# THE IMPACT OF INNOVATION, EDUCATION AND TRADE ON ECONOMIC GROWTH: EVIDENCE FROM EUROPE

**ABSTRACT**

This paper studies the effects of innovation, education and international trade on economic growth. We collected a panel data of 22 European countries over the period 2000-2020 for these variables. Four different econometric models were estimated, and the results of the final specification showed that there is no statistically significant evidence of the relationship of innovation and international trade on economic growth in the sample analyzed. According to the results, education presents a positive impact on economic growth in the countries considered.

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## 1. INTRODUCTION

It's well-known that an important goal for world economies is to reach an economic growth that persists in time, or in other words, a long-run economic growth. This achievement allows the increase in the quantity of goods and services that an economy can produce over time and improves the life's quality of their citizens. The study of the factors that sustain economic growth has long been, and continues being, an object of interest for researchers, economists, policy makers, and scholars. According to the new growth theories, technological change is considered an important source of economic growth, and innovation a key driver of economic growth in global economies.

In this paper we try to analyze the role of innovation in economic growth of European nations. We also focus on important variables potentially explaining economic growth that have a linkage with innovation, like education and international trade. Education is considered to improve human capital of countries providing knowledge and skills to citizens, increasing their creativity and the innovations' capacity of the economy, and therefore growth. International trade can improve the efficiency of economies and contribute to knowledge and technology diffusion, stimulating innovation and economic growth.

The main objective of this paper is to evaluate if there is an influence of innovation on economic growth in European countries. Also, the effects of others variables considered like education and international trade on economic growth are object of study.

We aim to clarify these relationships. To that end we use Research and Development expenditure variable to quantify innovation. Also tertiary education on one hand and trade openness and FDI on the other hand are considered proxies of education and international trade, respectively. Lastly, in order to quantify economic growth, we use the annual growth rate of gross domestic product per capita.

In order to analyze the effects of the variables mentioned in economic growth we have collected a panel data of 22 European countries over the period 2000-2020. Different econometric estimations were run to study the relationships mentioned above. According to the model finally selected, innovation and international trade are not statistically significant on explaining economic growth and education has a significant and positive impact on economic growth.

This paper is organized as follows. First, there is a review of the main literature that inspired this work. Second, the principal hypothesis will be presented. Third, data and methodology of the study will be detailed extensively. And last, the results and conclusions will be commented and discussed.

## 2. LITERATURE REVIEW

To understand the background and the role of innovations, education and international trade in explaining economic growth in countries we have reviewed the relevant literature.

### 2.1. Historical growth models and innovation

The relationship between innovation and economic growth has been attractive for authors since half of 20th century, although the first early thinker to include this relationship in his theories was Joseph Schumpeter. According to Schumpeter, economic growth and economic development represent two different concepts, the first considered as a progressive and slowly change of the economic system due to external factors, and the second as the result of internal changes caused by economic innovations (Schumpeter, 1912). From his point of view, economic change is related with innovations, entrepreneurship and market power. He argued that the incorporations of innovations in companies are the best way of gaining market power compared to incurring in price competition with the competence. The connection between innovation and entrepreneurship is also fundamental, being the innovations of entrepreneurs, the main source of long-run economic growth, despite the process of "creative destruction", in which old companies are smashed by new products (Schumpeter, 1934).

Schumpeter introduced to the literature that technological progress and innovations are an important characteristic when explaining economic growth. But in the pioneering work by Solow in 1956, technological progress was included for the first time in an economic growth theory. According to Solow's model, economic growth is driven by capital accumulation and population growth, given a certain level of technology progress. In this model, technological progress is an exogenous variable that is determined outside the model, but is considered a root of long-run economic growth (Solow, 1956). This model became the reference model in other neo-classical growth studies like Nadiri (1993) that empirically showed that long-run growth depends on the growth rate of inventions, which is also exogenously determined.

The exogeneity of technological progress in the neo-classical models of growth, like Solow's model, was a limitation to the growth models theories. Other authors, in order to reduce the exogeneity limitation of growth models, investigated the economic forces underlying technological progress. First, an attempt to incorporate innovation into growth models showed that knowledge with increasing marginal productivity could be an explaining factor in long-run growth (Romer, 1986). Finally, a growth theory with technological change endogenously included in the model was developed (Romer, 1990). Innovations that are carried out by rational and profit-maximizing agents were the principal factor of technological change. Endogenous growth models like Romer (1990), Grossman and Helpman (1991) and Aghion and Howitt (1992), supported the fundamental role of knowledge, knowledge spillovers and technological substitution in the economic growth process. The studies that incorporate endogenous technological change in growth models are called "endogenous growth" or "new growth" theories and they are the reference in which growth models works are based on.

### 2.2. Innovation and economic growth

We have mentioned the main authors that set-up the basis of economic growth theories. We focus into the concept of innovation and its characteristics.

As we have seen above, Joseph Schumpeter was the first in including the innovation concept in his studies. He described innovation as "The fundamental impulse that keeps the capitalist engine in motion comes from the new consumers, goods, the new methods of production or transportation, the new markets, the new forms of industrial organization that capitalist enterprise creates" (Bayarçelik and Taşel, 2012).

According to Katila and Shane (2005) innovation can be described as "A process that begins with an invention, proceeds with the development of the invention, and results in the introduction of a new product, process or service to the marketplace".

Historically, definitions have been changing and have been widely studied by authors, but all refer to the creation of something new, a new idea or a new process. In Damanpour (1991) innovation concept is separated in product innovation and process innovation. The first one refers to the new products or service that are designed and created to cover a market need and process innovation is the new process which is designed and implemented in production normally to improve or get an efficient production.

Nevertheless, the differentiation of innovation in both product innovation and process innovation doesn't exist according to Blaug (1963). He argued that this differentiation is artificial, because these concepts are interwoven. He explains that to introduce a process to reducing costs sometimes is linked to a new way of product mixing, meanwhile the new products frequently needs the design of new equipment.

Other authors also have distinguished different types of innovation. Bayarçelik and Taşel (2012) separated radical and incremental innovation, making reference the grade of revolution in technology, being radical those innovations that change considerably the technology, making the ancient technology obsolete. Incremental innovation refers to those minimal improvements in current technology. It's interesting to know all this innovations characteristics and typologies but in this work we are not going to focus on that.

More relevant for this paper are the externalities that the innovation process produces. These externalities, according to Nguyen and Doytch (2022), are knowledge and technological spillovers growth, and the increase in competition and entrepreneurship. Later on, we will focus on some of these externalities and they will be analyzed in detail.

Due to the importance of innovation on ensuring sustainable economic growth through competitiveness and progress in global economies, there are many empirical works that study this relationship.

Hasan and Tucci (2010) analyzed the importance of quantity and quality of innovation process in economic growth using patent data as innovation proxy in a sample of 58 countries. The results of the model showed a positive relationship between economic growth and the level of patenting in a country. Level of patenting was used as proxy in order to quantify innovation process. The increase in patents' quality also results in higher economic growth for a country. Bayarçelik and Taşel (2012) also reported a positive and significant impact of innovation on economic growth using research and development expenditure as proxy of the innovation process.

Pece et al. (2015) used patent, number of trademarks and research and development expenditure as variables to represent the innovation process of a country. Through a multiple regression model, the results showed a strong relationship between these innovation variables and economic growth. The work also presented a positive effect of education and human capital in economic growth.

The difference in emerging and developed countries is also a focus point for many authors due to the gap in technology level and progress in different economic development situations. Ulku (2004) empirically showed, using the model proposed by Romer (1986), that innovations have a positive effect in GDP/per capita in both emerging and development countries. Vučković (2016) also analyzed innovation process in emergent markets.

Despite the fact that most literature on this subject present positive results on linking innovation to economic growth, other authors have noted a non-significant relationship in this aspect. Pessoa (2007) focused on the relationship of the R&D expenditure with growth in two specific countries, Sweden and Ireland. The study results suggested that there is not a strong linkage in the variables in those countries.

Vučković (2016) focused on innovation process in emergent markets. According to the results of the work, there are no statistical relationship between economic growth and innovation in emergent markets, using patent as innovation proxy.

As we can see, in literature there is an extensive interest on studying the drivers of sustainable economic growth in world economies, and hence, the innovation process that establishes the technology level and progress of countries. In some works, the relationship between innovations and economic growth is relevant and positive, and in other works this relationship seems not to be empirically relevant. In this work we aim to clarify this relationship in some countries of Europe.

### 2.3. Education and economic growth

As well as innovation, education has long been considered an important determinant of economic growth and well-being. According to Ortega et al. (2022), education is "the set of skills and competencies that contribute to productivity applied to work". It is a fundamental component of a country's human capital due to the fact that education helps economies to move up their value chain.

According literature, there are at least three mechanisms that economic growth is influenced through education. First, education affects economic growth through the increase of human capital, that increases labor productivity, and therefore growth. Second, education can increase the innovations' capacity of the economy and the knowledge of new technologies incentives the creation of new products and processes, and thus enhancing economic growth. And third, education provide the tools to understand and process the new technologies and new innovation processes devised by others, contributing in the knowledge spillover process and promoting economic growth (Hanushek and Wößmann, 2010).

Already in times of Schumpeter (1934), the education was considered an important issue when explaining economic growth. Also Harbison and Mysers (1964) pointed out in their study a close relationship between the schooling rate of second and higher education and gross national product. According to a more recent study, (Vandenbussche et al., 2006), education is important as human capital investment and fundamental in the progress of innovation and technology area.

So, education is a tool that provides citizens the skills and knowledge for growing up their creativity potential resulting on scientific advances and technological developments, providing knowledge spillover on others and improving country's economic development (Hava and Erturgut, 2010).

In this paper, the relationship between education and economic growth will be studied, for being a potentially determinant of economic growth in countries, and a close contributor in innovation process.

### 2.4. International trade and economic growth

The last variable we are taking into account in this paper is the international trade between countries. This concept is closely related with innovations and competitiveness. According to Grossman and Helpman (1991), trade contributes world-wide diffusion of technological knowledge stimulating innovation and therefore growth. In Hadhek and Mrad (2015), the role of international trade in economic growth is analyzed. According to the authors, trade has fundamental role in world economies. It enhances knowledge transfer, international technology transfer, and improves the production efficiency of a country. Through opening to trade, countries are able to take advantage of the positive consequences of competition and economies of scale due to the expansion of their markets.

Due to the importance of economies of scale in world economies and contributing economic growth, we will make a parenthesis to develop some details of them. According to Krugman et al. (2017) economies of scale represent an incentive for international trade. This occurs when in an economy exists increasing returns. This means that production is more efficient as the scale of production increases. For example, a firm or industry with constant economy of scale, in which we double the production factors, will increase his production in exactly the double, but if we have increasing economy of scale, with the same increasing of production factors, the production will increase more than the double. We can differentiate internal and external economies of scale. The individual cost of production in the internal economy of scale depends on the size of the individual firm, while external economy of scale is related to industry size. Both internal and external economies of scale are main reasons for trade between countries.

External economies are characterized by the formation of industry clusters. These clusters take advantage of the specialized suppliers, labor market pooling and knowledge spillover that characterize industry concentration for becoming bigger and efficient. This fact allows countries to have more specialized industries, and in deed more competitiveness due to economies of scale. There are many examples of industry clusters, like the semiconductor industry in Silicon Valley or the computer industry in the Bangalore (Krugman, 2017). Closing the economies of scale paragraph, we have noted that they are a main reason for incrementing economies' competiveness and for trade between countries.

Lastly, we highlight some channels in which trade affects innovation. Kiriyama (2012) sets three channels in which innovation is affected by trade. The first one is that imports and foreign direct investment (FDI) are important channels of technology diffusion contributing in the innovation process. Second, imports, FDI and technology licensing increase competition, that incentives innovation. And third, exports represent a learning opportunity and stimulate innovative activities.

According to Kinoshita (2001), foreign direct investments are pointed as an important factor in technological progress, due to the technological transfer and spillover effects of the process. This improves innovation and enhances economic growth. In this study, foreign direct investment will be considered as an important variable potentially explaining economic growth.

As in education, we consider that international trade represents an important variable when analyzing economic growth and a contributor to innovation process in countries. That's why we also study the relationship between trade and economic growth on this paper.

## 3. HYPOTHESES

As we will see in the data and methodology section, we have approached the innovation process through the research and development expenditure of countries. Also tertiary education on one hand and trade openness and foreign direct investment on the other hand are considered proxies of education and international trade, respectively.

Considering the previous literature and to evaluate the objectives of the study we have proposed some initial hypothesis that we expect to answer at the end of this work. These hypotheses are the following.

**Hypothesis 1: Research and Development expenditure will have a positive impact on economic growth**

Innovation is a complex process where research and development investments can represent the innovation input in the economy (Nguyen and Doytch, 2022). The increase in this input usually represent an increase of innovations in an economy, and leads to increased competitiveness and progress, improving productivity and ensuring sustainable economic growth. Although literature established a duality in the study of this relationship, we expect that the effect of innovation on economic growth will be positive and relevant.

**Hypothesis 2: Tertiary education will have a positive impact on economic growth**

Third education represents the higher level of education in a country, and education level in which students acquire more specialized knowledge and skills. As we have seen in literature, a high level of education in a country increases the creativeness of citizens and impulse innovation and entrepreneurship. Also improves human capital, workers productivity and knowledge spillover diffusion, promoting economic growth. According to these arguments we expect that the relationship between education and economic growth will be positive and relevant.

**Hypothesis 3: Trade openness and FDI will have a positive impact on economic growth**

Opening to trade allow countries to get more specialize industries, through scale economies and incremented efficiency due to the expansion of their markets. This specialization improves competiveness and promotes innovation due to knowledge spillover, specialized suppliers and labor market pooling, enhancing economic growth in countries. According to Nguyen and Doytch (2022), economic growth is positively influenced by trade openness, improving domestic productivity through innovation and technology development. Also Kiriyama (2012) and Kinoshita (2001) remarked the importance of foreign direct investment on innovation and economic growth. We follow literature on expecting that the relationship between economic growth and trade openness will be positive and relevant. We also expect a positive relationship between foreign direct investment and economic growth.

## 4. DATA AND METHODOLOGY

Once analyzed the literature background that motivated this investigation and the main hypotheses of this work, we proceed to explain the data and methodology through which we have conducted this study.

### 4.1 DATA

With the purpose of measuring the impact of innovation and the other variables considered on economic growth, we have collected statistical data from different sources of 22 countries of Europe. These countries have been selected according to the data available of the variables selected and to observe different development and economic situations. The variable that limited the most the final selection of countries due to the reduced availability of data was tertiary education. This way, the final selection of countries was: Austria, Belgium, Czechia, Germany, Denmark, Spain, Estonia, Finland, United Kingdom, Croatia, Hungary, Iceland, Lithuania, Luxembourg, Latvia, Netherlands, Poland, Portugal, Romania, Slovak Republic, Sweden and Turkey. The time period considered is 2000-2020 in annual frequency, resulting in a micro panel data of 462 observations. Panel data allowed us to have observations of different variables and countries over time, combining temporal and cross-section dimension, and controlling cross-section dependency and unobserved heterogeneity.

The data used in this work was collected in different sources. Due to the importance of the reliability in the observations, we focus on the different ways that we have collected the data. We have used two sources in data collection: Eurostat and World Bank.

On one hand, Eurostat have provided us tertiary education statistics. This variable measures the students that are enrolled in tertiary education at a certain year. In this variable we have to remark that dataset is composed by two different Eurostat's dataset. This is due to the change in 2011 of the International Standard Classification of Education (ISCED). This change consisted of an increase in the number of levels that the education is classified, having 6 levels until 2011, and 8 levels from that point forward. Eurostat have two different dataset, one before the classification change and one after. In order to have a dataset in which third education is correctly collected for the period of 2000 to 2020, we have mixed the old dataset (until 2011) and the new one (with tertiary third education equivalence), to having a complete dataset of third education for the whole period. In this variable we need to scale these education levels to the population of the countries, so we have calculated the percentage of the population that is enrolled in tertiary education. The population data of each country was collected from World Bank database.

On the other hand, in World Bank database (World Development Indicators) we have collected the rest of the variables, namely annual growth rate of gross domestic product per capita, research and development expenditure, trade openness and foreign direct investment.

As we introduced in the literature review, foreign direct investment is considered an important contributor to economic growth. Other works like Pece et al. (2015) or Nguyen and Doytch (2022) used FDI inflows as a control variable in explaining economic growth. In this study we follow this line and include foreign direct investment in the econometric model.

The study of the implications of innovation on economic growth has been studied by many authors in many ways. There is an extensive discussion in which are the variables that better represent the whole innovation process in countries. Some authors have used number of patents or trademarks as proxy of innovation and others research and development expenditure, others like Pece et al. (2015) and Heng et al. (2021) included patents, trademarks and research and development expenditure as variables representing innovation process of countries. In this paper, due to the data available of countries we use research and development expenditure as proxy of innovation. Next, we detail the variables included in this study and their main characteristics.

**Dependent variable**

- *GDPgpc*: Annual percentage growth rate of Gross Domestic Product per capita has been used as proxy of economic growth in countries. GDP per capita is Gross Domestic Product divided by midyear population. Expressed in percentage points (%).

**Independent variables**

- *RDe*: Research and Development expenditure as a percentage of GDP. It is the ratio of total research and developments expenditure over the total GDP of countries. Expressed in percentage points (%).

- *TertiaryEducation*: Rate of students enrolled in tertiary education in total population. To normalize this variable we measured the ratio between the number of students enrolled in tertiary education over the total population. Expressed in percentage points (%).

- *TradeOpenness*: Rate of trade openness in the economy. This is the sum of exports and imports of goods and services measured as a share of GDP. The logarithmic form of this variable is taken in order to reduce heteroscedasticity and excessive intra-group variance. Expressed in percentage points (%).

- *FDInetinflows*: Foreign direct investment net inflows as a share of GDP. This variable shows net inflows in the reporting economy from foreign investors, divided by GDP. The logarithmic form of this variable is taken in order to reduce heteroscedasticity and excessive intra-group variance. Expressed in percentage points (%).

### 4.2 DESCRIPTIVE STATISTICS

In this section we show the main statistics of the data set. Next, we will observe the main univariate statistics, the correlation matrix of all variables and the individual correlation between GDP per capita growth and the other variables.

The main univariates statistics of this data set are:

| Variable | Obervations | Mean | Median | Standard deviation | Min | Max |
|---|---|---|---|---|---|---|
| **GDPgpc** | 462 | 2.082 | 2.064 | 3.799 | -14.464 | 12.997 |
| **Rde** | 456 | 1.605 | 1.362 | 0.915 | 0.359 | 3.874 |
| **l_TradeOpenness** | 462 | 4.594 | 4.514 | 0.430 | 3.746 | 5.940 |
| **TertiaryEducation** | 449 | 4.138 | 4.042 | 1.218 | 0.562 | 9.592 |
| **l_FDInetinflows** | 413 | 1.354 | 1.314 | 1.151 | -2.757 | 4.694 |

**Table 1.** Summary of univariates statistics

The relationships between variables are collected in the next Spearman's correlation matrix:

| Variable | GDPgpc | Rde | l_TradeOpenness | TertiaryEducation | l_FDInetinflows |
|---|---|---|---|---|---|
| GDPgpc | 1.000 | | | | |
| Rde | -0.442*** | 1.000 | | | |
| l_TradeOpenness | 0.096* | 0.048 | 1.000 | | |
| TertiaryEducation | 0.064 | 0.099** | -0.065 | 1.000 | |
| l_FDInetinflows | 0.151*** | 0.039 | 0.368*** | -0.099** | 1.000 |

Note: (*), (**), (***) represent that coefficients are statistically significant at 10%, 5% and 1%, respectively.

**Table 2.** Spearman's correlation matrix of variables

As we can see in Table 2, for the data sample considered of 22 countries the assumption of non-perfect correlation of the variables is not violated. Nonetheless, we can see higher or lower degrees of correlation in the variables that represent the economic relation of them. Thus, the correlation exists in the sample, but is not excessively high to wonder about a multicollinearity problem between these variables.

Contrary to what we expected, the Spearman's correlation matrix shows an inverse and significant relationship between research and development expenditure and economic growth. Tertiary education, trade openness and foreign direct investment present a direct relationship with economic growth, as we expected, but only trade openness and FDI present a significant coefficient.

We can visually observe the relationship between the dependent variable and the rest of variables in Table 3. In each illustration we can see the correlation between the variables with adjusted regression lines.

Illustration 3: RDe-GDPgpc

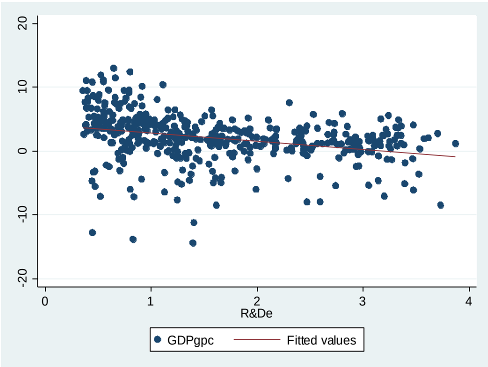


Illustration 4: l_TradeOpenness-GDPgpc

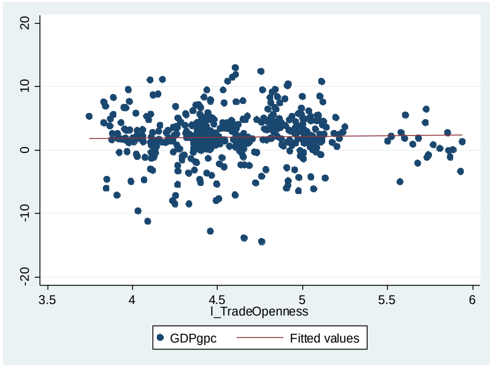


Illustration 5: TertiaryEducation-GDPgpc

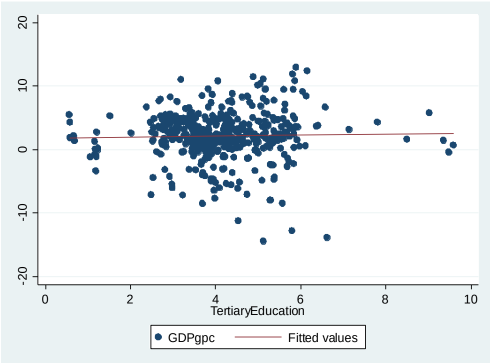


Illustration 6: l_FDInetinflows-GDPgpc

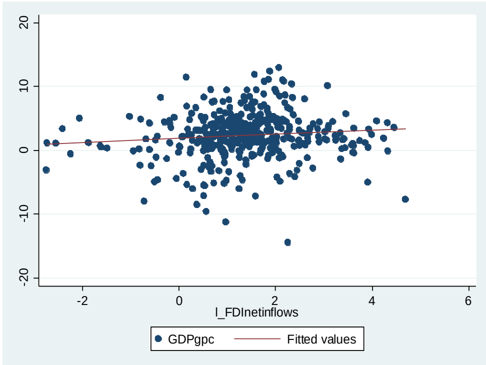


**Table 3.** Correlations GDPgpc- independent variables

### 4.3. ECONOMETRIC MODEL

Motivated by previous literature and based on Pece et al. (2015) and Pessoa (2007) studies, we have created a model where research and development expenditure represent innovation as a potentially influencing factor in GDP per capita growth. GDP per capita growth rate is used as a proxy of economic growth in countries. Also are included tertiary education, trade openness and foreign direct investment as explanatory variables of economic growth. In order to study these relationships, we used the following model specification:

$$GDPgpc_{it} = \beta_0 + \beta_1 RDe_{it} + \beta_2 l\_TradeOpenness_{it} + \beta_3 TertiaryEducation_{it} + \beta_4 l\_FDInetinflows_{it} + \alpha_i + \varepsilon_{it}$$

Where:

- *GDPgpc* represents the annual percentage growth rate of Gross Domestic Product per capita as a proxy variable of economic growth.
- *RDe* represents the share of research and development expenditure on total GDP.
- *l_TradeOpenness* represents the natural logarithm of the rate of trade openness.
- *TertiaryEducation* represents the percentage of students enrolled in tertiary education on total population.
- *l_FDInetinflows* represents the logarithm of foreign direct investment net inflows as share of GDP.
- $\alpha_i$ represents a binary variable that captures the individual effect of countries.
- $\varepsilon_{it}$ represents the error term of the estimation and capture the unobserved effects that affect the dependent variable, economic growth.

## 4.4. ESTIMATION

In order to study the impact of these variables on economic growth we have estimated the econometric model in four different methods. These methods are Pooled OLS, Fixed Effects, Individual and Temporary Fixed Effects and Random Effects. To decide which method fits better in our panel data model and sample we will make different statistical tests to find out which method is the most optimal and therefore, the one that provide better estimations.

### Estimation by Pooled Ordinary Least Squares (Pooled OLS)

In this estimation method the temporal and individual effects are not taken into account in the estimation, estimating the model by ordinary least squares. The lack of these data panel features triggers in a possible heterogeneity that can bias these estimates. Due to these characteristics, the model is specified as:

$$GDPgpc_{it} = \beta_0 + \beta_1 RDe_{it} + \beta_2 l\_TradeOpenness_{it} + \beta_3 TertiaryEducation_{it} + \beta_4 l\_FDInetinflows_{it} + u_{it}$$

Using Stata statistical software, we have estimated the model through robust standard deviations at heteroscedasticity. We can see the results in Table 4.

```
. reg GDPgpc RDe l_TradeOpenness TertiaryEducation l_FDInetinflows, robust

Linear regression                               Number of obs     =        395
                                                F(4, 390)         =      17.06
                                                Prob > F          =     0.0000
                                                R-squared         =     0.1503
                                                Root MSE          =     3.3679
```

| GDPgpc | Coef. | Robust Std. Err. | t | P>\|t\| | [95% Conf. | Interval] |
|---|---|---|---|---|---|---|
| RDe | -1.394909 | .1790651 | -7.79 | 0.000 | -1.746963 | -1.042855 |
| l_TradeOpe~s | .3978223 | .470573 | 0.85 | 0.398 | -.527355 | 1.323 |
| TertiaryEd~n | .5281281 | .1607113 | 3.29 | 0.001 | .2121591 | .844097 |
| l_FDInetin~s | .391102 | .1757321 | 2.23 | 0.027 | .0456011 | .7366028 |
| _cons | .022089 | 2.379511 | 0.01 | 0.993 | -4.656185 | 4.700363 |

**Table 4.** Pooled OLS estimation with robust standard deviations at heteroscedasticity

The results of the model showed that almost all the variables are statistically significant on explaining economic growth. Given the p-value of the variables, research and development expenditure and tertiary education are the variables with higher statistical significance, being statistically significant even at a 99% confidence level. Foreign direct investment is also significant at a 95% confidence level. Lastly, trade openness is not statistically significant in this first estimating method. The R-squared of the regression give an approximate value of 0.15. That is, in this estimation, the variation in economic growth can be explained in a 15.03% by the variables considered in the model.

Analyzing the results of the model, R&D expenditure has a negative impact on GDP per capita growth. An increase of 1 unit in the rate of research and development expenditure in total GDP would lead to a decrease of GDP per capita growth rate of 1.3949 units, ceteris paribus. These results contradict the first hypothesis presented at the beginning of the paper.

The rest of the variables present a positive effect on economic growth. Focusing on trade openness, an increase in 1% of the trade openness rate would increase GDP per capita growth in 0.0039 units, ceteris paribus, but this change is not statistically significant in this estimation. Also an increase in the rate of tertiary education of 1 unit would increase GDP per capita growth rate in 0.5281 units, ceteris paribus. Lastly, ceteris paribus, an increase in the share of FDI net inflows over GDP in a 1% would decrease GDP per capita growth in 0.0039 units.

In this method, the results supported our second and third hypothesis of positive impact of education and international trade on economic growth, although trade openness is not statistically significant in this model.

**Estimation by Fixed Effects**

In order to incorporate to the model the heterogeneity mentioned in the first estimation, we estimated a fixed effects model. This estimation allows the incorporation of dichotomous variables that capture the individual characteristics of each country considered that not change over time. So in this model we have to incorporate a new constant that captures this heterogeneity of countries ($\alpha_i$). So the model is:

$$GDPgpc_{it} = \beta_0 + \beta_1 RDe_{it} + \beta_2 l\_TradeOpenness_{it} + \beta_3 TertiaryEducation_{it} + \beta_4 l\_FDInetinflows_{it} + \alpha_i + v_{it}$$

We have run the fixed effects model in Stata statistical software and the results of the estimation can be observed in Table 5.

In this estimation, notable differences can be observed with respect pooled OLS estimation, due to the incorporation of the heterogeneity in the model. On the one hand variables' significance has changed notably. There is a decrease in the statistical significance of tertiary education, losing the statistical significance that had in the last estimation. On the other hand, an increase in the statistical significance is attached in variables like foreign direct investment and trade openness. FDI becomes statistically relevant at a 99% confidence level and trade openness increase its significance but not in the necessary measure to become significant. The significance of research and development expenditure remains constant.

Focusing on the estimated coefficients, we can observe that the direction of the effects of variables on economic growth have not changed in the fixed effects model, compared to pooled OLS, but the constant coefficient become negative.

```
. xtreg GDPgpc RDe l_TradeOpenness TertiaryEducation l_FDInetinflows, fe

Fixed-effects (within) regression               Number of obs      =       395
Group variable: Pais                            Number of groups   =        22

R-sq:                                           Obs per group:
     within  = 0.1050                                         min =         9
     between = 0.2830                                         avg =      18.0
     overall = 0.1195                                         max =        21

                                                F(4,369)           =     10.83
corr(u_i, Xb)  = -0.8412                        Prob > F           =    0.0000
```

| GDPgpc | Coef. | Std. Err. | t | P>\|t\| | [95% Conf. | Interval] |
|---|---|---|---|---|---|---|
| RDe | -3.703706 | .7428453 | -4.99 | 0.000 | -5.164447 | -2.242964 |
| l_TradeOpe~s | 2.308697 | 1.435261 | 1.61 | 0.109 | -.51362 | 5.131014 |
| TertiaryEd~n | .0637841 | .1971463 | 0.32 | 0.746 | -.323887 | .4514553 |
| l_FDInetin~s | .7066668 | .1789613 | 3.95 | 0.000 | .3547549 | 1.058579 |
| _cons | -3.639325 | 6.002003 | -0.61 | 0.545 | -15.44175 | 8.163095 |
| sigma_u | 3.1298122 | | | | | |
| sigma_e | 3.1412655 | | | | | |
| rho | .49817364 | (fraction of variance due to u_i) | | | | |

```
F test that all u_i=0: F(21, 369) = 3.78                      Prob > F = 0.0000
```

**Table 5**. Fixed effects estimation.

As we can see in Table 5, the relationships between the variables are presented through the estimated coefficient values. As in pooled OLS estimation, R&D expenditure presents a negative impact on economic growth. An increase of 1 unit in the rate of research and development expenditure in total GDP would lead to a decrease of GDP per capita growth rate of 3.7037 units, ceteris paribus.

As in the last estimation, trade openness has a positive impact on economic growth. We can measure this impact as follows. An increase in 1% of the trade openness rate, would lead to an increase of GDP per capita growth rate in approximately 0.0231 units, ceteris paribus. Also foreign direct investment has a positive impact on economic growth, so if the share of FDI net inflows over GDP increases in 1%, GDP per capita growth rate would increase in 0.0070 units, ceteris paribus. This highlights the importance in countries' economies of international trade.

Lastly, tertiary education impacts economic growth positively. We can measure the impact through its estimated coefficient. The estimation shows that, ceteris paribus, an increase of 1 unit in the rate of tertiary education would increase GDP per capita growth rate in approximately 0.0638 units. Fixed effects estimation reflects an R-squared of approximately 11.95%, being lower than in pooled OLS estimation.

There are two problems that usually appear in panel data estimations. These are autocorrelation and heteroscedasticity, and its presence would lead in inefficient and inconsistent estimators due to the biase that they generate in the estimation. We studied the possible existence of both autocorrelation and heteroscedasticity problems with Stata commands *xtcsd, pesaran abs* and *xttest3* respectively.

First, the presence of autocorrelation between the residuals of the data is studied through the Pesaran test for cross dependence of residuals.  We can see the results of the test in Table A.3. The null hypothesis of the Pesaran test is the non-correlation of the residuals. Due to the contrast p-value=0.000, we can reject the null hypothesis and assume that in the fixed effects model we have a problem of autocorrelation.

The other possible problem that is necessarily to be considered is the heteroscedasticity. In order to evaluate the presence of this problem we used the modified Wald test for fixed effects. This test evaluates the group wise heteroscedasticity of the model. The results of the test can be seen in Table A.4. The null hypothesis of the modified Wald test for fixed effects proposes homoscedasticity in the model. Due to the contrast p-value=0.000, we can reject the null hypothesis and assume that in the fixed effects specification we have a problem of heteroscedasticity.

Therefore, in order to consider autocorrelation and heteroscedasticity in the fixed effects model, we need to include them to the estimation. Stata statistical software command *cluster(Pais)*, allows this consideration. We can see the results of fixed effects estimation considering autocorrelation and heteroscedasticity in Table 6.

As we can observe, the estimators of independent variables remains exactly the same, while the statistical significance of some variables have changed. Research and development expenditure have lightly decreased its statistical significance from p-value=0.000 to p-value= 0.001. Also trade openness and FDI inflows have seen reduced their significance. Trade openness is still not being significance at any level and FDI is not statistically significant at a 99% confidence level, but still in 95%

confidence level. Contrary, tertiary education have increased its significance from p-value=0.746 to p-value= 0.741, still being far away of being statistically significant at any level of significance. The R-squared reflected in the model considering autocorrelation and heteroscedasticity is exactly the same than in original fixed effects model.

```
. xtreg GDPgpc RDe l_TradeOpenness TertiaryEducation l_FDInetinflows, fe clust
> er(Pais)

Fixed-effects (within) regression               Number of obs      =       395
Group variable: Pais                            Number of groups   =        22

R-sq:                                           Obs per group:
     within  = 0.1050                                         min =          9
     between = 0.2830                                         avg =       18.0
     overall = 0.1195                                         max =         21

                                                F(4,21)            =     10.67
corr(u_i, Xb)  = -0.8412                        Prob > F           =    0.0001

                                   (Std. Err. adjusted for 22 clusters in Pais)
------------------------------------------------------------------------------
             |               Robust
      GDPgpc |      Coef.   Std. Err.      t    P>|t|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
         RDe |  -3.703706   .9806186    -3.78   0.001    -5.743014   -1.664398
l_TradeOpe~s |   2.308697   2.373707     0.97   0.342    -2.627697    7.245091
TertiaryEd~n |   .0637841   .1905118     0.33   0.741    -.3324068    .4599751
l_FDInetin~s |   .7066668   .2745742     2.57   0.018     .1356586    1.277675
       _cons |  -3.639325   9.295402    -0.39   0.699    -22.97017    15.69152
-------------+----------------------------------------------------------------
     sigma_u |  3.1298122
     sigma_e |  3.1412655
         rho |  .49817364   (fraction of variance due to u_i)
------------------------------------------------------------------------------
```

**Table 6.** Fixed effects estimation considering autocorrelation and heteroscedasticity.

Apart from these individual fixed effects we also have to ask if there are temporary fixed effects that are relevant in the model. These temporary effects collect the heterogeneous behavior of the years in the model, which are constant between countries. In order to consider this time effects, a model of individual and temporary fixed effects is estimated.

**Estimation by Individual and Temporary Fixed Effects**

In this estimation, time effects are included through dichotomous variables in the model. These variables capture the temporary effects of the years considered that are constant for all countries. So in this model we incorporated a new constant that captured the time effects ($\eta_t$):

$$GDPgpc_{it} = \beta_0 + \beta_1 \, RDe_{it} + \beta_2 \, l\_TradeOpenness_{it} + \beta_3 \, TertiaryEducation_{it} + \beta_4 \, l\_FDInetinflows_{it} + \alpha_i + \eta_t + v_{it}$$

We have run the individual and temporary fixed effects in Stata statistical software and the results of the estimation can be observed in the next page, Table 7.

In this model, temporary fixed effects are considered. Also is considered the presence of heterogeneity and autocorrelation in the model. As we can see in table 7, the different temporary effects are distinguished in the model, so we can see the effects of years from 2001 to 2020. The 2000 year is not included in the temporary variables due to the fact that is used as a base year, and is part of the constant coefficient.

Considering the results, important changes in variables' significance can be noted. Including time fixed effects, R&D expenditure and FDI inflows are no longer statistically significant at any significance level. However, tertiary education becomes statistically significant at a 90% confidence level and trade openness increases its significance but is still not statistically significant. The direction of the effects of variables to economic growth remain constant except FDI net inflows that now has a negative effect on economic growth, but not significant.

Focusing on the temporary fixed effects, we note that all have a negative effect on economic growth except those for 2004, 2006 and 2007. If we focus on critical recession years, like 2009 and 2020, corresponding to financial crisis and Covid-19 situation, respectively, we can note a highest negative coefficient that in the rest of years. For example, the 2009 coefficient indicates that, ceteris paribus, GDP per capita growth rate, within the 22 countries considered was approximately 9.49 units lower than in the base year, 2000. The coefficient of 2020 shows that GDP per capita growth rate was approximately 9.53 units lower in 2020 than in 2000, ceteris paribus. The year that presents the higher positive value is 2006. That is, in 2006, ceteris paribus, GDP per capita growth rate was approximately 0.32 units higher than in 2000, according to the model.

```
. xtreg GDPgpc RDe l_TradeOpenness TertiaryEducation l_FDInetinflows i.Año, fe
>  cluster(Pais)

Fixed-effects (within) regression               Number of obs     =        395
Group variable: Pais                            Number of groups  =         22

R-sq:                                           Obs per group:
     within  = 0.5862                                         min =          9
     between = 0.1319                                         avg =       18.0
     overall = 0.4863                                         max =         21

                                                F(21,21)          =          .
corr(u_i, Xb)  = -0.1750                        Prob > F          =          .

                                 (Std. Err. adjusted for 22 clusters in Pais)
------------------------------------------------------------------------------
             |               Robust
      GDPgpc |      Coef.   Std. Err.      t    P>|t|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
         RDe |  -.4984865   .5416698    -0.92   0.368    -1.624951    .6279776
l_TradeOpe~s |   3.570226   2.296417     1.55   0.135    -1.205436    8.345887
TertiaryEd~n |   .2896865   .1511285     1.92   0.069    -.0246024    .6039755
l_FDInetin~s |  -.0686085   .1343023    -0.51   0.615    -.3479055    .2106884
             |
         Año |
       2001  |   -1.78423   .7547081    -2.36   0.028    -3.353731   -.2147283
       2002  |  -1.472261   .6086164    -2.42   0.025    -2.737948   -.2065736
       2003  |  -1.212748   .5612924    -2.16   0.042     -2.38002    -.045477
       2004  |   .0336817   .6994489     0.05   0.962    -1.420902    1.488265
       2005  |   -.381429   .6011401    -0.63   0.533    -1.631568    .8687103
       2006  |   .3194486   .6176484     0.52   0.610    -.9650216    1.603919
       2007  |   .0127397   .7505977     0.02   0.987    -1.548214    1.573693
       2008  |  -3.986114   1.126289    -3.54   0.002    -6.328359   -1.643869
       2009  |  -9.490555   1.087346    -8.73   0.000    -11.75182   -7.229294
       2010  |  -3.094412   1.068602    -2.90   0.009    -5.316691   -.8721329
       2011  |  -2.678005   .9498369    -2.82   0.010    -4.653299   -.7027107
       2012  |  -4.864252   .9151625    -5.32   0.000    -6.767437   -2.961068
       2013  |  -4.156956   1.129047    -3.68   0.001    -6.504938   -1.808974
       2014  |  -3.461026   .8825687    -3.92   0.001    -5.296429   -1.625624
       2015  |  -2.456692   .8201369    -3.00   0.007     -4.16226   -.7511243
       2016  |  -2.794224   .7233161    -3.86   0.001    -4.298442   -1.290005
       2017  |  -1.797407   .8682253    -2.07   0.051     -3.60298    .0081663
       2018  |  -2.825016   .7717212    -3.66   0.001    -4.429898   -1.220134
       2019  |  -3.130323   .7576888    -4.13   0.000    -4.706023   -1.554623
       2020  |  -9.525744   1.116029    -8.54   0.000    -11.84665   -7.204835
             |
       _cons |  -11.54369   9.842772    -1.17   0.254    -32.01285    8.925478
-------------+----------------------------------------------------------------
     sigma_u |  1.7827304
     sigma_e |  2.1964464
         rho |  .39714163   (fraction of variance due to u_i)
------------------------------------------------------------------------------
```

**Table 7.** Individual and Temporary Fixed effects estimation

If we look at the significance of the time fixed effects, we note that some of them are statistically significant and others are not. To make sure whether time fixed effects are or not jointly statistically significant we use the *testparm* command in Stata to prove the joint significance of time effects. Results can be observed in Table A.5.

According to the results of the joint significance F-Test for time effects, p-value associated with statistic F (20, 21) =3340.85 is 0.000, rejecting then the null hypothesis of joint non-significance of the time effects. Thus, temporary fixed effect must be included in the fixed effects model.

Finally, is convenient to consider a random effects model that takes into account a different point of view of heterogeneity in the data.

**Estimation by Random Effects**

In this model, individual effects of countries are not considered fixed and constant in time, they are considered as a randomly variable with a mean value and a non-zero variance. In addition, a necessary condition for the consistence of the estimation in this model is the no correlation among the explanatory variables and the unobserved effects.

Thus, the random effects model is the following:

$$GDPgpc_{it} = \beta_0 + \beta_1\, RDe_{it} + \beta_2\, l\_TradeOpenness_{it} + \beta_3\, TertiaryEducation_{it} + \beta_4\, l\_FDInetinflows_{it} + \alpha_i + \varepsilon_{it}$$

Using Stata we have estimated the random effects model and results are shown in Table 8.

Before analyzing the results of the model, we studied the presence of possible autocorrelation in the model. For this propose, we have used the *xtserial* command in Stata that evaluates the autocorrelation in the model. Results can be observed in Table A.6. Wooldridge test for autocorrelation consider non-existence of autocorrelation in the residuals as null hypothesis. As we can see in the results, the statistical value of the test is F (1, 21) =15.524 and p-value=0.0007, so we can reject the null hypothesis of non-autocorrelation in residuals and consider the existence of an autocorrelation problem in the model.

```
. xtreg GDPgpc RDe l_TradeOpenness TertiaryEducation l_FDInetinflows, re

Random-effects GLS regression                   Number of obs      =       395
Group variable: Pais                            Number of groups   =        22

R-sq:                                           Obs per group:
     within  = 0.0769                                        min =           9
     between = 0.4137                                        avg =        18.0
     overall = 0.1457                                        max =          21

                                                Wald chi2(4)       =     49.19
corr(u_i, X)   = 0 (assumed)                    Prob > chi2        =    0.0000

------------------------------------------------------------------------------
      GDPgpc |      Coef.   Std. Err.      z    P>|z|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
         RDe |  -1.487452   .2470163    -6.02   0.000    -1.971595   -1.003309
l_TradeOpe~s |  -.0584909   .5602361    -0.10   0.917    -1.156533    1.039552
TertiaryEd~n |   .3818894   .1605288     2.38   0.017     .0672588    .6965201
l_FDInetin~s |   .5124246   .1663263     3.08   0.002     .1864311    .8384181
       _cons |   2.668551   2.704044     0.99   0.324    -2.631279     7.96838
-------------+----------------------------------------------------------------
     sigma_u |   .7158397
     sigma_e |  3.1412655
         rho |  .04936683   (fraction of variance due to u_i)
------------------------------------------------------------------------------
```

**Table 8.** Random effects estimation

Thus, a model of random effects considering autocorrelation and standard deviations to heteroscedasticity is estimated. Again, using Stata we estimated a random effects model with the *cluser(Pais)* command for considering autocorrelation and heteroscedasticity in the model. Results are shown in the next page, Table 9.

As we can see in the results research and development expenditure is statistically significant at a 99% confidence level and FDI inflows is statistically significant at a 95% confidence level. Trade openness and tertiary education are not statistically significant in this model.

Focusing on the effects of the dependent variables on economic growth in this estimation, ceteris paribus, an increase of 1 unit in the rate of total research and development expenditure in total GDP would lead to a decrease of GDP per capita growth in approximately 1.4875 units. As in fixed effects, the impact of this variable on economic growth contradicts the first hypothesis of the study.

Also trade openness has a negative, but not significant effect on economic growth in this estimation. An increase in 1% of the trade openness rate would lead to a decrease of GDP per capita growth rate of approximately 0.0006 units, ceteris paribus. This effect contradicts the third hypothesis of the study.

Contrary, tertiary education and FDI inflows have a positive impact on economic growth. In education, for an increase of 1 unit in the ratio of students enrolled in tertiary education on total population, we expect an increase of approximately 0.3819 units in GDP per capita growth rate, ceteris paribus. This effect supports our second hypotheses, indicating a positive effect of tertiary education on economic growth, but it’s not statistically significant. Lastly, FDI inflows have a positive and significant effect on economic growth, at a 95% confidence level, so an increase in this variable in 1% would lead to an increase of GDP per capita growth rate of 0.0051 units, ceteris paribus. This positive impact of FDI inflows on economic growth supports the third hypothesis of the study. The R-squared of the regression registers a value of approximately 14.57% for this random effects estimation, being higher than in fixed effects estimation.

```
. xtreg GDPgpc RDe l_TradeOpenness TertiaryEducation l_FDInetinflows, re clus
> ter(Pais)

Random-effects GLS regression                   Number of obs     =        395
Group variable: Pais                            Number of groups  =         22

R-sq:                                           Obs per group:
     within  = 0.0769                                         min =          9
     between = 0.4137                                         avg =       18.0
     overall = 0.1457                                         max =         21

                                                Wald chi2(4)      =      26.15
corr(u_i, X)   = 0 (assumed)                    Prob > chi2       =     0.0000

                                  (Std. Err. adjusted for 22 clusters in Pais)
```

| GDPgpc | Coef. | Robust Std. Err. | z | P>\|z\| | [95% Conf. | Interval] |
|---|---|---|---|---|---|---|
| RDe | -1.487452 | .3000619 | -4.96 | 0.000 | -2.075563 | -.8993418 |
| l_TradeOpe~s | -.0584909 | .7822105 | -0.07 | 0.940 | -1.591595 | 1.474614 |
| TertiaryEd~n | .3818894 | .2348913 | 1.63 | 0.104 | -.0784891 | .8422679 |
| l_FDInetin~s | .5124246 | .2306214 | 2.22 | 0.026 | .060415 | .9644343 |
| _cons | 2.668551 | 3.822413 | 0.70 | 0.485 | -4.823241 | 10.16034 |
| sigma_u | .7158397 | | | | | |
| sigma_e | 3.1412655 | | | | | |
| rho | .04936683 | (fraction of variance due to u_i) | | | | |

**Table 9.** Random Effects estimation considering autocorrelation and heteroscedasticity

### 4.5. MODEL SELECTION

Once realized the estimation of the four models proposed, we aim to choose the best estimation that better fits in our panel data characteristics, providing the best possible estimators for the study. In order to select the final model, we have used the following Stata tests that helped us to select the better estimation.

**Joint significance of Fixed effects F- test**

This test is used to contrast pooled OLS estimation and fixed effects estimation. Basically, it is used to prove if the regression constants do not vary among the countries considered in the data. The null hypothesis of the test considers that explanatory variables are joint non-significant that is H0: $\alpha 1 = \alpha 2 = \ldots = \alpha 22$. As we can see in Table A.7, the fixed effects model shows a statistic F (21, 369) = 3.78, linked with a p-value=0.0000. So, null hypothesis can be rejected and thus fixed effects method will be preferred than using pooled OLS method.

**Breusch-Pagan test for Random effects**

As we have seen in the last test, fixed effects model has a better estimation than pooled OLS model. We have also wondered if random effects model is better than pooled OLS or not. For that propose, the Breusch-Pagan test is used through *xttest0* command in Stata Software. This test studies the variance of individual effects, so the null hypothesis considers the variance of the individual effects as zero. If null hypothesis is rejected, it would mean that exists an unobservable component of the variance associated with each individual and therefore it will be more optimal to choose random effects instead of pooled OLS.

As we can see in Table A.8, results of the test showed a $\chi^2$=23.95 associated with a p-value of 0.0000. Therefore, we can reject the null hypothesis of null variance of individual effects and consider random effects model a better estimation than pooled OLS model.

At this point, after the previous contrasts, we can affirm that pooled OLS estimation is not the better option for having efficient estimators. But for selecting the best estimation model is necessarily to compare fixed effects model with random effects model using the next contrast.

**Hausman test**

The Hausman test is used to compare fixed effects model and random effects model. In this test, the correlation between the components of the individual errors and the explanatory variables is studied. If this correlation exists and we do not introduce the individual error terms in the model, would cause biase to the estimation. The null hypothesis of the Hausman test is H0: corr ($u_i$, x) = 0, that is, the fixed effects estimators and the random effects estimators do not differ significantly. If the null hypothesis is rejected, we will use fixed effects instead of random effects model.

Using the Stata *hausman fe re* command, we obtain the results observed in Table A.9. As we can see, the contrast show a chi-squared statistical of 39.78, associated with a p-value of 0.000, thus rejecting the null hypothesis and considering fixed effects model the best and efficient model that fits in the data considered.

Therefore, the final model selected is the fixed effects model. Due to the relevance of time effects in the fixed effects estimation, we also include them to the model, along with heterogeneity and autocorrelation that are also considered. So, the estimation finally selected is the one represented in Table 7.

## 5. CONCLUSIONS

In order to analyze the conclusions of the work, it is necessary to recapitulate and remember the main motivations that started this investigation. The main objective of this study was to analyze the role that innovation process, education and international trade have in economic growth of countries. This objective was motivated by the importance of economic growth on development, economic progress and citizens' life's quality in countries. The investigation of the variables that have a contribution in economic growth is an important issue for designing and developing policies to follow growth objectives in countries. In this paper we have analyzed three potential contributors to economic growth that are innovation, education and international trade. At the beginning of the paper we propose three hypotheses of the expected relationships between these variables and economic growth, thanks to the results of the econometric model developed it has been possible to clarify some of the questions that have been raised throughout the study. Results are analyzed as follows.

As argued in the model selection, the final model selected for evaluating the effects of the variables is the individual and temporary fixed effects model incorporating heteroscedasticity and autocorrelation. The results of the model can be observed in Table 7 and they are presented next.

First, education is the only variable that is a relevant factor when explaining economic growth, being marginally significant. The rest of variables, are unexpectedly not statistically significant in the model, given the data and countries considered. According to the individual and temporary fixed effects model, the estimated coefficients of the variables are presented next.

Beginning with research and development expenditure variable, a negative relationship with economic growth is showed in the model. The estimated coefficient that is attached to the variable is -0.4985, but is not statistically significant in this model. This coefficient shows that, ceteris paribus, an increase of 1 unit in the rate of total research and development expenditure in total GDP would lead to a decrease of GDP per capita growth in approximately 0.4985 units. Although the impact of this variable in economic growth is negative according to the model, this negative effect is not statistically relevant.

The coefficient of trade openness shows a positive relationship between the variable and economic growth. The value of the estimator is 3.5702 which mean that an increase in 1% of trade openness rate would lead to an increase of GDP per capita growth rate of 0.0357 units, ceteris paribus. The estimator of trade openness has a p-value associated of 0.135, but is not considered statistically significant for any usual confidence level.

Education is noted to have a positive effect in economic growth according to the selected model. The model shows a positive relationship between education and economic growth due to an estimated coefficient of 0.2896. According to the model, an increase of 1 unit in the ratio of students enrolled in tertiary education on total population would lead an increase of 0.2896 units in GDP per capita growth rate. The p-value associated to the estimator is 0.069, being marginally significant.

Lastly, foreign direct investment has a negative impact on economic growth in the model. The estimated coefficient of the variable is 0.0686. An increase in FDI inflows of 1% would lead to an increase of GDP per capita growth rate of approximately 0.0007 units, ceteris paribus. The p-value associated to the estimator is 0.615, not being statistically significant at any level of confidence.

The model presents an R-squared of 0.4863, indicating that GDP per capita growth rate can be explained in a proportion of 48.63% through the independent variables considered.

Considering the results presented by the selected estimation, we can analyze the hypotheses proposed at the beginning of the paper, and discuss them.

The first hypothesis proposed was that the innovation variable, research and development expenditure would have a positive impact on economic growth. As we have seen in the results of the final econometric model developed, we did not find evidence to confirm this hypothesis. The results of the model showed that research and development expenditure is not statistically significant in explaining economic growth, according to the data and model developed. A surprising result in this variable is that it is negatively correlated with economic growth.

These results can be explained by the existence of a catch-up process between innovation and economic growth in European countries. A paper that presented the same negative relationship in innovation and economic growth was Petrariu et al. (2013). In the work, based in CEE countries for the period 1996-2010, the negative effect of the innovation process in economic growth rate is argued by a catch-up process. The argument on this study was that these countries had a relatively low innovation process compared to the high economic growth that they were experimenting. In this case, innovations were imported from other developed countries and the interest of domestic research and development was reduced. That was the reason of the negative relationship of the variables. Due to the similar country sample of this work and the nearly years considered, maybe the reason of the negative relationship of innovation and economic growth is the same catch-up process in countries' economies.

Nonetheless, results of the estimated model match with (Pessoa, 2007), and suggested that there is not a strong linkage in the relationship between research and development variable and economic growth.

The second hypothesis expected that tertiary education would have a positive impact on economic growth. According to the results of the model, we found evidence confirming this hypothesis as the coefficient of education is significantly different from 0 and positive. In the final model estimations, tertiary education had a positive and marginally significant impact on economic growth. Works like (Vandenbussche et al., 2006) and (Hava & Erturgut, 2010) already presented the positive contribution of education in the innovation process and economic growth, through the increase of human capital, increase of the innovations' capacity of the country's economy and the contribution to the knowledge spillover process. So, in concordance with literature, we consider that knowledge and skills acquired in tertiary education improves human capital and impulse innovation and economic growth.

The last hypothesis presented at the beginning of the work refers to trade openness and foreign direct investment. In literature review we focused on works like Grossman and Helpman (1991) and Kinoshita (2001) that presented a positive impact of trade openness and foreign direct investment in economic growth. According to literature, we expected that trade openness rate and foreign direct investment inflows have a positive impact on economic growth. On one hand, results showed that a positive relationship between trade openness and economic growth exists, but not in a statistically significant way in the country sample considered. On the other hand, foreign direct investment presents a negative but not significant relationship with economic growth. After the econometric model results, we did not find evidence to confirm the third hypothesis, according to the data sample considered. To summarize the results of this study, we present some of the important conclusions next.

According to the econometric model developed, R&D expenditure representing innovation process in European countries has a negative, but not statistically significant effect on economic growth. Tertiary education used as proxy of education, has a positive and marginally impact on economic growth. Lastly, trade openness and foreign direct investment, used as proxies of international trade; present a positive and negative impact on economic growth, respectively, but not in a significant way. This paper contributes to the innovation research area and in the study of the factors that sustain economic growth in countries.

**Limitations and future research**

Finally, it is important to comment the limitations that this study had and some of the perspectives of future in the respective research area.

The limitations of the study were basically those related with the data availability of the variables included in the study. The variable that reduced the most the countries included in the panel data was tertiary education variable. This was a complicated variable to data collection process due to the difficult in some least developed countries to collect and register tertiary education enrollments. Also research and development expenditure caused problems in data collection process. This is due to the difficulty of the data availability of some small European countries. These availability problems of the data leaded to a decrease of the countries included in the sample that is a great limitation that reduced the number of observations in the panel data.

Another limitation of this study is that innovation process is represented only by the research and development expenditure. This variable collects the effects of part of the innovation process, but not all the innovation effects on economic growth are collected in this variable. This limitation can motivate others authors to include more innovation variables to collect effects that represent better innovation process in countries.

The future research attached to this study could be the consideration of specialized innovation process of different industries and not in a general vision of countries. The investigation of innovation in specific industries could be interesting in order to develop policies and measures to support those industries to get bigger and efficient. Also the study of research and development expenditure in different sectors of the economy is interesting. This investigation could contribute to know, in which sectors is better to invest in research and development.

The investigation of innovation process is fundamental to developing more efficient products and processes, increasing productivity and growth in countries. It is essential that the innovation research continues in future works.

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## 7. APPENDIX

**Table A.1.** Summary of univariates statistics.

```
. summarize GDPgpc RDe l_TradeOpenness TertiaryEducation l_FDInetinflows
```

| Variable | Obs | Mean | Std. Dev. | Min | Max |
|---|---|---|---|---|---|
| GDPgpc | 462 | 2.082318 | 3.799151 | -14.46433 | 12.99696 |
| RDe | 454 | 1.604862 | .9149381 | .3593 | 3.8738 |
| l_TradeOpe~s | 462 | 4.593614 | .4296245 | 3.746073 | 5.940445 |
| TertiaryEd~n | 449 | 4.137505 | 1.218002 | .5620387 | 9.591804 |
| l_FDInetin~s | 413 | 1.353505 | 1.151012 | -2.756781 | 4.694376 |

**Table A.2.** Spearman's correlation matrix.

```
. spearman GDPgpc RDe l_TradeOpenness TertiaryEducation l_FDInetinflows, stats(rho p)
(obs=395)
```

| Key |
|---|
| *rho*<br>*Sig. level* |

| | GDPgpc | RDe | l_Tra~ss | Tertia~n | l_FDIn~s |
|---|---|---|---|---|---|
| GDPgpc | 1.0000 | | | | |
| RDe | -0.4423<br>0.0000 | 1.0000 | | | |
| l_TradeOpe~s | 0.0958<br>0.0572 | 0.0483<br>0.3388 | 1.0000 | | |
| TertiaryEd~n | 0.0637<br>0.2066 | 0.0997<br>0.0477 | -0.0655<br>0.1939 | 1.0000 | |
| l_FDInetin~s | 0.1507<br>0.0027 | 0.0378<br>0.4537 | 0.3681<br>0.0000 | -0.0995<br>0.0482 | 1.0000 |

**Table A.3.** Pesaran test for cross dependence of residuals.

```
. xtcsd, pesaran abs

Pesaran's test of cross sectional independence =    26.064, Pr = 0.0000

Average absolute value of the off-diagonal elements =     0.468
```

**Table A.4.** Wald Test for Heteroscedasticity in Fixed effects model

```
. xttest3

Modified Wald test for groupwise heteroskedasticity
in fixed effect regression model

H0: sigma(i)^2 = sigma^2 for all i

chi2 (22)  =      223.70
Prob>chi2 =      0.0000
```

**Table A.5.** Joint Significance F-Test for Time Effects.

```
. testparm i.Año

 ( 1)  2001.Año = 0
 ( 2)  2002.Año = 0
 ( 3)  2003.Año = 0
 ( 4)  2004.Año = 0
 ( 5)  2005.Año = 0
 ( 6)  2006.Año = 0
 ( 7)  2007.Año = 0
 ( 8)  2008.Año = 0
 ( 9)  2009.Año = 0
 (10)  2010.Año = 0
 (11)  2011.Año = 0
 (12)  2012.Año = 0
 (13)  2013.Año = 0
 (14)  2014.Año = 0
 (15)  2015.Año = 0
 (16)  2016.Año = 0
 (17)  2017.Año = 0
 (18)  2018.Año = 0
 (19)  2019.Año = 0
 (20)  2020.Año = 0

       F( 20,    21) = 3340.85
            Prob > F =    0.0000
```

**Table A.6.** Wooldridge autocorrelation test.

```
. xtserial GDPgpc RDe l_TradeOpenness TertiaryEducation l_FDInetinflows, outpu
> t

Wooldridge test for autocorrelation in panel data
H0: no first-order autocorrelation
    F(  1,      21) =     15.524
           Prob > F =      0.0007
```

**Table A.7.** Joint significance F-test for fixed effects**.**

```
. xtreg GDPgpc RDe l_TradeOpenness TertiaryEducation l_FDInetinflows, fe

Fixed-effects (within) regression               Number of obs      =       395
Group variable: Pais                            Number of groups   =        22

R-sq:                                           Obs per group:
     within  = 0.1050                                         min =         9
     between = 0.2830                                         avg =      18.0
     overall = 0.1195                                         max =        21

                                                F(4,369)           =     10.83
corr(u_i, Xb)  = -0.8412                        Prob > F           =    0.0000

------------------------------------------------------------------------------
      GDPgpc |      Coef.   Std. Err.      t    P>|t|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
         RDe |  -3.703706   .7428453    -4.99   0.000    -5.164447   -2.242964
l_TradeOpe~s |   2.308697   1.435261     1.61   0.109     -.51362    5.131014
TertiaryEd~n |   .0637841   .1971463     0.32   0.746     -.323887    .4514553
l_FDInetin~s |   .7066668   .1789613     3.95   0.000     .3547549    1.058579
       _cons |  -3.639325   6.002003    -0.61   0.545    -15.44175    8.163095
-------------+----------------------------------------------------------------
     sigma_u |  3.1298122
     sigma_e |  3.1412655
         rho |  .49817364   (fraction of variance due to u_i)
------------------------------------------------------------------------------
F test that all u_i=0: F(21, 369) = 3.78                     Prob > F = 0.0000
```

**Table A.8.** Breusch-Pagan test for Random effects

```
. xttest0

Breusch and Pagan Lagrangian multiplier test for random effects

        GDPgpc[Pais,t] = Xb + u[Pais] + e[Pais,t]

        Estimated results:
                         |       Var     sd = sqrt(Var)
                ---------+-----------------------------
                  GDPgpc |   13.21348       3.635036
                       e |   9.867549       3.141265
                       u |   .5124265       .7158397

        Test:   Var(u) = 0
                             chibar2(01) =    23.95
                          Prob > chibar2 =   0.0000
```

**Table A.9.** Hausman test

```
. hausman fe re

                 ---- Coefficients ----
             |      (b)          (B)            (b-B)     sqrt(diag(V_b-V_B))
             |       fe           re         Difference          S.E.
-------------+----------------------------------------------------------------
         RDe |   -3.703706    -1.487452       -2.216253        .7005727
l_TradeOpe~s |    2.308697    -.0584909        2.367188        1.321405
TertiaryEd~n |    .0637841     .3818894       -.3181053        .1144428
l_FDInetin~s |    .7066668     .5124246        .1942422        .0660508
------------------------------------------------------------------------------
                           b = consistent under Ho and Ha; obtained from xtreg
            B = inconsistent under Ha, efficient under Ho; obtained from xtreg

    Test:  Ho:  difference in coefficients not systematic

                  chi2(4) = (b-B)'[(V_b-V_B)^(-1)](b-B)
                          =       39.78
                Prob>chi2 =      0.0000
```