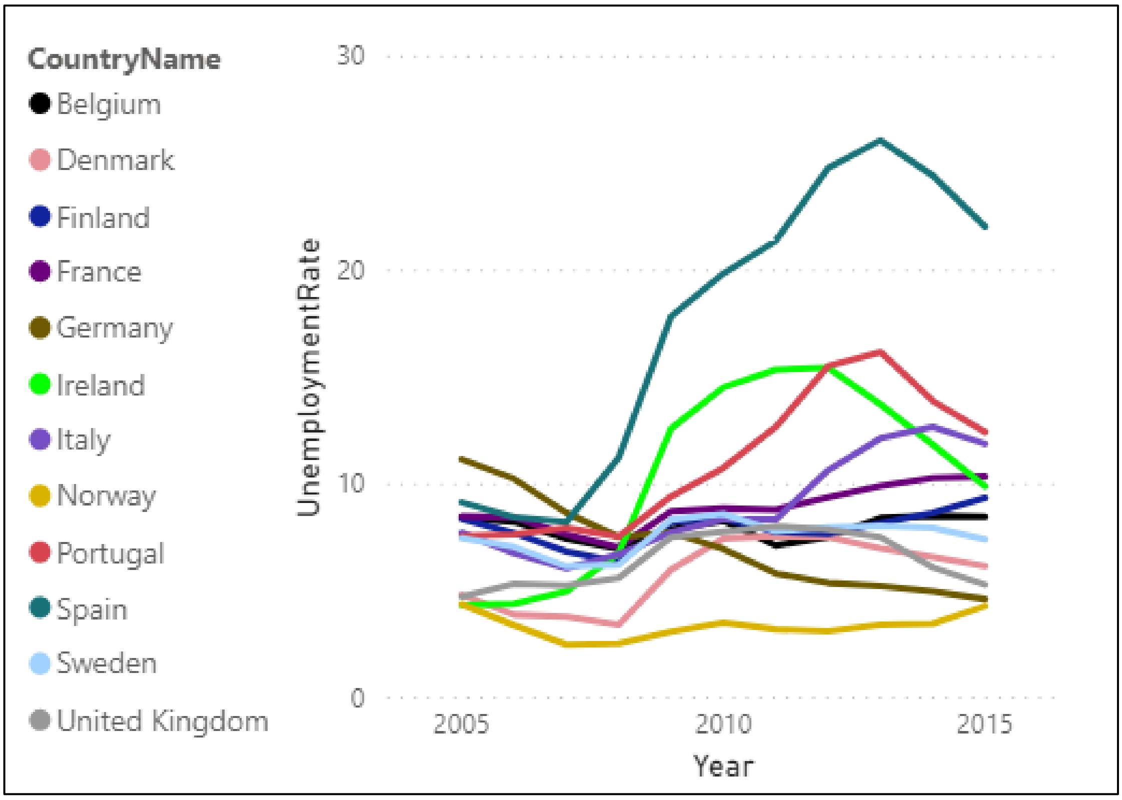

Figure 12. Unemployment progress* (ILOSTAT, 2019)

* % of total labor force (national estimates)

5. Data Analysis

In this chapter we describe the data, the variables which will be included on the model, the way of dealing with missing data in order to work with a balanced panel and also a descriptive statistic. The period of analysis ranges between 2005 and 2015 and 12 OECD countries are considered, namely: Belgium, Denmark, Finland, France, Germany, Ireland, Italy, Norway, Portugal, Spain, Sweden and United Kingdom.

5.1. Data collection

In order to answer the main question posed in this research, data has been compiled from three major well-known data sources, such as World development Indicators (WDI), OECD and World Bank.

The period of data analysis is from 2005 to 2015, mainly to allow capturing the impact and evolution of modern technologies. This way, it may be more conceivable to detect synergies between education, economic growth and technological advances.

Panel regression models are estimated in order to explain human capital effect over economic growth. The representative dependent variable is the log of the GDPppe, which is a function of education measures (population with tertiary education, children out of school, government expenditures on education) and of control variables including trade, productivity (MFP), investment (GFC), unemployment and fertility rate.

Starting with the full set of variables, we first apply the two most common panel data estimation methods. Namely, we estimate two types of regression, (a) fixed effects, and (b) random effects. These panel data allow to study complex behavior models, for instance the business cycles and can take explicit account of individual-specific heterogeneity.

5.2. Description of the variables

In this section, the variables complying the panel linear model are listed. The definitions and details regarding the inputs and outputs are presented on table A.3 in the Appendix.

5.2.1. Dependent variable

To represent economic growth and labor productivity levels across countries, the dependent variable chosen was the growth rate of GDP per person employed (log_GDPppe). This variable was expressed in logarithm in order to avoid dimensional problems. Unlike the majority empirical studies, the gross domestic product will be used in employed terms and not per capita.

5.2.2. Independent variables

The independent representative variables are assumed as follows: population with tertiary education, government expenditures on education and children out of school. The other control variables considered are trade, productivity (MFP), investment (GFC), unemployment rate and fertility rate.

5.3. Amelia package

During the data collection, a slight portion of missing data was encountered. Hence, in order to work with balanced models, Amelia program was used to overcome that problem. Amelia is a complete R package for multiple imputation of missing data (Pratt, 2018). This package implements a new expectation-maximization with a bootstrapping algorithm, is similar to use as various Markov chain and Monte Carlo approaches but gives essentially the same answers. The program also improves imputation models by allowing researchers to put Bayesian priors on individual cell values, thereby including a great deal of potentially valuable and extensive information. It also includes features to accurately impute cross-sectional datasets, individual time series or sets of time series for different cross-sections. The simplicity of the algorithm makes it fairly robust; both a simple command line and an extensive graphical user interface are included (Honaker et al., 1998).

5.4. Descriptive statistics

Table 2 summarizes the descriptive statistics process, outlining the main features of the collection of information.

Variable		Mean	Std.dev	Min	Max	Observations
Log_GDPppe	Overall	11.39465	.1833331	10.90749	11.86345	N = 132
	Between		.1872659	10.96296	11.71789	n=12
	Within		.0349216	11.31603	11.66026	T=11
Tertiary education	Overall	38.08536	8.895928	16.10503	52.00417	N = 132
	Between		8.817418	20.75684	47.14767	n=12
	Within		2.706575	28.23597	45.67567	T=11
Children out of school	Overall	1.201335	1.084628	.00138	4.9212	N = 132
	Between		.7836602	.02401264	2.671192	n=12
	Within		.7804962	-.1633626	4.483403	T=11
Government expenditures on education	Overall	5.774415	1.181614	3.76971	8.55955	N = 132
	Between		1.145363	4.304546	7.936476	n=12
	Within		.4295304	4.367001	6.732511	T=11
Productivity	Overall	.920639	1.7228	-6.313136	8.186183	N = 132
	Between		.4085029	-.7133543	.8154096	n=12
	Within		1.677469	-6.310771	7.462837	T=11
Investment	Overall	21.28705	3.215649	14.75427	31.05298	N = 132
	Between		2.213254	16.46848	24.34074	n=12
	Within		2.411604	14.94444	29.31643	T=11
Trade	Overall	87.0117	39.10828	45.60912	215.1366	N = 132
	Between		3986454	53.68356	178.1381	n=12
	Within		7.847806	57.15343	124.0102	T=11
Unemployment Rate	Overall	8.60106	4.327344	2.495641	26.0919	N = 132
	Between		3.490689	3.362733	17.59722	n=12
	Within		2.73334	-.7641778	17.09574	T=11
Fertility rate	Overall	1.705303	.2533183	1.2	2.1	N = 132
	Between		.2553546	1.345455	2	n=12
	Within		.062783	1.532576	1.850758	T=11

Table 2. Descriptive statistics

6. Econometric Methodology

6.1. Baseline specification model

From a statistical modeling viewpoint, first and foremost, panel data techniques address one broad issue: unobserved heterogeneity, aiming at controlling possible biased estimation for unobserved variables (Baltagi, 2013). In order to have more truthful results regarding school and technology allocation in economic growth, use was made of R Studio to estimate the regression model. The baseline specification can be represented as follows:

$$Y_{it} = \beta_0 + \beta_1 HC_{it} + \beta_2 X_{it} + u_{it}$$

Where Y is the dependent variable of the model, β_0 is a constant, $\beta 1$ is a coefficient associated to the human capital variables HC^*, $\beta 2$ is a coefficient associated to the set of control variables X^{**}, *u* is a random disturbance term (factor other than *X* that affects *Y*) and

$$\begin{cases} i = 1,2,\dots,12 & \text{denotes countries} \\ t = 1, 2,..,11 & \text{denotes years} \end{cases}$$

Three different equations were used to have more meaningful results as well as to avoid multicollinearity issues and dismissed information. Each equation has one different independent education variable.

Therefore, the first approach (REG1) considers tertiary education, the second (REG2) focuses on children out of school and the third (REG3) addresses government expenditures on education.

Explicitly, the models to estimate can be written as follows:

REG1:

$$Log(GDPppe)_{it} = \beta_0 + \boldsymbol{Tert.Educ.}_{\boldsymbol{it}} + Productivity_{it} + Investment_{it} + Trade_{it} + Unemployment_{it} + Fert.Rate_{it} + u_{it}$$

---

* HC variables – Population with tertiary education, Children out of school and Government expenditures on education

** X variables – Productivity, Investment, Trade, Unemployment and Fertility rate

REG2:

$$Log(GDPppe)_{it} = \beta_0 + \boldsymbol{Child.Out.School}_{\boldsymbol{it}} + Productivity_{it} + Investment_{it} + Trade_{it} + Unemployment_{it} + Fert.Rate_{it} + u_{it}$$

REG3:

$$Log(GDPppe)_{it} = \beta_0 + \boldsymbol{Govern.Exp.}_{\boldsymbol{it}} + Productivity_{it} + Investment_{it} + Trade_{it} + Unemployment_{it} + Fert.Rate_{it} + u_{it}$$

6.2. Estimation with fixed effects (FE) and random effects (RE)

The fixed effect model is a regression analysis model that focuses on the relationship between the dependent and independent variables of different countries over time. Fundamental differences exist between all countries, some of which are unlikely to be reflected by the different independent variables used in the analysis. The fixed-effects model accounts for these differences through the inclusion of a constant term α_i displaying these time-invariant characteristics. Thus, the fixed effects regression model becomes the key insight if the unobserved variable does not change over time. In this case, any changes in the dependent variable must be due to factors other than these fixed characteristics (Stock and Watson, 2003). This model is represented as follows:

$$Y_{it} = B1X_{1,it} + \cdots + BkX_{k,it} + \alpha_i + u_{it}$$

With i=1,…,n and t=1,…,T. The coefficients α_i are entity-specific intercepts that capture heterogeneities across entities. u_{it} is the error term. The fixed effects model assumes that each country has a non-stochastic group-specific component to *Y*. This is a way of controlling for unobservable effects on *Y*. But these unobservable effects may be stochastic (i.e. random). On random effects estimation, the individual-specific effect (α_i) is a random variable that is uncorrelated with the explanatory variables and the unobservable component (V_{it}) is treated as a component of the random error term. (U_{it}) is the element of the error which varies between groups but not within groups and the element of the error (V_{it}) varies over time within a given group. The model equation is represented below:

$$Y_{it} = \beta X_{it} + \alpha_i + u_{it} + V_{it}$$

Indeed, the crucial distinction between fixed and random effects is whether the unobserved individual effects embody elements that are correlated with the regressors in the model, not whether these effects are stochastic or not (Greene, 2008). On this research, the model estimation is made with both fixed and random effects.

6.3. Overview of the estimations

Tables 3, 4 and 5 present a summary of the model estimations on REG1, REG2 and REG3 respectively, with random effects (RE) and fixed effects (FE).

First and foremost, in all linear regressions estimated, the education elements are mostly different on explaining any variation of log_GDPppe. As seen in Table 3, on REG1, the population with tertiary education is considered irrelevant on FE in contrast with RE, which affects positively, presenting a p-value of 0.067. Additionally, the remaining variables, both on FE and RE, are considered relevant and have different signals as well as different confidence levels upon the dependent variable.

Concerning R^{2*}, its value is higher in the FE estimation, which means that approximately 61.7% of the inputs can explain changes in the output. In the RE estimation, this value is 58.8%. However, in the adjusted R^{2*}, the RE model attains the highest value (56.8%) in comparison with the FE (56%) although very similar.

Regarding REG2, as noticed in Table 4, children out of school appears to be insignificant in the FE and RE model. The remaining variables, both on FE and RE, are considered relevant and have different signals as well as different confidence levels, upon the dependent variable. R^{2*} is higher in the FE estimation, which means that approximately 61.5% of the inputs can explain the changes in the output. Where in the RE is 56.8%. The adjusted R squared, on FE model, attains the highest relative value (55.7%).

On REG3, as seen in Table 5, both in FE and RE, the variable, government expenditures on education, is relevant on explaining the variation on log_GDPppe. Its contribution is negative on both. The remaining independent variables, both on FE and RE, are considered relevant and have different signals as well as different confidence levels, upon the dependent variable. R^{2*} is higher in the FE estimation, which means that approximately 62.3% of the inputs can explain the changes in the output, where in the RE is 57.4%. The adjusted R squared attains the highest relative value in the FE model (56.7%).

However, to determine which estimation is the most efficient and accurate between FE and RE, several econometric tests were made in order to choose the best fit estimation.

Variables	FE	RE
Tertiary education	0.002 p = 0.103	0.002* p = 0.067
Trade	0.003*** p = 0.000	0.003*** p = 0.000
Productivity	0.002* p = 0.057	0.003** p = 0.050
Investment	0.008*** p = 0.001	0.008*** p = 0.001
Unemployment rate	0.008*** p = 0.0002	0.007*** p = 0.0002
Fertility rate	-0.109*** p = 0.002	-0.102*** p = 0.003
Constant		11.044*** p = 0.000
Observations	132	132
R2	0.617	0.588
Adjusted R2	0.560	0.568
F Statistic	30.638*** (df = 6; 114)	178.041***

*significance at 10% level ** significance at 5% level *** significance at 1% level

Table 3. Linear regression estimations: model REG1

Variables	FE	RE
Children out of school	- 0.004 p = 0.164	-0.004 p = 0.147
Trade	0.003*** p = 0.000	0.003*** p = 0.000
Productivity	0.002* p = 0.062	0.002* p = 0.059
Investment	0.007*** p = 0.004	0.006** p = 0.011
Unemployment rate	0.007*** p = 0.0005	0.006*** p = 0.002
Fertility rate	-0.109*** p= 0.003	-0.096*** p = 0.007
Constant		11.132*** p = 0.000
Observations	132	132
R2	0.615	0.568
Adjusted R2	0.557	0.548
F Statistic	30.322*** (df = 6; 114)	164.624***

*significance at 10% level ** significance at 5% level *** significance at 1% level

Table 4. Linear regression estimations: model REG2

Variables	FE	RE
Government expenditures on education	-0.011** p = 0.035	-0.010* p = 0.053
Trade	0.003*** p = 0.000	0.003*** p = 0.000
Productivity	0.002* p = 0.066	0.002* p = 0.065
Investment	0.006** p = 0.012	0.005** p = 0.027
Unemployment rate	0.007*** p = 0.001	0.006*** p = 0.002
Fertility rate	-0.106*** p = 0.003	-0.093*** p=0.009
Constant		11.205*** p = 0.000
Observations	132	132
R2	0.623	0.574
Adjusted R2	0.567	0.554
F Statistic	31.442*** (df = 6; 114)	168.526***

*significance at 10% level ** significance at 5% level *** significance at 1% level

Table 5. Linear regression estimations: model REG3

6.3.1. Authentication

In order to get an efficient and unbiased model, the Hausman test was made to choose the model most suitable to the research. In panel data analysis, the Hausman test relief is used to choose between a FE model and a RE model (Greene, 2008).

The following table, provided by R documentation, presents the p-values associated to this test.

FE VS RE	Hausman test
REG1	0.000
REG2	0.81
REG3	0.4

Table 6. Fixed effects vs random effects

This test evaluates the consistency of an estimator when compared to an alternative. The hypotheses are as follows:

$$H0: preferred\ model\ is\ RE$$

$$HA: preferred\ model\ is\ FE$$

In REG1, the p-value number is lower than 0.05 (0.000); therefore H0 is rejected, leading to the use of a FE estimation model. However, in REG2 and REG3 the p values are above the confidence level α =0.05 (0.8104) and (0.4003) respectively, leading to use of RE on these two last models.

7. Robustness

7.1. Residual tests (diagnostic)

Before considering the authentication results of REG1 (with FE), as well as REG2 and REG3 (with RE), it is crucial to perform several tests in order to evaluate matters required for the diagnostic of the models. Such diagnostics, tests (provided by R documentation) and the corresponding results are presented in Tables 7, 8 and 9.

Diagnostic	Test	REG1 (p-value)
a. Cross-sectional dependence	Pesaran CD for cross-sectional dependence in panels	0.06
b. Serial correlation	Breusch-Godfrey/Wooldridge test for serial correlation in panel models	0.0004
c. Heteroskedasticity	Breusch-Pagan	0.000

Table 7. Diagnostics on REG1 estimation

Diagnostic	Test	REG 2 (p-value)
a. Cross-sectional dependence	Pesaran CD for cross-sectional dependence in panels	0.005
b. Serial correlation	Breusch-Godfrey/Wooldridge test for serial correlation in panel models	0.0008
c. Heteroskedasticity	Breusch-Pagan	0.0004

Table 8. Diagnostics on REG2 estimation

Diagnostic	Test	REG 3 (p-value)
a. Cross-sectional dependence	Pesaran CD for cross-sectional dependence in panels	0.009
b. Serial correlation	Breusch-Godfrey/Wooldridge test for serial correlation in panel models	0.0004
c. Heteroskedasticity	Breusch-Pagan	0.0007

Table 9. Diagnostics on REG3 estimation

According to Henningsen (2019), cross-sectional dependence is a problem in macro panels and arises if the countries in the sample do not have independently drawn observations but affect each other's outcomes. Therefore, Pesaran's CD or test for cross-sectional dependence in panel models is performed, where the hypotheses are:

$$H0: Residuals\ across\ entities\ are\ not\ correlated$$
$$HA: Cross - sectional\ dependence$$

For REG1, as seen in Table 7, the p-value is 0.06, greater than 0.05. Therefore, H0 is not rejected; thus, it is assumed that there is no cross-sectional dependence in the model. This means the residuals across entities are not correlated. Contrary, for REG2 and REG3 (cf. Tables 8 and 9), the p-values are below the confidence level (α =0.05), exhibiting cross sectional dependence. Ignoring cross-sectional dependence of errors can have consequences, although the presence of some form of cross-sectional correlation of errors in panel data applications in economics is likely to be the rule rather than the exception (Pesaran, 2013).

Indeed, serial correlation tests apply usually to macro panels with long time series. Serial correlation will not affect the unbiasedness or consistency of OLS estimators, but it does affect their efficiency. This will lead to the conclusion that the parameter estimates appear more precise than they really are (Williams, 2015). Consequently, use is made of the Breusch-Godfrey test for panel models, which is a test of serial correlation for the idiosyncratic component of the errors in panel models. The corresponding hypotheses tested are:

$$H0: No\ serial\ correlation\ in\ idiosyncratic\ errors$$
$$HA: Serial\ correlation\ in\ idosyncratic\ errors$$

Since the p-values obtained are 0.0004 (for REG1), 0.0008 (for REG2), 0.0004 (for REG3), all lower than the level of significance (α = 0.05), the null hypothesis (H0) is rejected. This leads to the conclusion that the parameter estimates seem more precise than they really are.

For assessing heteroskedasticity*, the Breusch-Pagan is performed. It tests whether the variance of the errors V(e)) from a regression is dependent on the values of the independent variables (R documentation). The hypotheses tested are: $H0: V(\varepsilon) = 0.$ $HA: V(\varepsilon) \neq 0$

In this case, the p-values obtained from the test are 0.000 (for REG1), 0.0004 (for REG2) and 0.0007 (for REG3), all less than the level of significance (α = 0.05). Hence, the null hypothesis is rejected, that is, heteroskedasticity is found to be present. If heteroskedasticity is detected, a robust covariance matrix, as described in the following section, can be used to account for it.

* Standard errors of a variable, monitored over a specific amount of time, are non-constant. With heteroskedasticity, the tell-tale sign upon visual inspection of the residual errors will tend to fan out over time.

Indeed, stationarity was also taken into account. This is a property necessary for the application of many procedures in the analysis and to avoid the problem of counterfeit regressions. In order to know if the variables can be assumed as stationary, the Levin-Lin-Chu test* was made. This test assumes a common autoregressive parameter for all panels, so it does not allow for the possibility that some countries' real exchange rates contain unit roots while other countries' real exchange rates do not (Levin et al., 2002). The hypothesis tested are as follows:

$$H0: Panels\ contain\ unit\ roots$$
$$HA: Panels\ are\ stationary$$

Stationarity tests have been applied to a variety of key economic issues with the expectation that the increased power of these tests, due to the exploitation of the cross-section dimension, would provide more compelling evidence. In the majority of the cases, the null hypothesis is rejected, and it is concluded that the series are stationary. Only two explanatory variables, such as population with tertiary education and fertility rate seems to have unit roots. However, to achieve more accuracy with stationarity, the Augmented Dickey-Fuller Test (ADF test) test was performed on both variables. And as detected by this test, these panels are found to be stationary.

In the Appendix (Table A.4) the stationarity of the variables can be observed.

7.2. Robust estimator literature

Subsequently, attention is given to a robust estimator needed to control the presence of heteroskedasticity and serial correlation.

Applied researchers have sometimes ignored the problematic of heteroskedasticity, probably because major statistical packages do not estimate robust standard errors in RE models. Not surprisingly, this can lead to severe bias in the standard error estimates, both in hypothetical and real-life situations.

Arellano (1987) and Froot (1989) in the different contexts of fixed effects panels with serial correlation and of industry-clustered financial data, developed independently what is computationally the same estimator.

From the point of view of political science, where panel data are an important methodological field, this tool allows researchers to progress beyond the now-ubiquitous application of panel-corrected standard errors (Beck and Katz, 1995), along the lines of Wilson and Butler (2007): both comparing it with alternative strategies and possibly combining it with individual effects, in order to tackle the all-important, and often overlooked, issue of individual heterogeneity. Therefore, the suggestion found in the literature was to use a variance-covariance matrix for a fitted model object (vcov), which estimates heteroskedasticity-consistent covariance estimators. This is done using Arellano method on REG1, recommend for fixed effects, which controls both heteroskedasticity and serial correlation.

Nonetheless, both REG2 and REG3 suffer from serial correlation and cross-sectional dependence. To mitigate this issue and to have more accurate results, an attempt was made of the 1st difference equation on the database. The following equation represents the transformations made:

$$\Delta Yi,t, = Yi,t,z - Yi,t,-1$$

$$\begin{cases} i = 1,2,\ldots,12 \text{ denotes countries} \\ t = 1, 2,..,11 \text{ denotes years} \end{cases}$$

Where *Y* represents the dependent variable. This transformation was also done for the independent variables.

In spite of this effort, the estimation results were inconsistent. So, for REG2 and REG3 the estimators HC1 (Heteroskedasticity consistent type 1) suggested by MacKinnon and White (1985) were adopted to improve the performance in small samples after controlled by RE. That option gives less weight to influential observations, minimizing the problems of cross-sectional dependence and serial correlation. Serial correlation tests apply to macro panels with long time series. This is not generally a problem for micro panels (with few years).

8. Results and Discussion

8.1. Model results (2005-2015)

This study aimed to investigate how a country's human capital can influence its economic growth by controlling other variables which are, theoretically and empirically, considered as determinants of economic performance, such as trade, productivity, investment, fertility rate and unemployment rate. It was established as a measure of economic growth and therefore as the dependent variable, the growth rate of GDPppe. Three models were developed, REG 1, REG2 and REG3, just differing from the education variables included on each of them: REG1 - population with tertiary education; REG2 - children out of school; REG3 - government expenditures on education. Table 10 displays the regressions with a robust estimator and suggests that most of the control variables have significant influence on the dependent variable (log_GDPppe), with different levels of significance.

Variables	REG1	REG2	REG3
Tertiary education	0.0016 p = 0.3	-	-
Children out of school	-	-0.004* p = 0.09	-
Government expenditures on education	-	-	-0.01 p = 0.365
Trade	0.003*** p = 0.0002	0.003*** p = 0.0001	0.003*** p = 0.000
Productivity	0.0024* p = 0.068	0.0024* p = 0.089	0.0024* p = 0.06
Investment	0.008* p = 0.09	0.006 p = 0.18	0.005 p = 0.14
Unemployment rate	0.008** p = 0.02	0.0065** p = 0.02	0.0063** p = 0.02
Fertility rate	-0.109* p = 0.07	-0.095 p = 0.17	-0.093* p = 0.09
Constant	-0.11* p = 0.07	11.13199467*** p = 0.000	11.20451854 *** p = 0.000

*significance at 10%level ** significance at 5% level *** significance at 1% level

Table 10. Robust estimation – REG1, REG2, REG3

With respect to model REG1, population with tertiary education remained irrelevant for explaining output changes, both before and after applying the robustness. This in accordance with Henderson (2010) and Stengos (1999), who state insignificance for human capital on economic growth, and also with many empirical studies where the dependent variable was defined in per capita terms and not per person employed. Thus, it is conceivable to assume that higher education is not always found to benefit economic growth (Aghion et al., 2009).

Nevertheless, many studies found robust evidence that an increase in the number of university students is positively associated with faster subsequent economic growth. In fact, according to Valero and Reenen (2016), doubling the number of universities is associated with over 4% higher GDP per capita in a region. But, since not all students might finish their degree, this assumption may suffer from bias on capturing tertiary education effects, unlike our model.

Regarding model REG2, as observed in Table 10, it turns out that children out of school have a negative impact on economic growth. An increase in one unit of this variable leads to a decrease of 0.4% in log_GDPppe. Thus, part of decline of GDP is affected by the percentage of primary-school-age children who are not enrolled in primary or secondary school. A study conducted by the Results for Development Institute (R4D, 2013) revealed that out-of-school children of primary age significantly impact the economic growth of developing countries. It is shown here that the same occurs in developed OECD countries. Until universal primary education is achieved in countries where progress has stuck, children out of school will continue to represent an unconscionable underinvestment in human capital and a costly barrier that prevents nations from reaching their full economic and social potential (Burnett, 2015). That lead us to state that the contribution of primary and secondary schooling to economic development is greater than what has conventionally been perceived.

Concerning model REG3, government expenditures on education revealed insignificance for explaining the dependent variable, as seen in Table 10. Since the basis on which public expenditures for education are made may not lie on such a strong foundation as often assumed, a question arises whether these expenditures are actually legitimate if found not contributing to a country's economy. Even if this type of investment is considered useful, the nature and dynamics of the relationship between governmental spending on education and economic growth is always of great importance, therefore justifying thorough investigation and re-evaluation. However, it should be mentioned that in Section 8.2 this variable shows a different behavior.

Definitely, technological advances may contribute to a more global economy. As seen in Table 10, OECD countries can benefit from foreign markets. Consequently, one unit increase in trade represents an increase in 0.3% of log_GDPppe. This support theoretical models from Grossman and

Helpman (1991), who have shown that trade openness improves the transfer of new technologies, facilitating technological progress and productivity improvement. Trade is both positive and significant in all models (REG1, REG2, REG3).

In Table 10 is also noticed that productivity (MFP) is positive and statistically significant in all models, with the same relative value. An increase in one unit of this variable leads to an increase of 0.24% in log_GDPppe. Hence, the part of GDP growth that cannot be explained by changes in labor and capital inputs is due to the influence of this indicator measured as a residual. As referred before, power knowledge, network effects, spillovers from production factors and adjustment costs also affect positively the expansion of the economy.

About investment (GFC), the results go in partial disagreement with Lukasz (2010), who states that the existence of a positive long run influence of fixed assets on GDP proves that this type of capital is still under its growth-maximizing level**.** In fact, after applying the robust estimator, investment is not significant for explaining the output of REG2 and REG3. Yet, in REG1 investment has a positive and significant effect on the dependent variable, as an increase in one unit of investment leads to an increase of 0,8% in log_GDPppe. However, since the time-data is fairly sensitive due to the crisis period, a robustness check was made to assess if any significant changes would occur. Again, a different behavior of this variable is seen in Section 8.2.

Unemployment rate has a positive effect on log_GDPppe, both before and after applying the robust estimator, conflicting with Bräuninger and Pannenberg (2000), who reported a negative interaction between these two variables. In fact, an increase in one unit of this variable leads to an increase of 0.8% on REG1, 0.7% on REG2 and 0.6% on REG3.

Conversely, demographic effects, measured by the fertility rate, exhibit a negative relationship with the dependent variable of the model on REG1 and on REG3 and are insignificant on REG2. This relationship makes sense, according to some macroeconomic models, such as the overlapping generations model (OLG). According to these models, as long as the population growth rate increases, the capital accumulation goes down, leading to a decrease on the production per capita of a certain country. In the present study, this negative correlation is confirmed, although in per employed terms, contradicting Mester statement (2017). Indeed, an increase in one unit of this variable decreases log_GDPppe by 11% in REG1 and 9% in REG3. The continuous increase on birth rates appears to reduce economic growth through investment effects and possibly through "capital dilution". In contrast, birth rate declines have a strong medium-term positive impact on the income per capita (Brander and Dowrick, 1994). Hence, the economy endogenously undergoes a demographic transition in which the traditionally positive relationship between income per capita and population growth is reversed (Galor and Weil, 1998).

8.2. Robustness checks

Due to the context of the time data considered (2005-2015), the original sample was divided into two segments in order to perceive the behavior of the variables during the crisis period (2005-2012) as well as during the economic recovery (2013-2015). In fact, it is believed that for each period investment will have different contributes on explaining the dependent variable, log_GDPppe.

In the following subsection, the estimations of the models used previously are presented and commented.

8.2.1. Crisis period (2005-2012)

On this sample, after running the Hausman test, it was decided to apply FE in REG1 and RE in REG2 and REG3. A robust estimator was applied to all regressions to control heteroskedasticity and serial correlation. The corresponding results are shown in Table 11.

Variables	REG1	REG2	REG3
Tertiary education	-0.0001 p = 0.9	-	-
Children out of school	-	-0.003* p = 0.06	-
Government expenditures on education	-	-	-0.007** p = 0.03
Trade	0.001*** p = 0.000	0.001*** p = 0.000	0.001*** p = 0.000
Productivity	0.003*** p = 0.000	0.003*** p = 0.000	0.0029*** p = 0.000
Investment	0.007*** p = 0.0006	0.006*** p = 0.0008	0.005** p = 0.006
Unemployment rate	0.009*** p = 0.0002	0.008*** p = 0.0003	0.008*** p = 0.0004
Fertility rate	-0.029 p = 0.45	-0.023 p = 0.48	-0.002 p = 0.94
Constant		11.11989417 *** p = 0.000	11.14641021 *** p = 0.000

*significance at 10%level ** significance at 5% level *** significance at 1% level

Table 11. Robust estimator in the crisis period

During the crisis period, the contribution of tertiary education is irrelevant. However, children out of school and government expenditures on education have significant and negative impact over log_GDPppe. In fact, an increase in one unit of both variables leads to a decrease to the dependent variable of 0.3% and 0.7%, respectively. As pointed out before, government expenditures on education were insignificant in explaining any change to the output, and after the robustness check they even displayed a negative effect. Therefore, the level of such expenditures may justify further re-evaluation.

In Table 11, it can be noticed the strong contribution of investment (GFC), which was not so evident in the previous original data (2005-2015). In REG1, REG2 and REG3, an increase in one unit of this variable affects positively the dependent variable of 0.7%, 0.6% and 0.5%, respectively. After scoping our time-data, it is reasonable to state that increasing an investment during a recession can enhance the economy of developed countries. As Rao (1980) has pointed out, "increase in saving, use of increased saving for increased capital formation, use of increased capital formation for increased saving for a further increase in capital formation constituted the strategy behind economic growth”.

To sum up, as noticed before, trade and productivity exhibit positive outcomes over economic growth, even in a crisis context.

8.2.2. Economic recovery (2013-2015)

On this sample, after running the Hausman test, RE estimation was applied to REG1, REG2 and REG3. There was no need to apply any robust estimator since all regressions did not exhibited serial correlation or heteroskedasticity.

As shown in Table 12, in economic recovery is observed an irrelevant effect regarding education variables (tertiary education, children out of school and government expenditures on education) for explaining the evolution of the dependent variable. Possibly, this fact can be explained by the higher influence of other independent variables in this period, relatively to what was found to occur previously, during the crisis. Such interaction effects between variables may result in model misrepresentations, particularly in scenarios of economic instability as the one under study.

Variables	REG 1	REG2	REG3
Tertiary education	-0.0005 p = 0.98	-	-
Children out of school	-	-0.008 p=0.45	-
Government expenditures on education	-	-	-0.02 p = 0.18
Trade	0.002** p = 0.03	0.002** p = 0.03	0.002** p = 0.04
Productivity	-0.006** p = 0.045	-0.006** p = 0.048	-0.006** p = 0.045
Investment	0.04*** p = 0.000	0.04*** p = 0.000	0.04*** p = 0.00
Unemployment rate	0.005 p = 0.13	0.004 p = 0.37	0.006* p = 0.09
Fertility rate	-0.15** p = 0.02	-0.14** p = 0.04	-0.13* p = 0.03
Constant	10.586636*** p = 0.000	10.609666*** p = 0.000	10.7358483*** p = 0.000

*significance at 10%level ** significance at 5% level *** significance at 1% level

Table 12. Robust estimator in economic recovery

Surprisingly, in Table 12 productivity appears as a negative asset on the variation of the log_GDPppe. The main reason to explain this unintelligible result may be related to the weakness of productive structure of some OECD countries and also to the expansionist (and perhaps inefficient) policies adopted by some companies. One suggestion for these entities would be to start measuring the productivity on a daily, weekly and monthly basis using a metrics such as number of units produced, sales or customer-satisfaction surveys. With effectiveness and efficiency in place, some baseline measures of the productivity can be established.

However, as seen in the crisis period, investment is also a crucial variable for economic recovery. As seen in Table 12, in REG1, REG2 and REG3, an increase in one unit of any of the variables considered in each model leads to an increase in the dependent variable of 4%.

In this period, in contrast with 2005-2012, it is seen that the unemployment rate is mostly insignificant for explaining any variation of the dependent variable.

9. Conclusion

Over the last few years, OECD economies have put emphasis on education as a way to continue to develop and achieve economic prosperity. In fact, on this research it was noticed an increase on different crucial variables in this field, such as tertiary education, number of researchers, public expenditures on education, and in contrast, a decrease in the number of children out of school. That is, OECD countries have become more knowledge based.

In order to answer the main question posed in this research, data has been compiled from three major well-known data sources, such as World development Indicators (WDI), OECD and World Bank. The period of data analyzed was from 2005 to 2015, mainly to allow capturing the impact and evolution of modern technologies. This way, it may be more conceivable to detect synergies between education, economic growth and technological advances. Additionally, a robustness check was performed in order to fetch other significant effects to the models estimated. While the previous literature has failed to reach a unique consensus as to the significance and relevance of educational attainment in growth models, a different approach was made to clarify this point.

To avoid collinearity issues, three different models were estimated, each one with one different education variable: REG1, with population with tertiary education, REG2 with children out of school and REG3 with government expenditures on education. The empirical literature recommended to apply Fixed Effects FE and RE, since we were working with panel data. However, since these models had drawbacks such as serial correlation and heteroskedasticity, a robust estimator was applied to tackle them. In consequence, as observed, tertiary education and government expenditures on education appear to be insignificant to explain any variation of the dependent variable.

After studying the interactions between human capital and economic growth, a feeble connection regarding education is identified in this topic. In spite of observing a positive relationship between tertiary education and GDPppe among the majority of OECD countries as well as the benefit to the total accumulation of productivity. It cannot be stated that tertiary education is the main level of education that provides higher income per worker. In fact, it was shown by the estimated models that this variable remains insignificant in explaining any changes over the growth rate of GDPppe, not only considering the original data (2005-2015) but also after performing the robustness checks for the periods 2005-2012 and 2013-2015.

This finding goes in opposition with numerous previous studies in the field of labor economics which have attempted to measure the relationship between a worker's education and its productivity, whereas such relationship has generally been found to be positive.

On the other hand, it is clearly perceived the negative effect from children out of school on OECD economies. This goes in accordance with UNICEF, which mention children as the most important resource for future economic growth. As denoted before, it is shown that the primary and secondary level of education may have more influence than the tertiary to economic growth.

To dig further on the research, the database of the model was divided. Consequently, the model was re-estimated during the crisis period (2005-2012) and during the period of economic recovery (2013-2015). In both subsamples, it is perceived the positive and significant effect of investment, which did not clearly happen when (2005-2015) was considered a whole. In crisis context, children out of school and government expenditures on education have shown a negative and significant impact over log_GDPppe. An increase in one unit of both variables leads to a decrease of the dependent variable of 0.3% and 0.7%, respectively. During economic recovery, it is seen an irrelevant effect regarding education variables (tertiary education, children out of school and government expenditures on education) for explaining the dependent variable.

Therefore, the results intuitively lead us to the following question: what should be done in order to adequately represent human capital in economic models? There are several possible answers to this question. First, it is plausible that the models considered here failed to include variables measuring all significant determinants of economic growth. Re-examination of additional potential growth factors, perhaps through a nonparametric lens, may reveal additional variables that significantly influence the growth process and therefore may overcome any omitted variable problem.

The sample used in this study, which includes OECD countries, is not representative of countries at very low levels of economic development. Thus, it may not be possible to generalize the results to all type of countries. However, if the sample had included a wider range of levels of economic development and less identical variables (GDPppe and productivity), it seems logical to assume that the results could have shown a different effect of human capital on growth. Nevertheless, this remains to be proved and demands further research.

The nature of this research exercise was mostly exploratory. The framework of analysis here utilized herein could be further developed to explore some causal interpretations of specific effects, for instance by developing instrumental variables to design a dynamic model. Nonetheless, since it was given priority to work with a balanced panel, some efforts were made in that direction. A large number of years and countries were removed, and a minimum portion of missing data was estimated by a software program.

Undeniably, it becomes crucial to be capable to evaluate the quality of education – measured on an outcome basis of cognitive skills – and its quantity. Improving the quality of education is likely to increase the explanatory power of education with respect to economic growth (Hanushek and Wößmann, 2007). Hence, to estimate and integrate into economic growth analyses a measure of human capital adjusted for quality, although being a very hard and though challenge, represents a useful research endeavor worth to be pursued in future. The issue of skills mismatch should also be further explored. In particular, it would be informative to establish which occupational groups are most affected by skills mismatch (as captured by various measures), which groups drive national trends and how these trends relate to structural changes in labor markets such as the declining share of jobs in the middle of the skill range in many countries. More detailed empirical investigations, as well as replication of the results using other data sources, would help to assess whether mismatch is likely to be temporal or structural, and which policy interventions are needed.

To sum up, education policy measures focused on the provision of facilities aimed at improving the number of trained teachers, reducing pupil-teacher ratios, schooling life expectancy and performance levels based on test scores along with market trends might have different and interesting contributes to economic growth. Such measures could be taken into account in future studies. Recently developed systems, such as sophisticated projection techniques developed through the construction of existing education databases, might be applied to measure changes in mean education achievement and to make use of larger and more widely available datasets.

10. References

Abramovitz, M. (1956). “Resource and Output Trends in the United States since 1870”. American Economic Review, 46, 5-23.

Aghion, P.; Boustan, L.; Hoxby, C.; Vandenbussche, J. (2009). “The Causal Impact of Education on Economic Growth: Evidence from the U.S.”. Brookings Economics Studies.

Agiomirgianakis, G.; Asteriou, D.; Monastiriotis, V. (2002).” Human Capital and Economic Growth Revisited: A Dynamic Panel Data Study”. International Advances in Economic Research, 8(3), 177-187.

Ahsan, H.; Haque, E. (2017). ”Threshold Effects on Human Capital: Schooling and Economic Growth”. Economics Letters, 156, 48–52.

Arellano, M. (1987). “Computing Robust Standard Errors for within Group Estimators”. Oxford Bulletin of Economics and Statistics, 49(4), 431–434. doi:10.1111/j.1468-0084. 1987.mp49004006. x.

Baltagi, H. (2013). ”Econometric Analysis of Panel Data”, 3rd Edition. John Wiley & Sons.

Barro, R.J. (2013). “Education and Economic Growth”. Annals of Economics and Finance, Society for AEF, vol. 14(2), 301-328.

Beck, N.; Katz, J.N. (1995). “What to Do (and Not to Do) with Time-Series Cross-Section Data”. The American Political Science Review, 89(3), 634–647. doi:10.2307/2082979.

Benhabib, J.; Spiegel, M.M. (1994). “The Role of Human Capital in Economic Development Evidence from Aggregate Cross-Country Data” Journal of Monetary Economics, Elsevier, vol. 34(2), 143-173.

Benos, N.; Zotou, S. (2014). “Education and Economic Growth: a Meta-Regression Analysis”. World Dev., 64, 669–689.

Bontis, N. (2000). “Assessing Knowledge Assets: A Review of the Models Used to Measure Intellectual Capital”. Working paper, Queen’s Management Research Centre for Knowledge-Based Enterprises.

Braakmann, N. (2009). “Are there Social Returns to both Firm-Level and Regional Human Capital? – Evidence from German Social Security Data”. University of Lüneburg, Working Paper Series in Economics, N. 143.

Brander, J.; Dowrick, S. (1994). ” The Role of Fertility and Population in Economic Growth: Empirical Results from Aggregate Cross-National Data”. NBER Working Paper No. 4270.

Bräuninger, M.; Pannenberg, M. (2007). ”Unemployment and Productivity Growth. An Empirical Analysis within the Augmented Solow Model”. IZA Discussion Paper No. 136, Institute of Labor Economics.

Burnett, N. (2015). ”The Economic Cost Out-of-School Children in Southeast Asia”. Document code: TH/DOC/APPEAL/15/026.

Busemeyer, M.R. (2007). “Determinants of Public Education Spending in 21 OECD Democracies, 1980-2001”. Journal of European Public Policy, 14(4), 582-610.

Cole, H.L.; Lee, E.O. (1999). “The Great Depression in the United States from a Neoclassical Perspective”. Federal Reserve Bank of Minneapolis Quarterly Review, V. 23, No. 1: 2-24.

Dulleck, U.; Foster, N. (2008). “Imported Equipment, Human Capital and Economic Growth in Developing Countries”. Economic Analysis and Policy, 38, 233-250.

Easterly, W.; Levine, R. (1997). “Africa’s Growth Tragedy: Policies and Ethnic Divisions”. Q. J. Econ., 11(4), 1203–1250.

Froot, K.A. (1989). “Consistent Covariance Matrix Estimation with Cross-Sectional Dependence and Heteroskedascity in Financial Data”. Journal of Financial and Quantitative Analysis, 24(3), 333-355.

Funke, M.; Strulik, H. (2000). ”On Endogenous Growth with Physical Capital, Human Capital and Product Variety”. European Economic Review, 44, 491-515.

Galor, O.; Weil, D.N (1998).” Population, Technology, and Growth: from the Malthusian Regime to the Demographic Transition and Beyond”. NBER working paper No.6811.

Goldin, C. (2001). “The Human Capital Century and American Leadership: Virtues of the Past”. NBER Working Paper No. 8239.

Goldin, C.; Katz, L.F. (2008). “Race between education and technology”. ISBN 978-0-674- 02867-8.

Goldin, C. (2016).” Human Capital”. In: “Handbook of Cliometrics”, Diebolt, C.; Haupert, M. (Eds.). Springer-Verlag, 55–86.

Greene, W.H. (2008).” Econometric Analysis”, 6th Edition. Prentice-Hall, Upper Saddle River, New Jersey.

Grossman, G.M.; Helpman E. (1991). “Innovation and Growth in the Global Economy”. MIT Press, Cambridge, MA.

Gürbüz, A.A. (2011). “Comparing Trajectories of Structural Change”. Camb. J. Econ., 35, 1061-1085.

Haldar, S.K.; Mallik, G. (2010). "Does Human Capital Cause Economic Growth? A Case Study of India". International Journal of Business and Economic Sciences Applied Research (IJBESAR), International Hellenic University (IHU), Kavala Campus, Greece, vol. 3(1), 7-25.

Hansen, G.; Prescott, E.C. (2002) “Malthus to Solow”. American Economic Review, V. 92: 1205-1217.

Hanushek, E.A.; Wößmann, L. (2007). ”The Role of Education Quality in Economic Growth”. World Bank, Policy Research Working Paper 4122.

Henderson, D.J. (2010). “A Test for Multimodality of Regression Derivatives with an Application to Nonparametric Growth Regressions”. Journal of Applied Econometrics, Vol. 25, 458-480.

Henningsen, G. (2019). ”Analysis of Panel Data using R”. In Panel Data Econometrics, 345-398. Academic Press. https://doi.org/10.1016/B978-0-12-814367-4.00012-5.

Hidalgo, C.; Klinger, B.; Barabasi, A.L.; Hausmann, R. (2007). “The Product Space Conditions the Development of Nations”. Science, 317, 482–487.

Honaker, J.; King, G.; Blackwell, M. (1998). “Amelia: A Program for Missing Data”. Journal of Statistical Software, 45. 10.18637/jss. v045.i07.

IMF - International Monetary Fund Publication Services (2013). “Financial Crises: Causes, Consequences, and Policy Responses”. ISBN 978-1-47554-340-7.

Karaçor, Z. (2015).” Relationship with Education Expenditure and Economic Growth in OECD Countries”. UDK: 37:330.35.

Levin, A.; Lin, C.-F.; Chu, C.-S.J. (2002). ”Unit Root Tests in Panel Data: Asymptotic and Finite-Sample Properties”. Journal of Econometrics 108, 1–24.

Lochner, L.; Moretti, E. (2004). “The Effect of Education on Criminal Activity: Evidence from Prison Inmates, Arrests and Self-Reports”. American Economic Review, 94(1), 155-189.

Lukasz, L. (2010). ”Fixed Capital and Long-Run Economic Growth: Evidence from Poland”. Systems Science, Vol. 36, No. 4, 34-46.

Mackinnon, J.; White, H. (1985). “Some Heteroskedasticity-Consistent Covariance Matrix Estimators with Improved Finite Sample Properties”. Department of Economics, Queen’s University.

Mankiw, N.G.; Romer, D.; Weil, D. (1992). “A Contribution to the Empirics of Economic Growth”. Quarterly Journal of Economics 107(2), 407-437.

Marimuthu, M.; Lawrence, A.; Maimunah, I. (2009). “Human Capital Development and Its Impact on Firm’s Performance: Evidence from Developmental Economics”. Journal of International Social Research, 2/8, 265-272.

McKinnon, R.I. (1964). “Foreign Exchange constraints in economic development and efficient aid allocation”. Econ. J., 74, 388–409.

Mester, L.J. (2017). “Demographics and their Implications for the Economy and Policy”. Cato’s Institute 35th Annual Monetary Conference, Washington DC.

Nelson, R.R.; Phelps, E. (1966). “Investment in Humans, Technology Diffusion and Economic Growth”. American Economic Review 56(2), 69-75.

OECD (2002). ”Education at a Glance, Glossary. Social Internal Rate of Return”. Accessed on: https://stats.oecd.org/glossary/detail.asp?ID=5426.

OECD (2010). ”The OECD Innovation Strategy: Getting a Head Start on Tomorrow”. OECD Publishing, Paris. Accessed on: https://doi.org/10.1787/9789264083479-en

OECD (2012). “Education at a Glance: Highlights”. OECD Publishing. Accessed on http://dx.doi.org/10.1787/eag_highlights-2012-en.

Pesaran, M.H. (2013). ”Large Panel Data Models with Cross-Sectional Dependence: A Survey”. Working Paper No. 153, Federal Reserve Bank of Dallas.

Pelinescu, E. (2015). “The impact of Human Capital on Economic Growth”. Procedia Economics and Finance, 22, 184-190.

Pratt, B. (2018). “Amelia – Multiple Imputation in R”. Accessed on: https://opr.princeton.edu/workshops/Downloads/2018Jan_AmeliaPratt.pdf

Prichett, L. (1996). “Where Has all the Education Gone?”. The World Bank Economic Review, Vol. 15, No. 3, 367-391.

Psacharopoulos, G.; Patrinos, H.A. (2018). “Returns to Investment in Education: a Decennial Review of the Global Literature”. Education Economics, 26(5), 445-458. DOI: 10.1080/09645292.2018.1484426.

Queirós, A.; Teixeira, A. (2016). “Economic Growth, Human Capital and Structural Change: A Dynamic Panel Data Analysis”. 0048-7333/© 2016 Elsevier B.V.

Rao, V.K. (1980). ”Savings, Capital Formation and National Income”. Economic and Political Weekly, vol.15, no.22, 965-977.

Rodriguez-Clare, A. (1997). “The Neoclassical Revival in Growth Economics: Has It Gone Too Far?” NBER Macroeconomics Annual, 73-102.

Romanello, M. (2016). “The Private and Social Return to Education Considering the Characteristics of Society”. Vol. 38, No. 15, page 13.

Romer, P.M. (1989). ”Human Capital and Growth: Theory and Evidence”. Carnegie Rochester Conference Series on Public Policy, 32, 251-286.

Romer, P.M. (1990). ”Endogenous Technological Change”. J. Political Econ., 98(5), 71-102.

Schultz, T.W. (1971). ”Education and Productivity”. National Commission of Productivity, Washington D.C.

Schultz, T.W. (1979). “Investment in Entrepreneurship and Agricultural Research”. Kaldor Memorial Lecture, Iowa State University.

Sianesi, B.; Reenen, J.V. (2003).” The Returns to Education: Macroeconomics”. J. Econ. Surv., 17 (2), 157-200.

Smith, A. (1776). “An Inquiry into the Nature and Causes of the Wealth of Nations”, Vol. 3. Whitestone, Dublin.

Stock, J. H.; Watson, M.W. (2003). “Forecasting Output and Inflation: The Role of Asset Prices.”. Journal of Economic Literature, 41 (3), 788-829.

Todaro, M.P.; Smith, S.C. (2015). ”Economic Development”, 12th edition. Pearson Education.

Valero, A.; Reenen, J.V. (2016). ”The Economic Impact of Universities: Evidence from Across the Globe“. NBER Working Paper 22501.

Williams, R. (2015).” Serial Correlation”. Accessed on https://www3.nd.edu/~rwilliam/stats2/l26.pdf

Wilson, S.E.; Butler, D.M. (2007). “A Lot More to Do: The Sensitivity of Time-Series Cross-Section Analyses to Simple Alternative Specifications”. Political Analysis, 15(2), 101-123. doi:10.1093/pan/mpl012.

11. Appendix

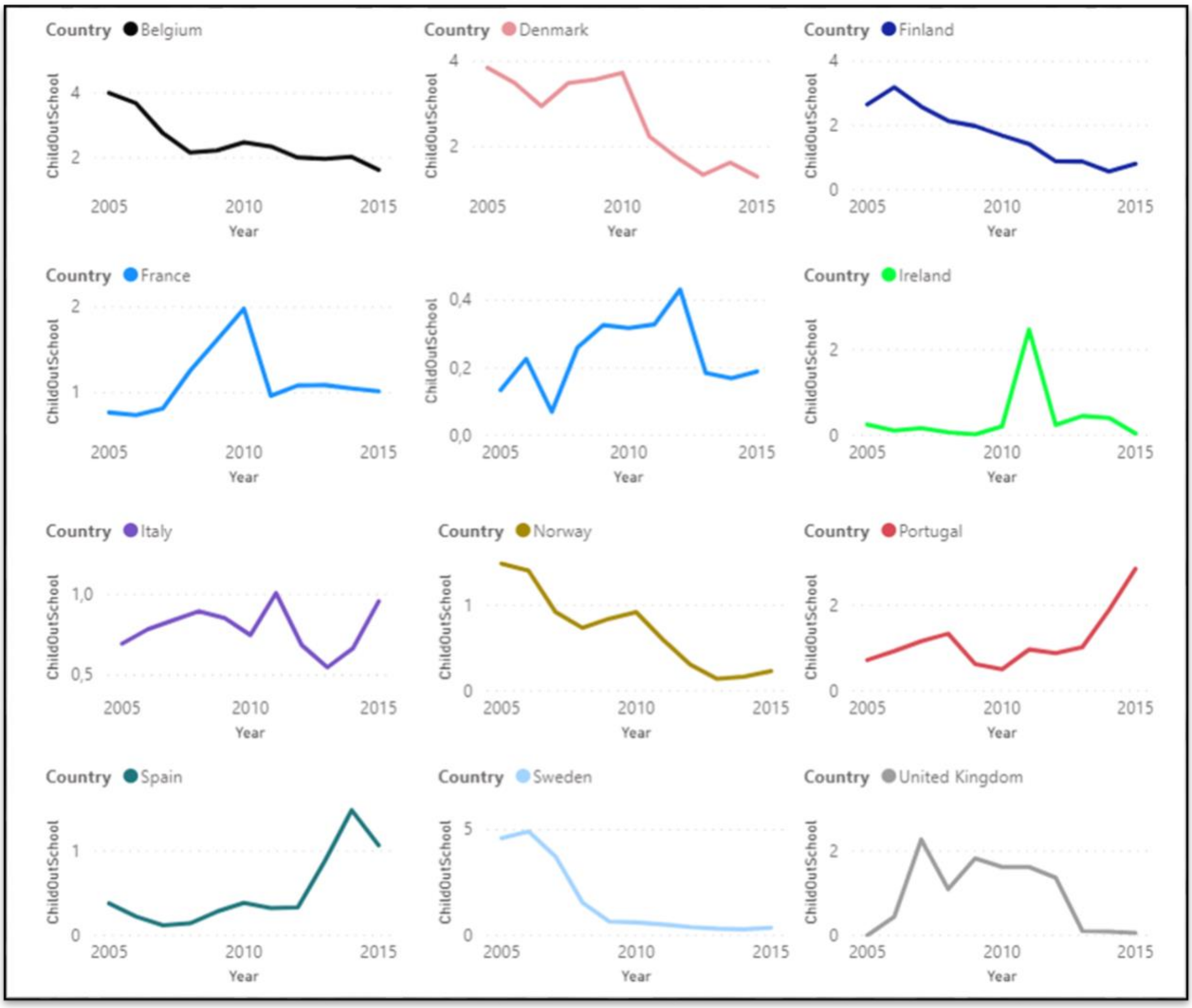

Figure A.1. Evolution of children out of school (UNESCO, 2019)

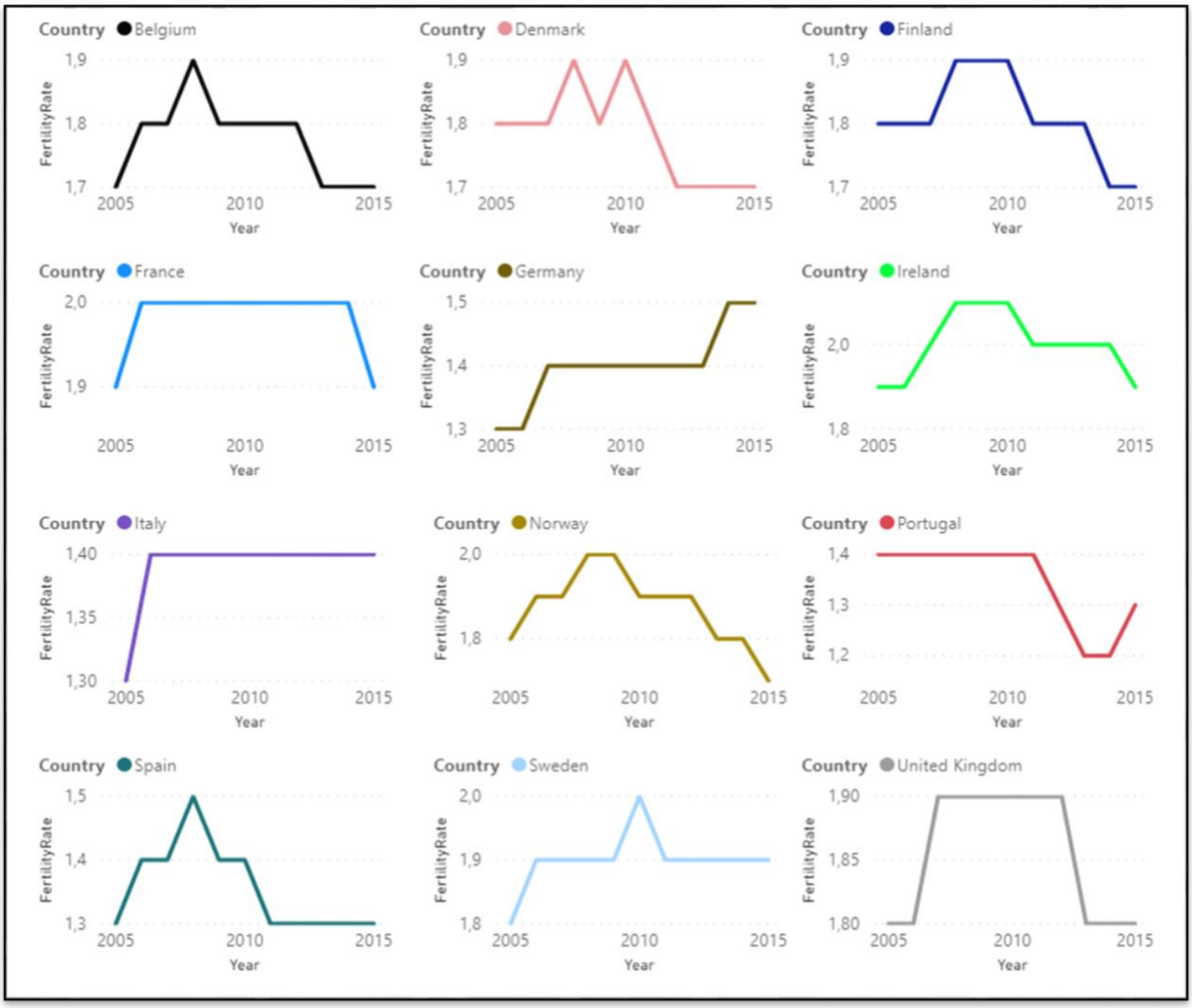

Figure A.2. Evolution of fertility rate (OECD, 2019)

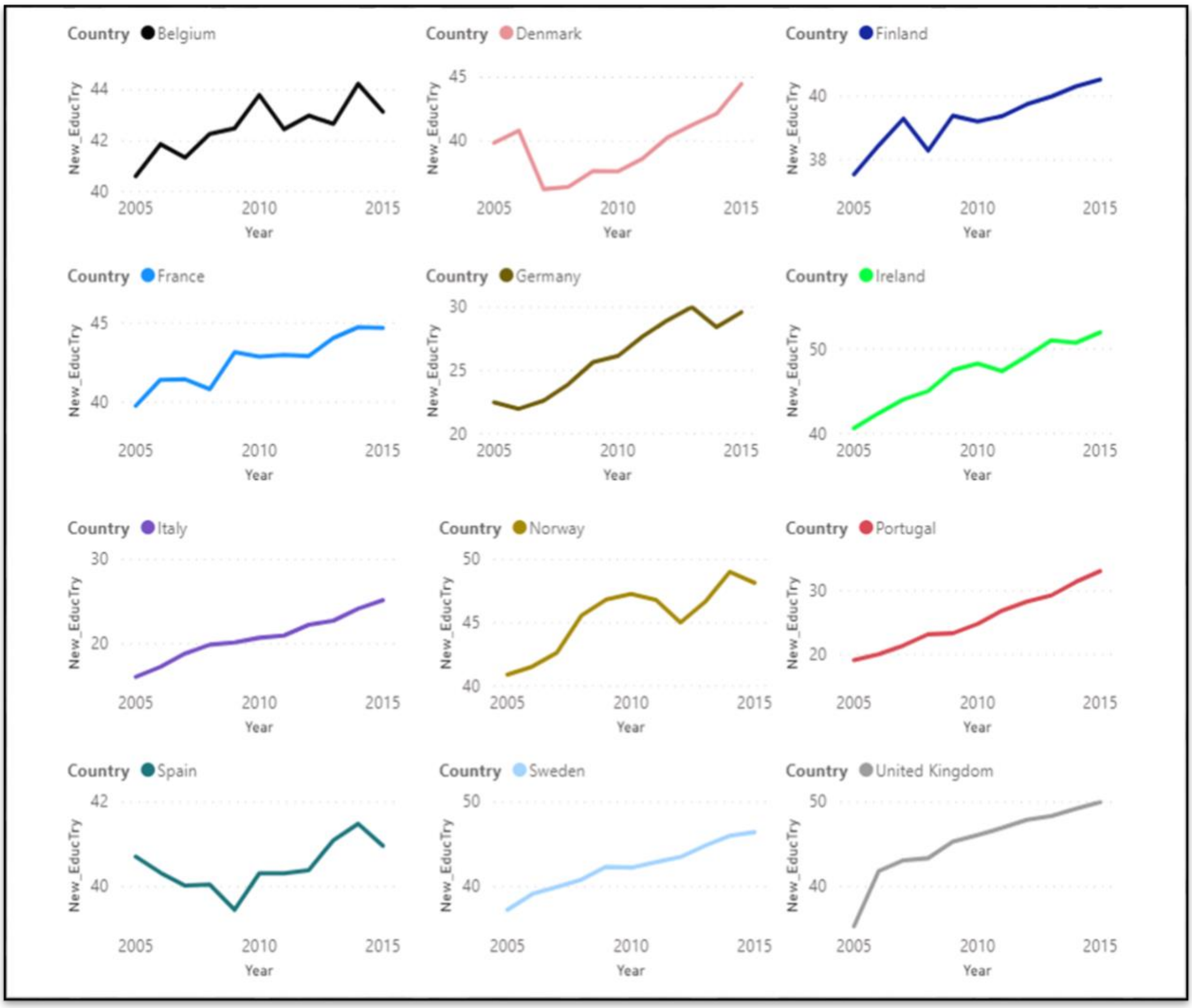

Figure A.3. Evolution of tertiary education (UNESCO, 2019)

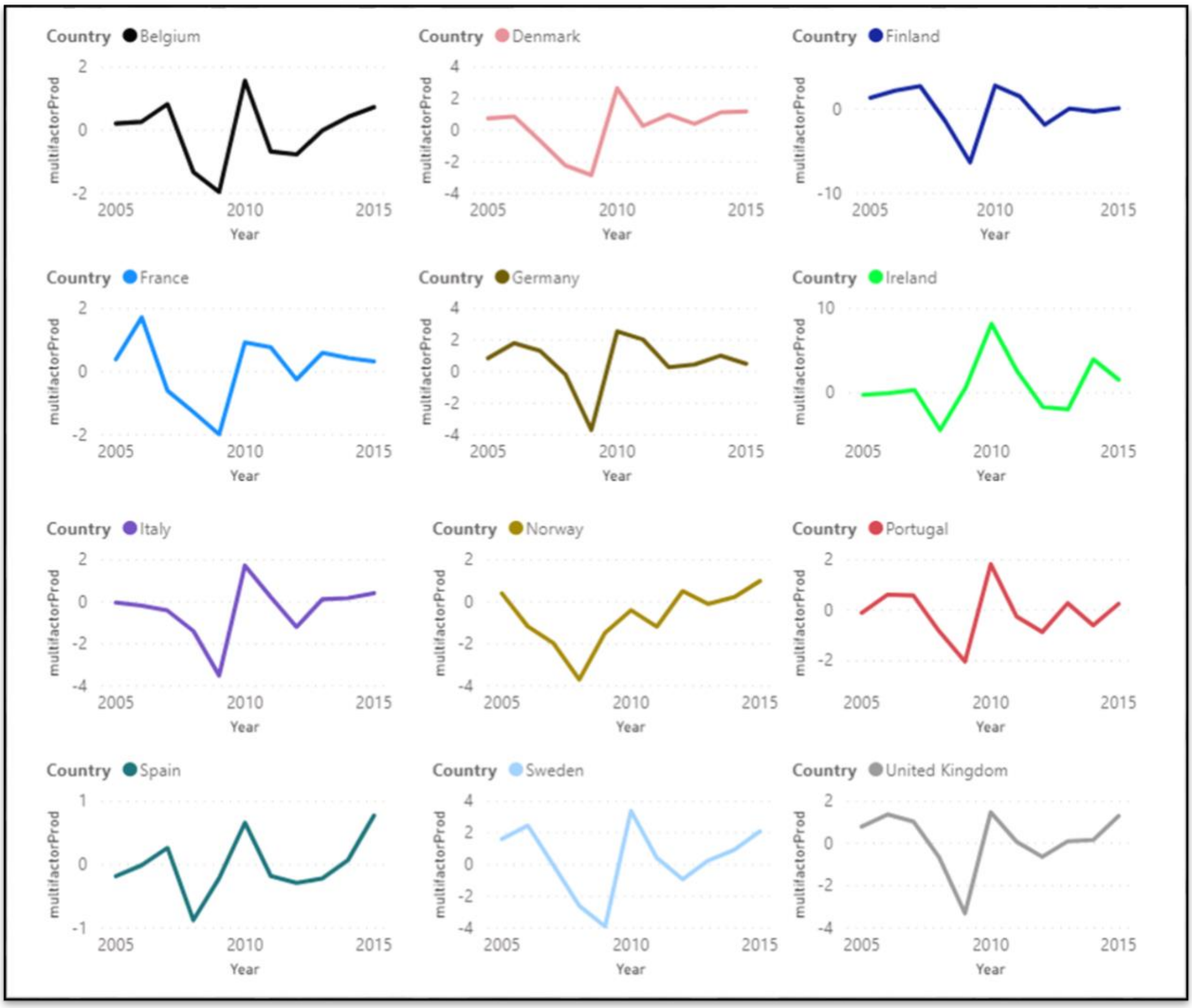

Figure A.4. Evolution of productivity (MFP) (OECD, 2019)

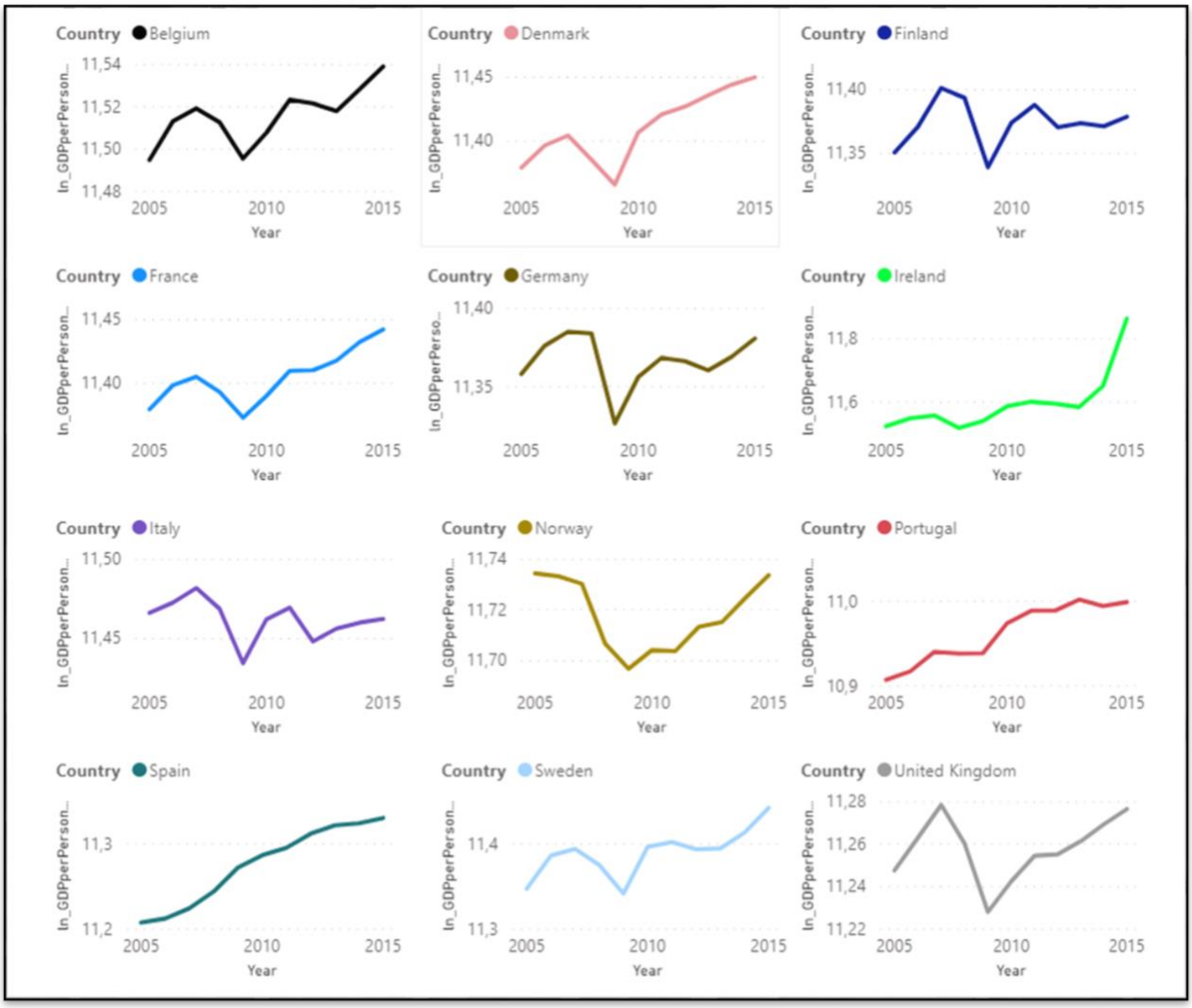

Figure A.5. Evolution of Log_(GDPppe) (ILOSTAT, 2018)

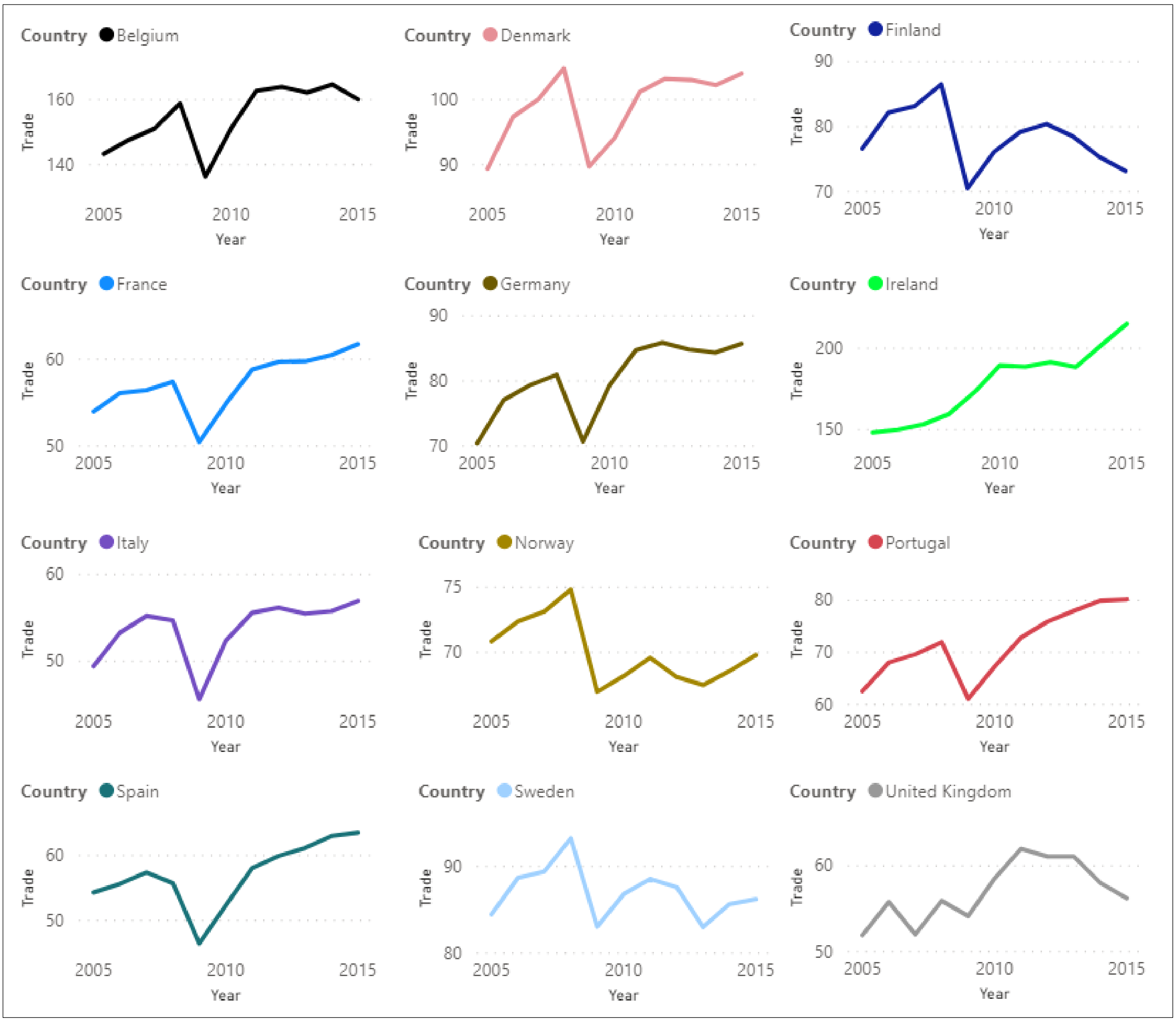

Figure A.6. Evolution of trade (World Bank, 2019)

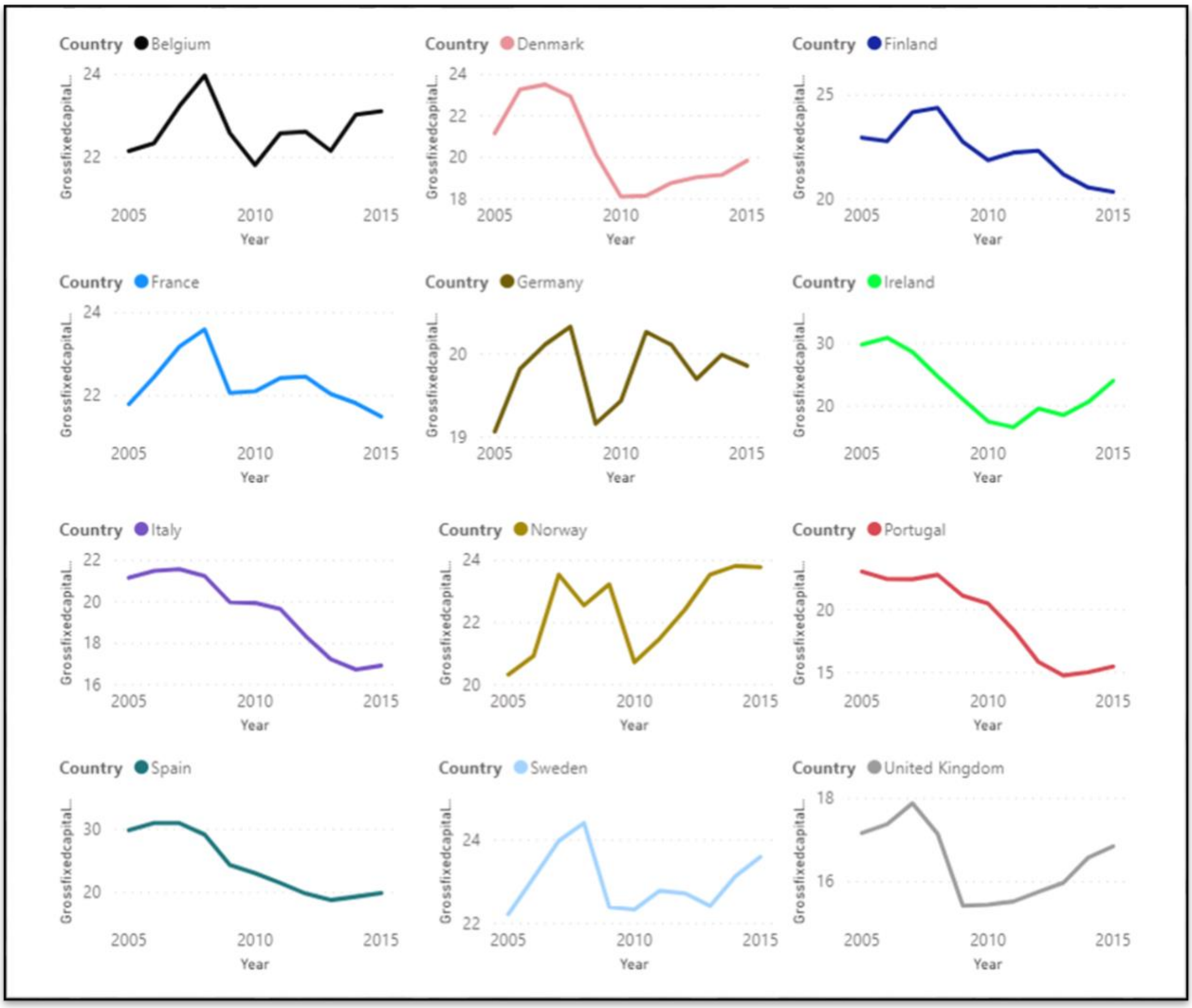

Figure A.7. Evolution of investment (GFC) (World Bank, 2019)

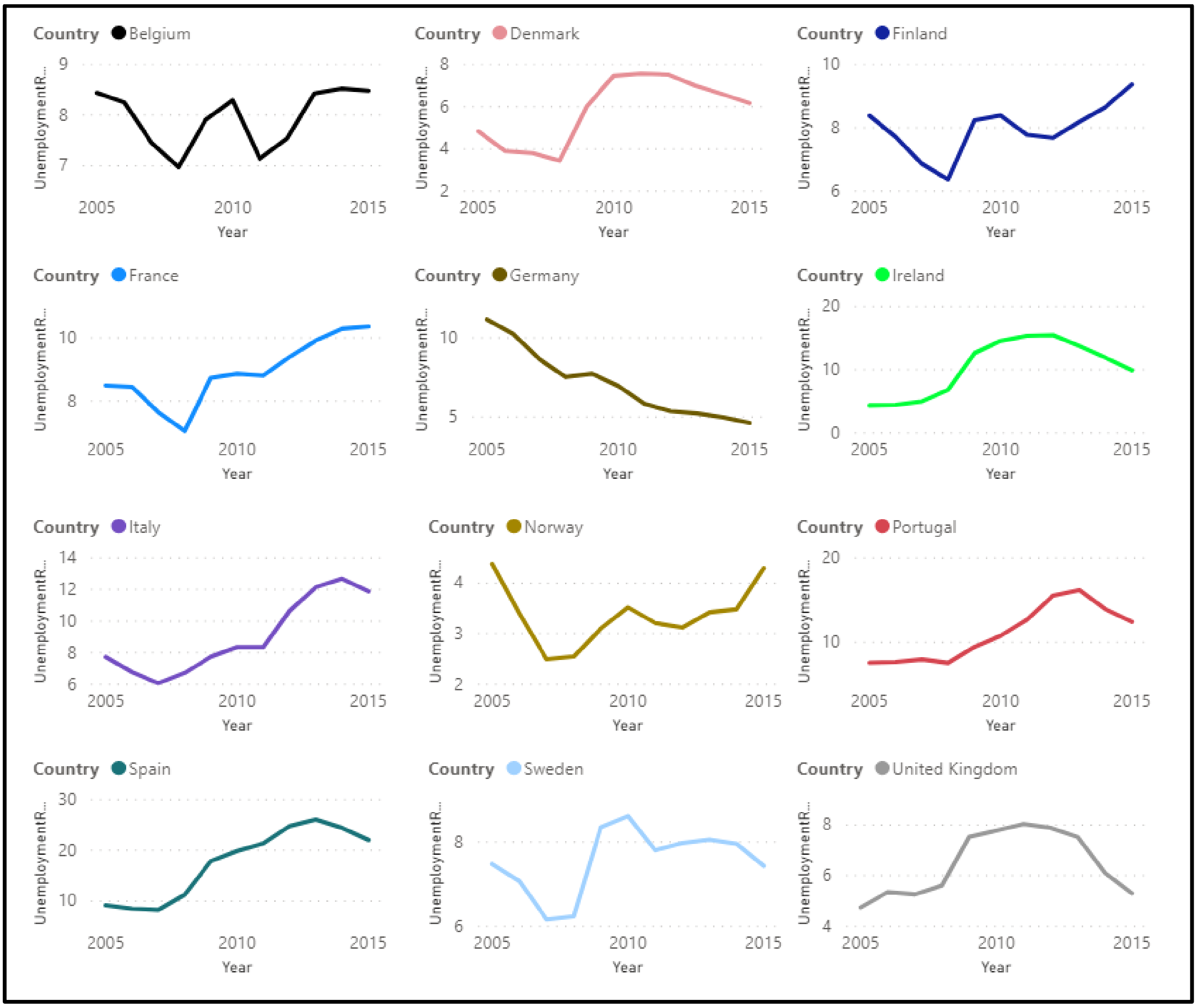

Figure A.8. Evolution of unemployment rate (ILOSTAT, 2019)

Sample of recent literature investigating human capital and economic growth

Paper	*Human capital data*	*Method*	*Summary and significance*
Barro (1991)	Primary and secondary school enrollment rates	OLS cross-section	Significant, positive effect of human capital on economic growth
Mankiw *et al.* (1992)	Secondary school enrollment rates	OLS cross-section	Significant, positive effect of human capital on economic growth
Durlauf and Johnson (1995)	Secondary school enrollment rates	OLS cross-section and regression tree	Human capital significance depends on sample of nations included in regression
Islam (1995)	Barro and Lee (1993)	OLS panel data with dummy variables	Insignificant and negative effect of human capital after controlling for fixed effects
Nonneman and Vanhoudt (1996)	Secondary school enrollment rates	OLS cross-section	Insignificance of human capital after controlling for 'technological know-how'
Liu and Stengos (1999)	Secondary school enrollment rates	OLS and semiparametric partial linear model	Insignificance of human capital in the parametric model; human capital is insignificant and linear in the semiparametric model
Barro (2001)	Barro and Lee (2001)	3SLS with panel data	Significant, positive effect of male secondary education; insignificant effect of female and primary male education
Durlauf *et al.* (2001)	Secondary school enrollment rates	Semiparametric smooth coefficient model	Significant, nonlinear effect of human capital conditional upon initial income estimates
Kalaitzidakis *et al.* (2001)	Barro and Lee (1996)	OLS and semiparametric partially linear regression model	Insignificance in parametric models; significant nonlinearities in semiparametric models
Temple (2001)	Barro and Lee (1993, 2000)	OLS and Least Trimmed Squares	Evidence of sensitivity to outliers; nonlinearities in education; tentative evidence of significance of education
Sala-i-Martin *et al.* (2004)	Barro and Lee (1993)	Bayesian Averaging of Classical Estimates	Significant relationship between growth and primary schooling; insignificant relationship between growth and higher education
Maasoumi *et al.* (2007)	Barro and Lee (2001)	OLS panel data with dummy variables and local-linear least-squares	Insignificance of human capital in the OLS model and significance in the LLLS model
Minier (2007)	Barro and Lee (2001)	OLS cross-section and regression tree	Positive, significant effect of human capital in baseline regressions; insignificance when controlling for policy and executive constraints
Durlauf *et al.* (2008)	Barro and Lee (2001)	Bayesian model averaging	Little evidence that human capital is significant and robust
Henderson (2010)	Barro and Lee (2001)	Nonparametric local-linear least-squares	Insignificance for human capital on economic growth

Table A.1. Education matter for economic growth

Variables	Tertiary education	Government expenditures on education	Children out of school	Productivity	GFC	Trade	Unemployment rate	Fertility rate	Log (GDPppe)
Tertiary education	1	0.477	0.082	0.053	0.158	0.378	-0.037	0.750	0.443
Government expenditures on education	0.477	1	0.401	-0.019	0.029	0.197	-0.392	0.545	0.290
Children out of school	0.082	0.401	1	0.027	-0.040	0.176	-0.128	0.214	-0.026
Productivity	0.053	-0.019	0.027	1	-0.115	0.157	0.115	0.007	0.034
GFC	0.158	0.029	-0.040	-0.115	1	0.154	-0.249	0.174	0.218
Trade	0.378	0.197	0.176	0.157	0.154	1	0.006	0.374	0.419
Unemployment rate	-0.037	-0.392	-0.128	0.115	-0.249	0.006	1	-0.410	-0.289
Fertility rate	0.750	0.545	0.214	0.007	0.174	0.374	-0.410	1	0.504
Log (GDPppe)	0.443	0.290	-0.026	0.034	0.218	0.419	-0.289	0.504	1

Table A.2. Correlation matrix

Variables	Description
GDP per person employed	GDP per person employed is the gross domestic product (GDP) divided by the total employment in the economy. Considering purchasing power parity (PPP), GDP converted to 2011 constant international dollars using PPP rates. An international dollar has the same purchasing power over GDP that a U.S. dollar has in the United States. GDP per person employed represents labor productivity — output per unit of labor input**. (World Bank definition)**
Population with tertiary education	People having completed the highest level of education, by age group. This includes both theoretical programs leading to advanced research or high skill professions such as medicine and more vocational programs leading to the labor market. This measure is expressed in percentage of same age population and also available by gender. As globalization and technology continue to re-shape the needs of labor markets worldwide, the demand for individuals with a broader knowledge base and more specialized skills continues to rise. **(OECD definition)**
Children out of school	Percentage of primary-school-age children who are not enrolled in primary or secondary school. Children in the official primary age group that are in preprimary education should be considered out of school. The rate of out-of-school children allows to compare across countries with different population sizes. **(World Bank definition)**
Government expenditures on education	General government expenditure on education (current, capital, and transfers), expressed as a percentage of GDP. It includes expenditure funded by transfers from international sources to government. The percentage of government expenditure on education to GDP is useful to compare education expenditure between countries and/or over time in relation to the size of their economy. **(World Bank definition)**
Trade	Sum of exports and imports of goods and services measured as a share of gross domestic product. **(World Bank definition)**

Table A.3: Definition and source variables

Variables	Description
Productivity (MFP)	Reflects the overall efficiency with which labor and capital inputs are used together in the production process. Changes in MFP reflect the effects of changes in management practices, brand names, organizational change, general knowledge, network effects, spillovers from production factors, adjustment costs, economies of scale, the effects of imperfect competition and measurement errors. Growth in MFP is measured as a residual, i.e. that part of GDP growth that cannot be explained by changes in labor and capital inputs. In simple terms, therefore, if labor and capital inputs remained unchanged between two periods, any changes in output would reflect changes in MFP. This indicator is measured as an index and in annual growth rates. **(OECD definition)**
Investment (GFC)	Consists of outlays on additions to the fixed assets of the economy plus net changes in the level of inventories. Fixed assets include land improvements (fences, ditches, drains, and so on); plant, machinery, and equipment purchases; construction of roads, railways, schools, offices, hospitals, private residential dwellings, and commercial and industrial buildings. Inventories are stocks of goods held by firms to meet temporary or unexpected fluctuations in production or sales, and "work in progress." **(World Bank definition)**
Unemployment rate	Unemployment refers to the share of the labor force without work but available for it and seeking employment. People who do not look for work but have an arrangement for a future job are also counted as unemployed. **(World Bank definition)**
Fertility rate	The total fertility rate in a specific year is defined as the total number of children that would be born to each woman if she were to live to the end of her child-bearing years and give birth to children in alignment with the prevailing age-specific fertility rates. It is calculated by totaling the age-specific fertility rates as defined over five-year (**OECD definition)**

Table A.3: Definition and source variables (continuation)

Variables	**Levin Li Chu test**
LOG (GDP per person employed)	*Panels are stationary*
Tertiary education	*Panel contain unit roots*
Children out of school	*Panels are stationary*
Government expenditures on education	*Panels are stationary*
Trade	*Panels are stationary*
MFP	*Panels are stationary*
GFC	*Panels are stationary*
Unemployment rate	*Panels are stationary*
Fertility rate	*Panel contain Unit Roots*

Table A.4. Variables stationarity (tests performed on Stata)

Variable		Mean	Std.dev	Min	Max	Observations
Log_GDPppe	Overall	11.38506	.1815099	10.90749	11.73444	N = 96
	Between		.1872428	10.94951	11.71538	n=12
	Within		.0216646	11.33595	11.44018	T=8
Tertiary education	Overall	37.03447	8.948531	16.10503	49.20501	N = 96
	Between		9.02381	19.53394	45.5973	n=12
	Within		2.155714	28.66741	41.97248	T=8
Children out of school	Overall	1.340055	1.173842	.00138	4.9212	N = 96
	Between		.956068	.26217	3.136584	n=12
	Within		.728829	-.3902633	4.130377	T=8
Government expenditures on education	Overall	5.720177	1.108874	4.079857	8.55955	N = 96
	Between		1.076815	4.378709	7.95478	n=12
	Within		.3943468	4.870489	6.725983	T=8
Productivity	Overall	-	1.926073	-6.313136	8.186183	N = 96
	Between	.0603529	.4782386	-1.119501	.6747175	n=12
	Within		1.870267	-6.506048	7.451113	T=8
Investment	Overall	21.76548	3.257306	15.42968	31.05298	N = 96
	Between		2.398848	16.46867	26.22936	n=12
	Within		2.297735	14.72579	29.09778	T=8
Trade	Overall	85.30536	37.20234	45.60912	191.537	N = 96
	Between		37.99767	52.79504	169.2339	n=12
	Within		6.824806	64.35137	107.6085	T=8
Unemployment Rate	Overall	8.100091	3.782067	2.495641	24.78815	N = 96
	Between		2.845346	3.223408	15.12226	n=12
	Within		2.608559	1.209809	17.76598	T=8
Fertility rate	Overall	1.721875	.2547251	1.3	2.1	N = 96
	Between		.2591027	1.375	2.0125	n=12
	Within		.0519362	1.609375	1.846875	T=8

Table A.5 Descriptive statistics – Crisis period (2005-2012)

Variable		Mean	Std.dev	Min	Max	Observations
Log_GDPppe	Overall	11.42022	.1882878	10.99481	11.86345	N = 36
	Between		.1903815	10.99884	11.72459	n=12
	Within		.0357536	11.30511	11.58374	T=3
Tertiary education	Overall	40.88774	8.230674	22.74491	52.00417	N = 36
	Between		8.430853	24.01791	51.28201	n=12
	Within		.8522789	38.90357	42.74715	T=3
Children out of school	Overall	.8314156	.6852761	.04938	2.85353	N = 36
	Between		.6550914	.08621	1.922347	n=12
	Within		.254914	-.0662211	1.762499	T=3
Government expenditures on education	Overall	5.919051	1.363357	3.76971	8.49443	N = 36
	Between		1.382578	4.106777	7.887663	n=12
	Within		.2375973	5.030791	6.576841	T=3
Productivity	Overall	.4985088	.8977558	-1.949643	3.964857	N = 36
	Between		.3980998	-.0235947	1.190589	n=12
	Within		.8102705	-2.641723	3.272777	T=3
Investment	Overall	20.01122	2.757145	14.75427	24.05917	N = 36
	Between		2.735669	15.08586	23.71224	n=12
	Within		.738656	17.48424	22.98496	T=3
Trade	Overall	91.56192	39.10828	55.46659	215.1366	N = 36
	Between		45.2071	56.05256	201.8829	n=12
	Within		3.428024	78.20066	104.8157	T=3
Unemployment Rate	Overall	9.936976	5.360891	3.422888	26.0919	N = 36
	Between		5.444781	3.734265	24.1971	n=12
	Within		.8874348	7.79643	11.94625	T=3
Fertility rate	Overall	1.661111	.2475916	1.2	2	N = 36
	Between		.2525959	1.233333	1.96667	n=12
	Within		.0338062	1.594444	1.727778	T=3

Table A.6. Descriptive statistics - Economic recovery (2013-2015)