LUND UNIVERSITY
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IDI AS A SOURCE OF LABOR PRODUCTIVITY

A Quantitative Analysis

A THESIS PRESENTED BY

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IDI as a Source of Labor Productivity

Abstract

Several discussions have taken place arguing whether technology is influencing in the productivity of the economy and furthermore if it is worth it to dedicate resources to the development and strategy of the Information and Communication Technologies (ICT). Productivity, therefore, becomes an important topic of discussion to understand the impact of technology at a macro-economic perspective and its applicability at a micro level. Our thesis aims to find a causal relationship between IDI and Labor Productivity through an econometric model (Panel Data) using as sample the European Union Economies. The result denotes a statistical relevance in the relationship between technology and labor productivity, supporting previous findings that only measure the investment on ICT rather than the entire complexity of it, like skills and usage, that the IDI index measure. The outcomes aim to be applicable to motivate not only nations but firms in how they should adapt to new technologies to be resilient.

Keywords: Digital Economy, Digital Transformation, Productivity, Labor Productivity, IT Capabilities, IDI, ICT, Productivity Paradox, Panel Data.

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List of Abbreviations

B2B	Business to Business
e-commerce	electronic commerce
EU	European Union
FDI	Foreign Direct Investment
GDP	Gross Domestic Product
ICT	Information and Communication Technology
IDI	ICT Development Index
IT	Information Technologies
RBV	Resource Based View
SNA	System of National Accounts

1. Introduction

This section provides definitions, context, and background on the research topic. Moreover, the authors discuss the purpose, the research question, and limitations present in this study. We are concluding this chapter with the thesis outline in order to give the reader an overall perspective of the thesis.

1.1. Background

Information and Communication Technologies (ICT) have contributed to faster gross domestic product (GDP) and labor productivity growth in a number of developed countries (Piatkowski, 2006), (Jorgenson & Khuong, 2005).

We should understand that Information and Communication Technologies as "an extended term for information technology (IT) which stresses the role of unified communications and the integration of telecommunications infrastructure (telephone lines, cable networks, wireless signals), computers and software. ICT enables users to access, store, transmit, and manipulate data" (Gutierrez, et al., 2017)

This means that the evolution of Information Technology into ICT's is the ability to sustain a networked system, designed to function in a collaborative environment with other systems, rather than focus on the processing and storage of data (Herselman & Britton, 2002)

Because of the relevance of internet and the fast pace of evolution of ICT, the investment in these technologies has grown in the last decade, focused on three components: "information technology equipment (computers and related hardware); communications equipment; and software. The software includes the acquisition of pre-packaged software, customized software, and software developed in-house." (OECD, 2019).

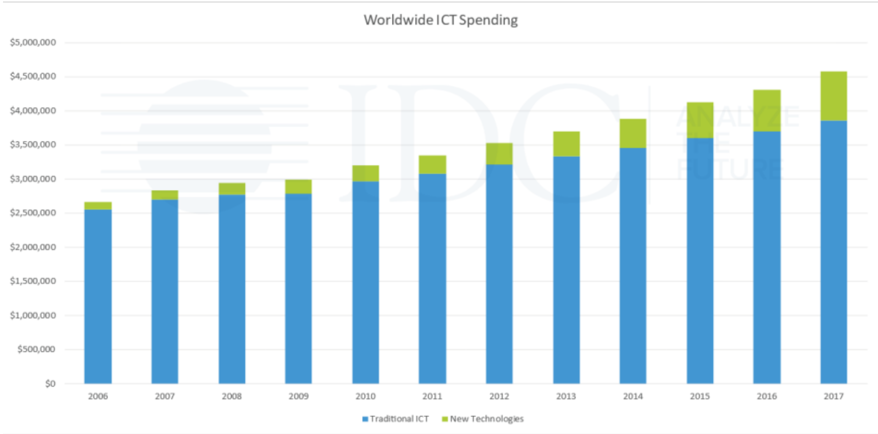


Figure 1 Worldwide ICT Spending – Source (IDC- International Data Corporation, 2019)

There are a number of studies showing that ICT investment bolstered the economies of the United States and several countries of the European Union, Jorgenson (2001); Jorgenson & Stiroh (2000); Jorgenson, Ho & Stiroh (2006), (2008); Oliner & Sichel (2002); Stiroh (2002); Colecchia & Schreyer (2002); Daveri (2002); Jalava & Pohjola (2007); van Ark, Inklaar & McGuckin (2003). Some of the factor measure in their studies are shown in *Figure 2*.

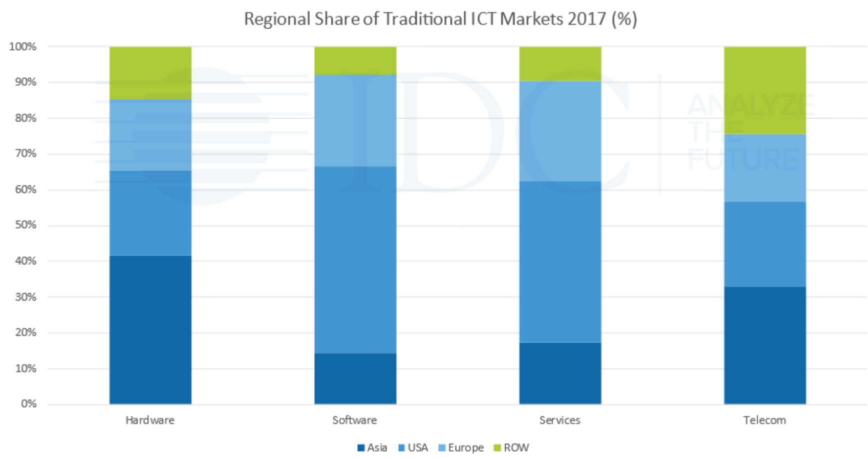


Figure 2 Regional Share of traditional ICT Markets - Source: IDC (IDC- International Data Corporation, 2019)

In some aspects, ICT investment is related to Solow's paradox, which states that "*You can see the computer age everywhere but in the productivity statistics*" (Solow, 1987). The quote marked the starting point of discussions and research of Information and Communication Technologies (ICT) on productivity (Polák, 2017). This quote can be interpreted as the return of the investment made on

ICT can be only visible in the long-term and is not possible without investments in complementary assets like tangible and intangibles, this last one being, for example, the skills and capabilities of the society in general.

In order to encompass this different approaches to technology, the creation of the ICT Development Index, is a relevant tool to measure in a holistic view, the most of the components of technology and society: access, use, and skills, where skills are the missing factor in previous studies and measures.

The fast pace of technology and the new dynamics that this has brought has developed the configuration of a new kind of economy based on digital development. However, the impact of this *Digital Economy* or *Internet economy* is challenging how growth in the countries' economies is being measured. Gross Domestic Product does not capture the entire effect on the economy and the repercussions of the extended use of technology.

Indexes like the ICT Development Index try to contribute to understanding the impact of technology in several aspects of the economy. This thesis aims to explain economic growth through the Labor productivity being influenced by the ICT Development Index and its applicability not only from a country perspective but also from a firm point of view.

1.2. Theoretical and Empirical Problem

Data is the raw information for knowledge (Zins, 2007) this data is generated through ICTs. Therefore, knowledge is becoming principal to the development of nations, transforming this knowledge that is necessary for governments and markets to function.

In the International Bank for Reconstruction and Development (2002, p. 1) it has been presented that expenditure on assets like machinery, roads, buildings (infrastructure in general) over the past forty years explain less than thirty percent of the variations in growth rates worldwide. Other variations are due to changes in the diffusion and application of knowledge (skills and capabilities) and the growth of educational opportunities (2002, p. 1).

On the one hand, Labor Productivity is a relevant topic to understand the dynamic changes and growth in the economy of countries. On the other hand, technology has become an enabler of the development of Digital Economy, making it into another source of growth of the economies.

However, productivity paradox seems to contradict the fact that technology and productivity could have a positive relationship and affect the economy growth at the same time. Several authors have described that investment in technology does not seem to have a positive effect on productivity. Furthermore, recent studies that have used several sources of data have found a link between productivity and Information Technologies (Brynjolfsson & Kahin, 2002, p. 16), leading to speculation that the paradox no longer applies.

Our research aims to find the relationship between technology (measured in the IDI) and Labor Productivity, a topic that has been studied from an investment in technology point of view (Gera, et al., 1999) (Brynjolfsson & Hitt, 1995) (Berndt & Morrison, 1995). For this thesis, a Panel Data analysis will be conducted in which the IDI will be used since it involves a more holistic approach of technology, by measuring not only different investments in technology and communication but by including skills and the extent of use of the technology.

Although the IDI index has been studied before, usually contrasting the indicator with GDP (Campisi, et al., 2013), just a few types of research have been conducted measuring the index and Labor productivity in a Panel Data model, and the existing ones were elaborated with no recent data (Relich, 2017) (Ceccobelli, et al., 2012). Our approach seeks to find a positive relationship between ICT and labor productivity that together creates growth and development on the economies. Given the fact that the top-ranked countries on the IDI are part of the European Union, we decided to take these economies as a sample for our model.

Studies around the topic have not used and focused on IT Capabilities (as it will be mentioned later on) most of the studies made are around ICT, leaving behind Capabilities. These capabilities help companies face the changes of technology and adapting better to the Digital Economy and Digital Transformation.

ICT Development Index then provides a more comprehensive index where the capability view is taken into account, making it a complete one, since those capabilities are crucial for employment overall outcomes like well-being.

1.3. Contribution

The ICT Development Index is a key indicator to understand the range of coverage of technology in the current information society. By comprehending the impact of the IDI at a macro-economic frame, it will be possible to translate these acknowledgments to the core of the economy: the enterprise. From a strategical management point of view, our contribution will focus on the impact of ICT and how technological capabilities are develop and engaged in the adoption of technologies increasing their productivity, the firms will be able to enhance their capacity of respond and adaptability, and therefore, achieve a successful Digital Transformation.

1.4. Research Purpose

This thesis aims to comprehend the productivity paradox of information technology defined by Erik Brynjolfsson (1993), which states that the productivity of an economy is not affected by the use and implementation of technology. Under this paradox, we seek to understand whether technology offers the potential for productivity growth.

We will estimate the relationships between our variables, the IDI index (independent variable) to Labor Productivity (dependent variable), controlling for Rule of Law, Foreign Direct Investment, Education Expenditure, Education years of schooling, and Inflation (control variables) with a Panel Data analysis. The independent variable IDI index will be acknowledged as one of the factors explaining Labor Productivity Growth. The study will be conducted with data of the European Union Economies from 2010 to 2017.

Once we have proved the existence of causality between Labor productivity and IDI from a macro-level perspective, it will be possible to understand the impact of technology and the challenges of the Digital Transformation on the firms. Since the economy is partly the reflection of how well companies perform and responds to changes in different sectors and industries, success on the adoption of new technologies will, therefore, have an overall impact in the nations.

1.5. Research Question

Does Productivity Paradox explain the relationship between IDI index and Labor Productivity, controlling for the effects of Rule of Law, Foreign Direct Investment, Education Expenditure, Education years of schooling, and Inflation?

1.6. Research Limitations

We are aware of the limitations regarding the use of panel data sets like data collection, design and distortion due to measurement errors, also acknowledge the possible distortion on the primary data collected (Baltagi, 2005) (Brynjolfsson & Kahin, 2002).

Also, we are aware that the findings of this thesis could be only used as an indicator of success on the implementation of new technologies at a country level. The practical matters of this topic are not addressed beyond the implementation of policies without further consideration of corporate dynamics. However, we firmly believe that the success of a national economy is the reflection of national firms' success.

1.7. Thesis outline

In the first part of this thesis, the introduction chapter will be explained.

Secondly, the theoretical review used in the analysis of the empirical data will be presented. This theoretical review will constitute an assessment to study components of productivity and its relationship with technology.

In the third part, a literature review of the relevance of technology for the current economy and one of its measures. Digital economy concept and Labor Productivity and its components will be explained.

The fourth part explains the methodology used to find the relationship between IDI and labor productivity through a panel data analysis. The collection of data, the variables, and the validity and reliability will be explained.

The fifth part will explain the Econometrical Model used (Panel Data), and the tests run to verify the reliability of the model and a short explanation of what was involved in it.

The sixth part has the analysis and discussion of our findings on the Panel Data and the interpretation of these outcomes. Graphs and tables will help the authors to provide a clearer explanation of the results and the importance of the variables used.

The seventh part of the report is the conclusions where the main takeaways from the study will be presented. To that, the answers to the research question will be summarized in this part. Then, the authors will give a review of the result of the analysis and conclusions of the model used to explain the causal relationship IDI in Labor Productivity.

2. Theoretical Review

2.1. Productivity as a Competitive Advantage for Nations

Adam Smith (1776) established a trade theory called "*The Absolute Advantage Theory of Trade*" (Bondarenko, 2019) in the context of international trade. According to this theory a nation should engage in trade with products where there´s a superior production capability, involving producing the good or service at a lower cost than other parties (e.g. person, company, country or any other creating this services or goods (Bondarenko, 2019), (Seretis & Tsaliki, 2016), (Aldrich, 2004).

Smith´s theory was dominant until David Ricardo developed his trade theory "*Comparative Advantage*" making labor the only factor of production and attributing the benefits and cause of international trade to dissimilarities in the relative opportunity costs (Encyclopaedia Britannica, 2019). In his theory, Ricardo explains that trade is based on labor productivity differences among nations, where environment favored some industries (Porter, 1990), (Encyclopaedia Britannica, 2019),

Both theories were influential during the eighteenth and nineteenth centuries, where production was less skill- and more labor-intensive, differences in the capital, natural resources, and growing conditions were reflected in trade (Porter, 1990).

Diverse stakeholders like academics, politicians, and practitioners have used competitiveness as a concept in various ways (Porter, 1990), (Sölvell, 2015), shifts in technology, government policy and country infrastructure are among the major factors that create major differences regarding the competitive position between firms from different nations (Porter, 1990).

Schumpeter highlighted that competition is dynamic in character and companies seeking to improve always evolve (Porter, 1990). Evolution is part of the adaptation of companies but also for nations, since it is the way of how they remain competitive. In a primary ambition, the goal is to improve profits and market share (Rouse B., 2005). However, evolution determines the National Competitive Advantage, so change respond to a deeper need of the companies in some cases to survive, and in some others to excel and create competitive advantages.

Some relevant tools of management come from the sixties and seventies (Hill & Westbrook, 1997) with the approach of determining whether the competitive advantages come from internal factors (Strengths and Weaknesses) or environmental advantages (Opportunities and treats).

Porter (1980) focus its attention on the external factors of the company to create advantages. Nations play a crucial role since the country environment support a segment or industry in particular with a proper strategy that encourages innovation and improvement. Sustaining a long term Competitive Advantage demands the above, but also continuous upgrade, making their home advantages valuable for other countries, requiring then a change from a domestic position into an international one (Porter, 1990).

The country where headquarters are located, "is where strategy is set, core products and process development takes place, and essential proprietary skills reside" (Porter, 1990, p. 69).

Porter (1990) established the determinants of national advantage *Figure 3* where a nation can as a system or individually create an environment in which firms compete, are created, skills and the resources needed are found.

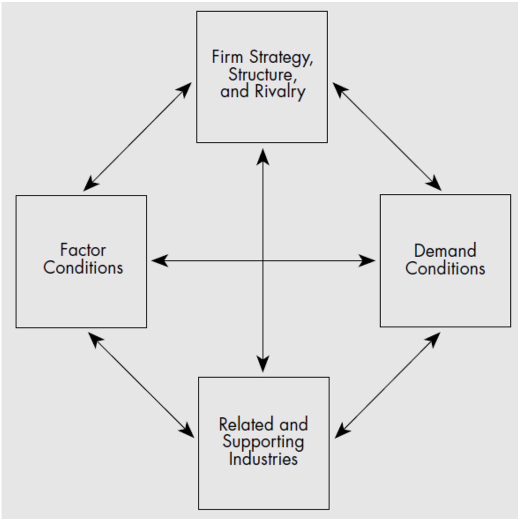


Figure 3 Determinants of National Competitive Advantage (Porter, 1990)

1. Factor Conditions productions factors/ inputs needed to compete in a particular industry (e.g., infrastructure, capital, labor, natural resources)
2. Demand Conditions the nation demand and gaining competitive advantage in global demand.
3. Related and Supporting Industries which are internationally competitive and that could be absent or present in a nation
4. Firm Strategy, structure, and rivalry involve the nature of domestic rivalry; conditions of a nation governing, also how companies are managed, created, and organized.

As Porter (1990) mentioned, economic prosperity depends on the productivity of the resources employed, and the national firm's exposure to international competition. Domestic Productivity will be possible only if nations compete with success in the global economy (Thurow, 1994).

The economic fortunes and the wealth of nations are driven by productivity (Cardona, et al., 2013). Krugman (1997) has commented that productivity in the long term is almost everything since the key indicator of national income per person (material well-being) is mainly determined by labor productivity growth.

2.2. Productivity Paradox

As mentioned in the introduction, Robert M. Solow (1987) 'Nobel laureate in economics' quote, marked the beginning of studies regarding the absence of influence of ICT in Productivity labor productivity. Economists such as (Attewell, 1994), (Brynjolfsson, 1993), (Brynjolfsson & Hitt, 1998), and (Willcocks & Lester, 1996), have named this phenomenon as the "Productivity Paradox".

Solow (1987) was also the one which highlighted that GDP per capita growth depended on technological progress. Innovation and development of new procedures, technology, and methods influence productivity growth. Hence, new technologies in areas like IT were expected to upgrade productivity, but during the nineties there was concern and uncertainty about the productivity impact of investments on IT (Roach, 1986), (Loveman, 1988); since studies at national and industrial level suggested that the payoff was minimal, and barely justified the costs incurred on investments (Willcocks & Lester, 1996). Hardly any positive effect was seen in initial results, making them inconclusive (Barua, et al., 1995). Turban et al. more formally defined this Paradox, as the "*discrepancy between measures of investment in information technology and measures of output at the national level*" (Turban, et al., 2008).

Examination of the 'Productivity Paradox' and attempts to explain the Paradox has been made, and researchers like (Dedrick, et al., 2003), (Stiroh, 2005) (Draca, et al., 2006) also found results contradicting it.

Brynjolfsson in (1993) suggested four explanations regarding the IT productivity paradox:

- The first, *measurement inaccuracies* being the core of the Paradox, according to this author.
- The second explanation involves adjustment and learning of new technologies, leading to *timing lags*. Outcomes of investments could take several years to show through in significant financial terms (Brynjolfsson, 1993), (Strassmann, 1990).

- The third will be redistribution, that although it may be beneficial to individual firms, it could turn out to be unproductive from industry or economy as a whole.
- The fourth concerns IT not being productive at a firm level. Brynjolfsson arguments decision-makers could have "political interests or poor evaluation practices that contribute to the failure to make real, observable gains from IS/IT investments" (Willcocks & Lester, 1996, p. 281)

Porter and Millar (1985) explain how competitive advantage an output of investments in ICT is. Moreover, they stated that the question is not when this investment will make an impact on the competitive position. Instead, the question should be focused on how and when the impact will strike.

2.3. IT Capabilities

Capability as a concept refers to the "ability to do something". (Oxford English Dictionary, 2019). In a more robust explanation, Day (1990, p. 38) makes a further definition in strategy, defining it as "*a complex bundle of skills and accumulated knowledge that enable firms to coordinate activities and make use of their assets*". In that sense, the capabilities englobe skilled personnel, facilities and equipment, process and routines, and coordination from the management to execute the tasks. In connection with this, the measurement of capabilities can be done through indicators of labor productivity, inventory turns, and time to completion (Teece, 2019).

However, the evolution of the concept in the modern firm enhances different modalities and factors, like operative, technological, managerial, or marketing (Teece, 2019) (Day, 1990). This leads to a focus on several fronts to develop activities that can create value when generating outputs and competitive advantages. Therefore, the deployment of capabilities become strategical for the firms.

In this matter, it is important to state that from the Resource Base View theory (Barney, 1991), the development of capabilities could be account as an internal competitive advantage and as a resource that could be sustainable through time.

On the other hand, the proper allocation of this type of resources will help improve performance (Day, 1990) not only of the particular firm but in the overall industry and economy.

In that aspect, Resource-Based View might indicate that firms could prioritize in the development of technological capabilities with the clear goal of acquiring sustainable competitive advantages (Song & Di Benedetto, 2007). This will build a stronger chain of reaction and adaptability to the new trends and flexibility to the blossoming of new markets.

Then, the development of IT capabilities is relevant for the construction not only of the strategy of a company but also for the capacity of adaptation to changes and trends of the market.

In terms of technological change, the concept refers to a change, even minor, on the way inputs are transformed into outputs; this also includes the quality on which the products are produced or rendered.

Fransman (1994) describes three aspects to take into account when addressing these technological changes, and even so, understand them as part of the development of capabilities in IT.

First, is the acknowledgment of technology as part of the *social organization*, this as a part of the production and labor processes. Second, *knowledge* plays a remarkable aspect of change. It is present in hardware, software, practice, and procedures that create an experience, seen in a positive vicious circle, where more experience can provide learning and new knowledge (Fransman, 1994).

Finally, competition as a factor that stimulates the best use of technology. As Fransman (1994) mentioned, "*Failure to meet these criteria will lead, in the longer run, to the undermining of the enterprises and their relatively inefficient technologies*".

In that matter, the development of IT Capabilities is essential to guarantee internal communication and cross-functional integration at the firm. For some authors, better IT could be associated with strategical flexibility and ultimately, with better financial performance (Bharadwaj, et al., 1999) (Day, 1994).

In order to identify what IT capabilities refer to, Bharadwaj et al. (1999) center their research in to find which ones were the required capabilities to sustain a technological innovation and then, classified them into six categories. The result is the definition of the factors that a firm must have to govern in an adequate way the development of IT.

These factors are IT business partnerships, IT linkages, IT Strategic thinking, IT business process integration, IT management, and IT Infrastructure (Bharadwaj, et al., 1999).

With that classification, Lu and Ramamurthy (2011) established a framework that narrow down the IT capabilities into three dimensions: 1) IT infrastructure capability, 2) IT business spanning capability and 3) IT proactive stance.

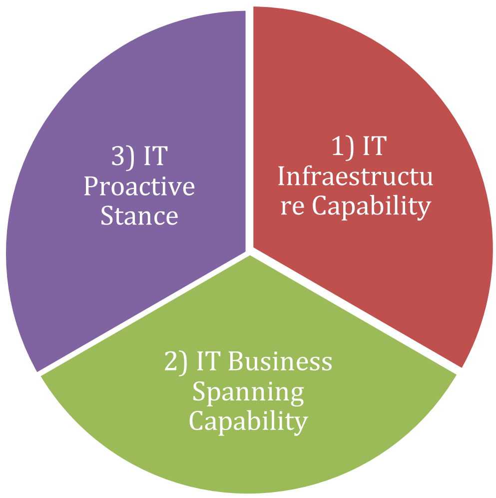


Figure 4 IT Capabilities classification (Lu & Ramamurthy, 2011)

The first dimension refers to the platform, access, and integration of process and data. The second dimension recalls the ability to create linkages and partnerships, this is, the capacity to integrate the infrastructure with the exchange of knowledge to enhance its use and functionality. The third dimension address the need for continual learning and renewal for acquiring needed skills to manage assimilation, adoption, and implementation of IT innovations (Lu & Ramamurthy, 2011).

The proper management of IT capabilities will help to develop companies prepared to face the changes of technology and adapt better to the Digital Economy and Digital Transformation that the society is entering in.

3. Literature Review

3.1. Digital Transformation

The current economy is being affected by new trends and activities like Industry 4.0 (Lasi, et al., 2014), Internet of Things (Gubbia, et al., 2013), and Digital Supply Chain (Pereira & Romero, 2017), topics that are becoming more relevant thanks to the *Digital transformation* that the economy is experiencing (Ashmarina, et al., 2019).

Several definitions of Digital transformation have arisen in the last years, where the term could be defined as part of *digital literacy*, acknowledging this as the third stage of the process that "*is achieved when the digital usages which have been developed, enable innovation and creativity and stimulate significant change within the professional or knowledge domain*" (Lanksher & Knobel, 2008, p. 173). Westerman et al (2014) define digital transformation as "*the use of technology to radically improve performance or reach of enterprises*", while Bharadwaj et al. (2013, p. 472) mentioned a definition in progress that describes the concept as "*organizational strategy formulated and executed by leveraging digital resources to create differential value*".

In this sense, it is possible to recognize the critical elements associated to the concept: The first one is a radical change that a company makes, the second one, the development of creative processes and innovation, and the third one is the identification of technology as a fundamental factor for this change.

One of the most important forces for Digital Transformation is the *Digitization* (Brynjolfsson & McAfee, 2014), a process where information is transformed from analog format, like sound, texts, images, data, and other ways of expression, into ones and zeroes, so this information can be stored and used in the native language of computers.

Thanks to the use of the internet and the connectivity, the sharing of these bytes are easy and accessible, and the growth of this information has been exponential, providing every day more data for companies to reshape their *operational process*. A route demanding the development of business capabilities leveraged by technical aspects of technology. This also requires the improvement of internal processes starting by the basic in technology as digitization and automation of process (Westerman, et al., 2014).

The majority of companies begin their path by remodeling their operational process. A route that requires the development of business capabilities leveraged by technical aspects of technology. This requires the improvement of internal processes starting by the basic in technology as digitization and automation of process (Westerman, et al., 2014).

It is possible to recognize several processes at the inside of the operation that has been addressed during the first steps of transformation. Processes like digitization, analytics, and data integration have been central at companies that pursue a strategy of Digital Transformation. (MIT Center for Business and Capgemini Consulting, 2011)

In this aspect is not only about the technical capabilities on which the company can invest some resources, but also the development of capabilities with their employees, especially in aspects like knowledge sharing and internal networks, in order to start establishing a technologically oriented mindset (Westerman, 2012).

3.2. Digital Economy

The internal processes of change along with the close interrelation between technology and business, are allowing the development of new opportunities of market and business model thanks to the usage and collection of data (Berman, 2012), an idea that is leading to use different aspects of technology into the economic development. Although this concept has a more relevant use in companies' change, the overall dynamic is leading to encourage a new definition on the economy like the concept of *Digital economy* or the *Internet economy*.

For Brynjolfsson and Kahin (2002, p. 1) *Digital Economy* refers "specifically to the recent and still largely unrealized transformation of all sectors of the economy by the computer enabled digitization of information", but it is also to complement this definition with the central role of the internet in the achievement of this task.

The evolution of technology in the economy context has its beginnings in the success of the internet and the electronic commerce (e-commerce) (Brynjolfsson & Kahin, 2002) where the usage of the internet has enhanced the relevance of data and access to new business markets that were unthinkable before (Ahmad & Ribarsky, 2018). The interconnectivity among information and individuals and the growing development and scope of the internet is shaping the current society, the culture, and the economy (Berman & Marshal, 2014).

In that sense, one of the economies that have reached a higher Digital transformation according to the OCDE (2018) is Sweden, whose economic growth in recent years has been driven by the embrace of digital technology and the widespread use of internet across the country. One of the main factors of success on this task is the relevance that Information and Communication Technologies (ICT) have for the companies, creating share value and moving from the value chain focus to the high value-added services.

3.2.1. How to measure the evolution of the Digital Economy

The current mechanism of measurement to monitor the economy rely on statistics around the growth of the Gross Domestic Product (GDP). Since it measures the value of goods and services produced by a country in a specific period, which objective is to measure the final value-added of these products and services. Generally, the value of the GDP is provided in nominal terms, which imply an adjustment for inflation. When this indicator is used to compare two or more economies, some adjustments are needed, and usually, the comparison is made through the GDP per capita (International Monetary Fund, 2018).

In the Digital Economy, the main characteristics or development is focused on the role of technological change, IT aspects, and electronic commerce, many times developing output on the economy in the form of intellectual property. The central issue with this is the value that these products or services have. On the one hand, the low capital-intensive investment that is required to develop them, centred sometimes on intellectual property, and on the other hand, the easily dissemination of information and the almost free cost of this activity (Kanwar & Robert, 2017), makes it challenging to include the added-value of the improvement of technologies in an accurate measure in the overall GDP.

The increasing adoption of ICT combined with the growth of performance and the fast decline in price on these technologies has helped to developed new activities in the public and private sector. For example, by expanding the market and lowering cost causing the blossoming of new products and services, in this products and services, we can find: electronic commerce, payment services, app stores, online advertising, cloud computing, high-frequency trading and participative networked platforms (OECD, 2014).

All of these new business models have common characteristics, where it is possible to identify a lower cost and a more efficient and customer-centered experience. In that sense, the improvements on quality and efficiency, not measured in monetary terms but well-being, are being left out of the GDP, therefore, the standard measures are missing a growing portion of the real value that is created in the economy thanks to the evolution of ICT (Brynjolfsson & McAfee, 2014).

3.2.2. Approaches to measuring Digital Economy

As Brynjolfsson and McAfee (2014) mention, new metrics are necessary to understand the impact of technology and in general ICT in the traditional economy. Draw the line between what is digital and what is traditional is difficult, moreover when traditional business models are transforming to reach new markets and satisfy the customer according to what data information reveal about preferences for consumption.

The main issue with the traditional measure of GDP is that this relies on the number of identifiable prices and quantities, but lacks on contemplated the value of the environmental benefits, health, longevity or non-market household (Watanabe, et al., 2018). With the fast pass of the digital economy and more precisely, the fact that the majority of services and goods on the internet, have no individual price for the use beyond the price of the monthly fee paid to the company that provides the service. This means then that the indicators that measure the impact of the technology and the product and services based on the web platform will need to quantify through tools for unpriced services (Brynjolfsson & Oh, 2012).

From this point of view, technology improvement should be measured from the welfare that the digitalization brings. In that sense, different projects have arisen intending to cover the non-financial metrics of technology improvement that the GDP does not measure. The human development index is an excellent example of these alternative measurements, where dimensions as health, education and living standards are taken into account with the purpose to explain the development of a country (United Nations Development Programme, 2019). However, the impact of technology is not entirely abstracted from this index.

In terms of digital transformation measurements, some index that tries to explain the impact and evolution of technology across the countries have been developed in the last years. The Digital Evolution Index is an example of this. This index seeks to explain more accurately way the competitiveness of the countries based on the potential of technological development, through the evaluation of supply and demand conditions, institutional environment and innovation and change (Chakravorti & Chaturvedi, 2017).

Another Index that is focused in the digital field, is the Digital Economy and Society index (DESI), which task also aims to measure the digital competitiveness of the nations, but in this case, the measure takes into account 5 factors: Connectivity, use of internet services, human capital, integration of digital technology and digital public services (European Commission, 2018).

Overall, the index presented, aim to assess the position of each country in terms of digital evolution, however, the intrinsic effect in the economy is not reflected in an amount of money, income or expense, but in a concept more qualitative of competitiveness, efficiency and productivity.

3.2.3 European Union Economies

When revising the different indexes around digital evolution, there is a pattern on the top countries that are ahead on the task of becoming more competitive thanks to the information and communication technologies.

Sweden, Denmark, Finland, Netherlands and United Kingdom tent to locate among top 10 in the countries with a higher digital competitive index (IMD World Competitiveness Center, 2018), Digital Economy and Society Index (European Commission, 2018) and Digital Evolution Index (Chakravorti & Chaturvedi, 2017). This is in part the result of different policies and activities that the countries of the European Union have taken in topics like Digital Transformation of Businesses, big data and digital platforms, digital skills and ICT standardization (European Comission , 2019).

However, it is vital to notice that although the European Union is looking forward to achieving policies among all the nations to achieve a fully developed society in terms of Digital and technological knowledge and infrastructure. There are still laggards in some economies, and the adoption of new technologies is not fully accomplished in all the dimensions and countries.

The advance of digitization in the different industries varies according to the sectors, especially when it comes to comparing high-tech and traditional businesses, and between the countries and regions of the European Union (European Comission , 2019). Therefore, it is essential to clarify that for the intent of this research, the European Union will be defined as the union of the 28 countries members.

3.3. Labor Productivity

The current model of work is a heritage of the proposition of the division of labor described in *The Wealth of Nations* from Adam Smith (1776), where the specialization and separation of tasks could create more efficient economies. The evolution of this theory helped to create a process of industrialization and development that are palpable in the modern industries.

"Growth in the extent of the market makes it economical to specialize labor to tasks and tools, which increases productivity – and productivity is the real wealth of nations" (Langlois, 2007, p. 3) based on (Smith, 1776).

To obtain outputs or final products or services, it is necessary to have inputs, and these inputs are labor and capital. In conjunction, these two factors will determine the performance to deliver outputs to the economy (Coelli, et al., 2005). Hence, the metric of performance is given by the productivity, seeing productivity as the efficiency with which an amount of inputs is transformed into the desired outputs (Syverson, 2011).

In that order of ideas, productivity can be measured in two traditional ways: through total factor productivity and labor productivity. For the first measure, TFP requires the level of capital, data that is not directly provided or acknowledge from the national accounts, which makes *labor productivity* a much trustful approximation to productivity (Žmuk, et al., 2018).

Following the context of the International Labor Organization (2015), the added value of labor increases when the factors are used more efficiently, leading to a growth in productivity. In that frame, the efficiently use of inputs could be addressed as better skilled working force, an improvement in equipment, better use of raw material and technological innovation and management approach. This sets the viability to rely on Labor productivity as a proxy measure of economic growth of a country (Žmuk, et al., 2018).

This indicator is a relevant measure of the economic analysis of a country. In general, it helps to understand the dynamics on the economic growth, standards of living (Cardona, et al., 2013) and competitiveness, among other variables that are key elements to social development. (Freeman, 2008), like is mentioned by the International Labour Organization:

"Each country's prosperity depends on how many of its people are in work and how productive they are, which in turn rests on the skills they have and how effectively those skills are used. Skills are a foundation of decent work." (International Labour Organization, 2010)

The relevance and relatively easiness of calculation of this indicator have helped it to become the most common productivity measure (Cardona, et al., 2013). This facilitates the data collection and the reliability of the data when comparing and studying different countries and economies.

Several authors have studied the relationship among labor productivity and economic growth through different lenses like research and development (Nekrep, et al., 2018), ICT Capital (Ceccobelli, et al., 2012), Foreign Direct, and Investment spillovers (Liu, et al., 2000), (Haskel, et al., 2007).

This denotes the complexity of the factors that can influence a growth or decrease in Labor Productivity, nonetheless, a strong influence from the current development in technologies could have a major impact on the economic repercussion of labor productivity, therefore, the relevance of analyze the impact of ICT, its components and complementary factors to understand the impact of technology.

Table 1 Results of Retrospective studies impact on Labor Productivity by (Mačiulytė-Šniukienė & Gaile-Sarkan, 2014)

Authors	Study period	Research sample / level	The main results
Oulton (2001)	1950–1973; 1973–1979; 1979–1989; 1989–1999	United Kingdom / Macro and sectoral (ICT, non-ICT) level	From 1989 to 1998, ICT output contributed a fifth of overall GDP growth. Since 1989, 56% of capital deepening has been contributed by ICT capital, and 88% since 1994. ICT capital deepening accounts for 23% of the growth of labour productivity over 1989-98 and 39% over 1994-98. But even when output growth is adjusted for the new ICT estimates, both labour productivity and TFP growth are still found to slow down after 1994

Pilat, Lee & van Ark (2002)	1990–1995; 1996–2000	19 OECD countries / Industries (ICT producing, ICT-using) level	The United States and Australia are almost the only OECD countries where there is evidence at the sectoral level that ICT use can strengthen labour productivity and MFP growth. For most other OECD countries, there is little evidence that ICT-using industries are experiencing an improvement in labour productivity growth, let alone any change in MFP growth
Khan & Santos (2002)	1988–2000	Canada / Macro level	Compared with the US, there was no acceleration in the contribution of ICT use to output growth in the late 1990s. Similarly, contributions from capital deepening in ICT use to labour-productivity growth did not exhibit any acceleration
Van Ark, Inklaar, McGuckin (2003)	1990–2000	European countries and the US, 51 industries / Industries level	United States productivity has grown faster than in the EU because of a larger employment share in the ICT producing sector and faster productivity growth in services industries that make intensive use of ICT.
Van Ark, Piatkowski (2004)	1995–2002	EU-15, CEE-10, US / Macro and industries levels	Labour intensity have been an important source of productivity convergence during the 1990s and are likely to remain so in the near future. ICT capital in the CEE-10 has contributed as much to labour productivity growth as in the EU-15

3.3.1. Elements of Labor Productivity

GDP

The gross domestic product of an economy represents the economic value of the economy in connection with the final services and goods. This measure considers the output generated within a country's border. The GDP is usually calculated by the national statistical agency whose task is to collect from several sources the required information to provide this information. (Callen, 2008). For the European Union, as well for most of the countries, the agencies follow the guidelines of the United Nations System of National Accounts (SNA), created in 1993 and adopted and implemented by countries in different stages (Ark & McGuckin, 1999).

It is relevant to acknowledge that, even though the measure is relevant to compare economic evolution and growth, the GDP does not measure several aspects of the economy like well-being or standard of leaving of a country, moreover, aspects like environmental impact or equality of distribution of wealth (Callen, 2008).

Employment

According to the International Organization of Labour, employment is defined as the all the persons of working age who, during a specific period, where paid or developed productive activities as self-employed (ILO, 2015).

Unluckily, in the national accounts, labor accounts are not as harmonized as other indicators. However, for the countries in the OECD, the labor statistics provides the employment estimates. The data collected is based on population surveys or labor force (Ark & McGuckin, 1999).

Average Hours Worked

This indicator is one of the most troublesome data to harmonize due to the different ways to collect information across countries (Ark & McGuckin, 1999). The OECD defines the average annual hours worked as "*the total number of hours worked per year divided by the average number of people in employment per year*" (OECD, 2019). This includes full-time, part-time, and part-year workers.

3.4. ICT Development Index (IDI)

Information and Communication Technology (ICT) has had a significant impact on countries around the world, particularly in the context of labor, communication, learning, from the perspective of economic growth of both countries and companies (Relich, 2017), (Dimelis & Papaioannou, 2011).

ITC has changed how firms do business from the development of Electronic Data Interchange (EDI) involving data exchange without human interaction to Business-to-Business e-commerce covering all kind of collaborations with the trading partners using ICT´s (Laudon & Laudon, 2006). It is because of the potential benefits ICT can deliver in changing people well-being and nations economy that focus in this development area has been the object of policy and academic consideration in the past decade (Belabbes, et al., 2015), and an overview of previous literature reviews on ICT contribution can be observed in the paper of Cardona et al. (2013).

Table 2 Overview of previous literature reviews on ICT contribution by Cardona et al. (2013)

Study	Method	Results
Brynjolfsson and Yang (1996)	Written survey based on over 150 studies	Discusses explanations for the **productivity paradox, measuring** the IT output link was practically impossible due to lack of data and use of inadequate analytical methods
Brynjolfsson and Hitt (2000)	Literature survey on how IT is linked to higher productivity and organizational transformation, based mainly on firm-level studies	IT performance depends on complementary organizational investments and these investments lead to improvements in intangible aspects. These factors are not well captured by traditional macroeconomic measurement approaches, hence generating the Solow Paradox

Baily (2002)	Summarizes growth accounting and case study evidence and assesses other indicators of structural change	IT is important, but not the only cause of the productivity resurgence in the 1990s. Competition and globalization were further basic drivers
Dedrick et al. (2003)	Written survey on 19 firm-level and 15 country-level studies between 1987–2002	Productivity paradox refuted, a wide range of IT investments among different organizations can be explained by complementary investments in organizational capital
Melville et al. (2004)	Develop a model of IT business value based on resource-based view to review the literature	IT investments provide value, but the impact depends on levels of complementary resources, competitive climate, and general macroeconomic environment. Synergies between technical and human IT resources yield short-lived competitive advantage
Stiroh (2005)	Meta-Analysis (20 studies from 1994–2002)	Study characteristics explain about 35% of the variation in the IT elasticities. Median elasticity at 0.046
Draca et al. (2008)	Survey micro and macro literature	Macro studies meanwhile show evidence of ICT impact. In micro studies the effect is larger than the neoclassical contribution would expect, which is due to organizational complements
Holt and Jamison (2009)	Literature survey on broadband studies	Broadband has a positive impact, but cannot be measured with any precision

Studies around the topic have shown that rigorous use of ICT accelerates productivity growth in various industries also affecting the country's economic growth (Dimelis & Papaioannou, 2011), (Piatkowski, 2006). Due to the relevance seen in ICT, an index was presented in 2009: *The ICT Development Index* (IDI) by the International Telecommunication Union (2019) which is a United Nations specialized agency for Information and Communication Technology (ICT).

IDI is a composite index combining 11 indicators into one standard measure; the purpose of this measure is to compare and monitor developments in information and communication technology overtime between countries. In 2017, 176 countries were covered for the study (International Telecommunications Union, 2017). Due to its global design, it reflects changes in ICT levels of development between countries; the focus of this index is on four main objectives (International Telecommunication Union, 2019) :

- The evolution and level of ICT developments in countries and their experience compared to other countries.
- The progress in ICT development in developing and developed countries.
- The Digital Divide, referring for example to differences among countries concerning their levels of ICT.
- The Development Potential of these ICTs and the degree to which countries make use of them to enhance development and growth, taking into account the skills and capabilities available.

This IDI designed to be global, reflect changes of countries whose level of ICT development varies amongst them. This index has three stages, which shows the steps for becoming an information society, displayed in the three-stage model *Figure 5* (International Telecommunication Union, 2019):

1. ICT Access – captures the level of readiness, networked infrastructure and access to ICTs
2. ICT Use – captures the level of use within the society
3. ICT Skills – captures the outcomes of more effective and efficient ICT use

Advancing in these stages is subject to a combination of ICTs: * availability, access, and Infrastructure *an elevated level of use * capability to use it efficiently because of relevant skills. Taking into account the above, we can say that those three dimensions integrate the following conceptual framework:

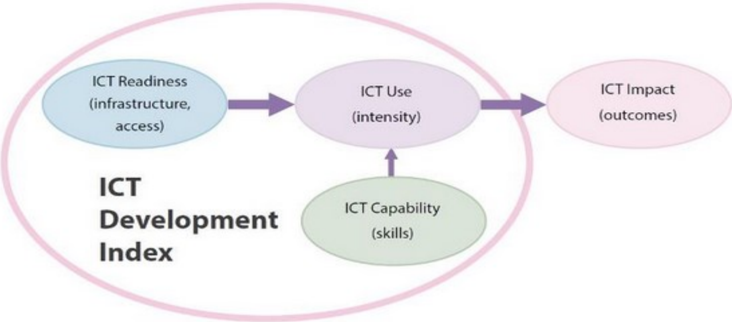
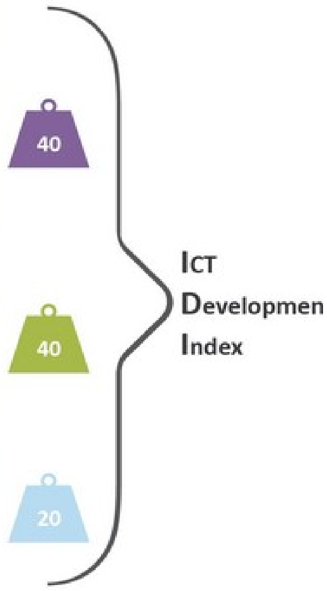


Figure 5 Three stages in the evolution towards an information society
Source: ITU

Sub-index of the ICT Development Index

Based on the conceptual framework, *Figure 5*, there are three sub-indexes: ICT Access, ICT Use, and ICT Skills, where 11 indicators are involved as observed in the following chart, *Figure 6*:

ICT access	Reference value	(%)
1. Fixed-telephone subscriptions per 100 inhabitants	60	20
2. Mobile-cellular telephone subscriptions per 100 inhabitants	120	20
3. International Internet bandwith (bit/s) per internet user	2'158'212*	20
4. Percentage of households with a computer	100	20
5. Percentage of households with Internet access	100	20
ICT use	**Reference value**	**(%)**
6. Percentage of individuals using the Internet	100	33
7. Fixed-broadband subscriptions per 100 inhabitants	60	33
8. Active mobile-broadband subscriptions per 100 inhabitants	100	33
ICT skills	**Reference value**	**(%)**
9. Mean years of schooling	15	33
10. Secondary gross enrolment ratio	100	33
11. Tertiary gross enrolment ratio	100	33



Note: *This corresponds to a log value of 6.33, which was used in the normalization step.

Figure 6 ICT Development Index: indicators, reference values and weights
Source: ITU

The weights in the indicator are selected based on the principal component's analysis outcome. Access and Use sub-indexes have equal weight (40 percent respectively) whereas the skills sub-index has twenty percent, since it is based on proxy indicators (International Telecommunications Union, 2017).

The IDI is useful statistical tool for monitoring progress towards a global information society, the aim of this index is that countries should track their progress over time in order to make policy adjustments to growth their ICT sector as well as their country competitiveness (Belabbes, et al., 2015) (International Telecommunications Union, 2017).

3.4.1. IDI in relation to alternative measures

As more people join the Digital Economy and broadband communication networks become an essential infrastructure, the need for monitoring and measuring the progress of ICT has become crucial for policies.

Due to potential benefits that ICTs deliver into transforming a nation's people well-being and economy, the assessment of development in the area of ICT (Belabbes, et al., 2015) has to be the object of policy and academic attention for the last decades (Porac, 1977), (OECD, 1986).

Thus, important efforts from different organizations have focused on benchmark and measure of ICT access and deployment. However, not many have assessed the outcomes ICTs can deliver to society and economy. Therefore, the policy maker's interest in the measure has changed into measuring the impact of ICTs rather than the access to it (Belabbes, et al., 2015).

Indexes give policymakers tools to know which factors must be improved and gives them guidance to reduce the digital divide through corrective actions and initiatives.

The objective of these indexes lies in ranking and assessing nations in the area of ICT development level. Several Indexes have been created, the major ones being:

- The E-Government Index (EGDI) published in the "United Nations E-Government Survey" by the United Nations Department for Economic and Social Affairs (UNDESA) every two years since 2004. Its focus relies on the website development patterns in a nation also incorporating the access characteristics (United Nations, 2019)
- Networked Readiness Index (NRI), published in "The Global Information Technology Report" from 2001 annually until 2016 by the World Economic Forum and INSEAD. This study seemed to cover important drivers grouped in four sub-indexes: Environment, Readiness, Usage, and Impact, making the last one the differentiation against other measures, this index was discontinued. Hence no datasets were available for a recent period (World Economic Forum, 2019)
- The ICT Development Index (IDI) presented in the "Measuring The Information Society Report" since 2001 by the International Telecommunications Union (ITU) (2019) which also focuses on the skills and access, the country competitiveness and policy effectiveness.

3.5. Hypothesis

Taking into account the Productivity Paradox, IT Capabilities, and understanding the impact of the Digital Economy, our hypothesis for this study seeks to find if:

H1- There is a relationship between IDI and labor productivity

4. Methodology

In this chapter, the authors will describe the research process conducted to answer the study research question by outlining the Methodology used and the motivation behind the choice of the research strategy and design.

4.1. Research Strategy and Design

The research strategy is a general orientation to the conduct of the study, and there are three different approaches: qualitative approach, quantitative or mixed approach (Creswell, 2014).

Quantitative studies aim to generalize theories about an environment from findings made from samples in that environment, following a positivist approach and scientific model. To be able to achieve this aim, the data collected and analyzed must be quantifiable; in most of the cases, the data should consist of numeric information or reports (Bryman & Bell, 2011).

Therefore, the research strategy selected for this study is a quantitative one, this choice requires us to combine and collect data from several sources (Creswell, 2014). The importance of the research strategy also derives from having the role as a critical link between data and theories (Bryman & Bell, 2011).

The research design provides a framework for the analysis and collection of data, this design reflects the choices of the research process about the priority given to a range of dimensions used and their importance (Bryman & Bell, 2011). In this study interpretation and analysis from a Panel Data and approach is presented, and it was used to complement the theory approach.

4.2. Data Analysis

We decided to start the process of Data Analysis with exhaustive literature and theoretical review regarding essential concepts like productivity, the productivity paradox, digital economy, labor productivity, and the IDI index. However, for the analytical analysis, an Econometric model was used (Panel Data) using data from the European Union Economies.

Panel Data or Longitudinal Data was chosen since it offers "the possibility of following the same individuals over time, facilitating the analysis of dynamic responses and the control of unobserved heterogeneity" (Arellano, 2004). Meaning that they are used when we have data comprising cross-sectional elements and time series (Brooks, 2008), a visual representation of a Panel Data is presented below *Figure 7*:

a) We have two dimensions:

- Cases (N) which will be *EU countries* and Variables (K)

b) We have two dimensions:

- Time (T) from *2010 to 2017* and Variables (K)

c) We have three dimensions where information of a) and b) is crossed giving us the Panel Data

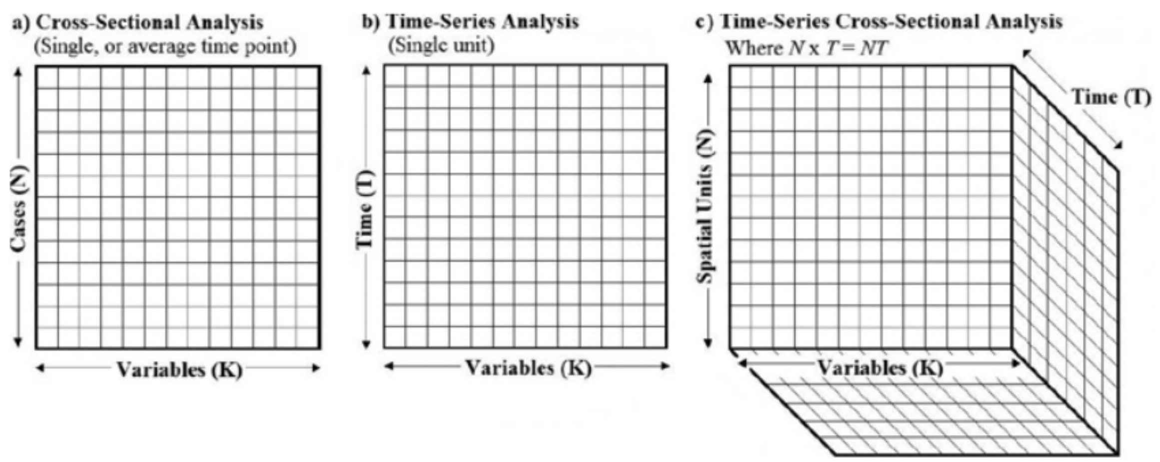


Figure 7 Data Structure by (Fortin-Rittberger, 2013)

Klevmarken (1989) and Hsiao (2007) mentioned several benefits from using panel data, like controlling for individual heterogeneity, give more informative data, more variability, less collinearity among the variables, more degrees of freedom and more efficiency. Panel Data is useful to study the dynamics of adjustment, to identify and measure effects that are not detectable in pure cross-section or pure time-series data, it also allows us to construct more complicated models (Baltagi, 2005).

By structuring data in panels allows more complex datasets to be analyzed and tested (Brooks, 2008). The statistical program used for this study was EViews 10 and the database was integrated from observations *'EU countries'* overtime *'from 2010 to 2017'*, usually involving the interaction of several variables (Fortin-Rittberger, 2013) (Gao & Cowling, 2019).

There are different types of Panel Data (EViews, 2019), but in this study, we are using:

- Balanced Panel Data- where data has a matrix structure, and no variable or observation is missing (Biørn, 2016), it has the same number of time-series observations for each cross-sectional unit (Brooks, 2008).
- Dated Panels- since the data follows a frequency and are defined by a variable like a year. Hence, we have an annual panel.
- Regular Panels- is where the cells in every group follow a regular frequency.

The technique used was the (Estimated) Generalized Least Squares (EGLS) (Brooks, 2008), which is a generalization of OLS regression. EGLS relaxes the assumption that errors are homoscedastic (having data values spread out or scattered) and uncorrelated (Kaufman, 2014). Hence, EGLS provides the most unbiased and efficient estimator (Kaufman, 2014).

4.3. Hypothesis formulation

The hypothesis that this model is testing is the following:

H1- There is a relationship between IDI and labor productivity

To test it, the authors choose a linear regression model developed through a regression equation (1) that considers a dependent variable, an independent variable, and a set of variables of control. This model explains how a change in the independent variable, change the dependent variable:

$$Y_{it} = \alpha + \beta X_{it} + \varepsilon_{it} \quad \textbf{(1)}$$

Where:

- Y = Dependent variable
- α = Intercept (value that Y takes when X is 0)
- β = Slope of the line
- X= Independent variable
- ε = White noise
- *it*= denotes '*i*' for the number of observation and '*t*' for the time-series on which the data was collected

The intention therefore is to use this model to understand first, if there is a relationship between both variables, and once this is defined, identify how the change in the IDI Index is reflected in the Labor Productivity, reason why this model is the most accurate to find the relationship and effects of our variables of study.

In this order of ideas, the result of our linear regression equation will be as follow:

$$Labor\ Productivity = \alpha + \beta_0(IDI\ Index) + \beta_1(Rule\ of\ Law) + \beta_2(FDI) + \beta_3(Educationexp) + \beta_4(Years\ of\ Schooling) + \beta_5(Inflation) + \varepsilon_{it} \quad \textbf{(2)}$$

Where:

- Labor Productivity is our dependent variable
- IDI Index is our independent variable of study and is intended to explain the growth of Labor Productivity

- $B_{1\ \text{to}}B_5$ are the coefficients of the variables of control: Rule of Law, Foreign Direct Investment, Government Education expenditure, Years of Schooling, and Inflation.
- ε is the error term (white noise). The *it* sub-index denote the panel data set

The model evaluates the observations of the 28 countries of the European Union for the period of 2010-2017.

The purpose of regression analysis is to identify the relationship between independent and control variables with the dependent variable. "The analysis of two (or more) variables can be carried out using multiple regression analysis which is a very powerful technique for examining many independent variables and determining which ones are significant, either by themselves or in combination (called an interaction) with another variable" (Boddy & Smith, 2009).

In order to determine the specification of the model in Equation **(2)**, i.e., if we should use pooled data, or account for the heterogeneity with fixed effects or random effects; we performed different tests. The fixed effects are meant to explain whether the "*different intercept terms for each entity and again these intercepts are constant over time, with the relationships between the explanatory and explained variables assumed to be the same both cross-sectionally and temporally"* (Brooks, 2008). In other words, if there are specific assumptions about the independent variable and the error distribution for the variable (Kreft & Leeuw, 1998).

In the case of random effects, the effects aim to infer beyond the particular values of the independent variable. Hence there is no need to establish precise assumptions on the variables (Kreft & Leeuw, 1998). Our model seeks to understand the relationship between the IDI index and Labor Productivity, beyond the country or the specific year where the information was collected. However, the effects the model requires can only be confirmed with a set of tests on the data.

We have four options to determine the use of random or fixed effects in the dimensions of the model: fixed- fixed, random-fixed, fixed-random, and random-random. For this, first we run the regression with fixed effects in both dimensions and perform the redundant fixed effects model- 'Likelihood Ratio' to check if indeed there is heterogeneity in both dimensions. The outcome of these tests indicated that we must take care of this. Secondly, we run the different options stated before, the corresponding Hausman's test for each specification. The null hypothesis (random effects) (Torre-Reyna, 2007) was not rejected; therefore, we can conclude that the correct specification is random effects in both dimensions.

The results of a regression provide a regression coefficient for each variable, which represents the average change in the dependent variable, for one unit **(1)** change in the independent variable when all the other variables remain constant. The idea is then to change the value of one of the independent variables, without changing the value of any other variable except for the dependent one.

4.4. Data Collection Method

The theoretical data was collected for the study with relevant literature expressed in the previous chapter. The literature and publications studied are secondary, meaning that the data is collected from another data source with another purpose than this study. This allowed the authors to have a broader understanding of labor productivity, and the several variables that could explain significant changes for it (Bryman & Bell, 2011).

In order to focus our thesis, we delimit our sample to include all the 28 European Union countries, the observations (**224**) comprehend a period from 2010 to 2017.

The Panel Data Model used in this study relies on the use of five variables: dependent, independent, and five control variables that will be explained below. Data were collected from several sources to develop the econometric model. Moreover, the model intended to explain the dependent variable and its relationship with the independent one, regarding the 28 nations within the European Union for seven years.

4.4.1. Dependent Variable

Labor Productivity

The primary source used to collect the data for labor productivity was Eurostat. This organization is the statistical office of the European Union, and its mission is to provide high-quality statistic for Europe (Eurostat, 2019).

The data is given as a 'real labor productivity per person employed – annual data' taking as base 100 the information for the year 2010 to all the countries of the European Union. The ratio is constructed from the information of the GDP divided by the total employment in all the industries, denoted in a number of persons. In this indicator is important to bear in mind that the total of persons employed do not make a distinction between part-time and full-time employment.

According to Eurostat, the input data is obtained through the transmission of the official national accounts of each country to the ESA 2010 - transmission program.

The GDP is defined in the metadata of this database as the final result of the production activity of resident producer units considering the Output (production), Expenditure, and Income. In terms of employment, the information considers all the persons engaged in some productive activity represented in direct employ or self-employment (Eurostat metada, 2018).

4.4.2. Independent Variable

ICT Development Index

The Information and Communication Technology (ICT) Development Index is an index compiled by the International Telecommunication Union (2019) which is a United Nations specialized agency. Each year, since 2009, the ITU releases an annual report benchmarking the measure of the information society. This report is a quantitative analysis that intends to explain the current and emerging trends and how countries are addressing them.

The IDI is calculated through the sum weighted of the three sub-indices value:

- ICT access is measured by fixed-telephone subscriptions per 100 inhabitants, mobile-cellular subscriptions per 100 inhabitants, international Internet bandwidth per Internet user, the percentage of households with a computer and the percentage of households with Internet access.
- ICT usage is measured by the percentage of individuals using the Internet, fixed-broadband Internet subscriptions per 100 inhabitants, and active mobile-broadband subscriptions per 100 inhabitants.
- ICT skills are approximated by mean years of schooling, secondary gross enrolment ratio, and tertiary gross enrolment ratio.

Each sub-index is normalized to obtain the same unit of measurement and the computation of the final result was the result of a weight of 40 percent to access, and usage and 20 percent to skills due to the proxy value of this sub-index.

To confirm the validity of the result, the index had several sensitivity analyses, where the combination of methods and techniques were considered in order to validate the robustness of the results. The values changed, but the message remains consistent, proving the accuracy on the construction of the index.

Some limitations on this index are reflected in the relative position of the countries included in the top performing countries, with "high" classification. The sensibility analysis changed the ranking on the top but not at the bottom (International Telecommunications Union, 2017).

Moreover, the Econometrics and Applied Statistics Unit of the European Commission's Joint Research Centre (JRC) assessed the IDI. This intending to safeguard that the IDI index is a statistically credible, legitimate tool and transparent for improve policy-making. "*The IDI has a very high statistical reliability of .96 and captures the single latent phenomenon underlying the three main dimensions of the IDI conceptual framework*" (International Telecommunications Union, 2017).

4.4.3. Control Variables

Rule of law

The Rule of law index captures the perception of the general public in terms of authority and influence of law in the general society (The World Justice Project, 2019). According to the World Justice Project (2019), the effective rule of law can show a decrease in corruption, fight poverty and disease, and explain the reliability in the justice system.

The index measures the perception of the law in eight different dimensions like Constrain in Government Powers, Absence of Corruption, Open government, Fundamental Rights, Order and Security, Regulatory Enforcement, Civil Justice and Criminal Justice, disaggregating the index in 44 sub-factors

The collection of the primary data was developed through a set of surveys that were answer by 300 hundred potential local experts per country and a General Population Poll, and this last one includes 127 questions based on perception and 213 questions based on experience. For each country the sample was of 1,000 people, adjusting the sample in those countries with a smaller population. The polls were conducted face-to-face, telephone, or online. To ensure the validity of the data, a cross-check review was performed against quantitative and qualitative third-party sources (The World Justice Project, 2019).

The measure of the indicator gives a score between -2.5 and 2.5 with an annual periodicity. The data was collected from the Worldwide Governance Indicators from the period 2010 to 2017 collected and organized by the database of the World Bank (Kaufmann, et al., 2010).

Foreign Direct Investment

The Foreign Direct Investment is a measure that intents to acknowledge the inflows and outflows of the direct investment of the economy of a nation. Several authors (Liu, et al., 2000) (Haskel, et al., 2007) have found that Foreign Direct

Investment has spillovers in the companies productivity. Therefore this became a control variable for our model.

The flows considered in this database include Equity capital, reinvested earnings, debt instruments, and balance of payments that are consistent with the components of national accounts statistics. Data are expressed as a percentage of the GDP. The data were collected from the Eurostat database (Eurostat, 2019).

Education Government Expenditure and Education Years of Schooling

The data-set collected for this variable is from the United Nations' UNESCO Institute for Statistics (UIS). The data on education expenditure is received from each country's government as a response to a survey on formal education. The expression of the expenditure of education comes as a percentage of the GDP. UIS (2019) takes the information for GDP from the World Bank in order to establish the ratios. The construction of the ratio helps to compare the expenses in education between countries over time without any distortion related to the size of the economy.

It is important to acknowledge that for some countries the households and/or the private sector may fund a higher proportion of total funding on education, which will lead to a lower government expenditure reported in the indicators, this is an important topic to bear in mind when comparisons among countries could be made (Unesco Institute for Statistics, 2019).

About the mean years of schooling, the data were extracted from the United Nations Development Programme. The Human Development report provides a set of statistics and indicators for several indexes that the entity is monitoring. Their sources for providing the data on education were UNESCO Institute for Statistics (2018), Barro and Lee (2016), ICF Macro Demographic and Health Surveys, UNICEF Multiple Indicator Cluster Surveys (2018) and OECD (2017).

Inflation

Inflation is a measure that intends to capture the annual percentage change in the cost of acquisition of an average basket of goods and services. This price index aims to explain the loose or gain in the acquisitive power of an individual during a period of time. Some studies have concluded that inflation might have a negative effect on productivity (Tang, 2014).

For this model, the data set was collected from the World Bank Datacenter, whose source are International Monetary Fund and the International Financial Statistics and data files (The World Bank, 2019), with an annual periodicity and median aggregation method.

4.5. Validity and Reliability

Quantitative Research is a term that involves a variety of approaches, sharing common factors. Researchers in this area are not interested in peoples experience, beliefs, and meaning from the perspective of people but in causal laws. Therefore, the methods used are more objective, and a study is possible to replicate since it involves public data.

We are aware that Validity and Reliability set the criteria in establishing and evaluating the overall quality of a study (Bryman & Bell, 2011) and are of utmost importance, although these two terms seem to have similar definitions, they are quite different especially from the Quantitative and Qualitative Perspectives.

In a Quantitative Perspective Reliability "*refers to the consistency of a measure of a concept*" (Bryman & Bell, 2011, p. 158) but in the bottom line the aim is to make sure the outcomes does not fluctuate when attempting to make other studies using the same data, since the data will be consistent and therefore also the measures. Replication is highly valued by several business researchers (Bryman & Bell, 2011) and the reliability of the data offers the possibility to replicate the study. To be aligned with the above we focus on getting data from trustworthy sources as:

- Eurostat (2019) this organization is the statistical office of the European Union for the Labor Productivity and FDI
- International Telecommunication Union (2019) which is a United Nations specialized agency for the IDI
- World Bank (Kaufmann, et al., 2010) for Rule of Law and Inflation

- United Nations' UNESCO Institute for Statistics (2019) for Education Government Expenditure and Education Years of Schooling

Bryman & Bell (2011) describe Validity as the research most important criterion, due to the fact that it is crucial for having integrity in the conclusions generated from research. For this study measurement validity criterion, also known as construct validity, was central since we were looking for measurements that were reflecting the concept that is supposed to be denoting. One of the most common issues while doing a Quantitative Study is the one regarding the mismeasurement of the variables, to overcome these control variables highly related to the topic and theory were used.

We should always bear in mind that although validity and reliability are analytically different, they are related because *"validity presumes reliability"* (Bryman & Bell, 2011, p. 161)

5. Econometric Model

5.1. Panel Data Results

As it was mentioned in section 4.2 a Panel Data regression is conducted. We accounted for the heterogeneity with the specification random-random effects, using balanced, dated, and regular data-sets for the 28 European Union Countries. Below the results of our model can be found in Table 3:

Table 3 Panel Data Results

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	84.56516	10.73417	7.878131	0.0000
IDI	2.746499	0.931327	2.949016	0.0035
RULE_OF_LAW	-0.981235	1.543243	-0.635826	0.5256
FDI_GDP	0.010308	0.010383	0.992850	0.3219
EDUCATION_YEARS_OF_SCHOOLING	2.012708	0.814425	2.471322	0.0142
EDUCATION__GOVERNMENT_EXPENDI...	-4.368034	1.196739	-3.649948	0.0003
INFLATION	-0.170709	0.299025	-0.570888	0.5687

Weighted Statistics			
R-squared	0.357022	Mean dependent var	28.36508
Adjusted R-squared	0.339244	S.D. dependent var	4.968020
S.E. of regression	4.038350	Sum squared resid	3538.895
F-statistic	20.08203	Durbin-Watson stat	0.433963
Prob(F-statistic)	0.000000		

The coefficient of our independent variable turned out to be 2,746499 significant at any confidence level, as the p-value is lower than 1%. This value means that in average an increase of one unit in the IDI would increase the productivity in 2,746499 units (ceteris paribus), according to the data sample.

Additionally, it reveals that the Rule of Law, FDI, and inflation variables are not significant for our model since the p-value is larger than 0,10. These variables are considered as the control variables and are not a central issue of discussion of this research.

Moreover, as it was previously mentioned in the Data Analysis section, the purpose of regression analysis is to corroborate and measure the causality between the independent variables with the dependent variable 'Labor Productivity'. In the results provided in *Table 3*, the statistical relevance of the IDI Index can be seen with the R-Squared[1] and the Adjusted R-Squared.

The model's R-squared is of 0.357022, in statistics this indicates the percentage of the variance in the dependent variable that the independent variables explain collectively. The value of this result is between 0 and 1, where zero denotes that the dependent variable is not explained at all by the independent variables, and the one indicates that the independent variables that were considered explain perfectly the dependent variable.

In our case, although the 0.357022 seems low, the fact that the probability of occurrence is statistically relevant validates the relationship that exists between the Index of ICT Development and Labor Productivity. A positive influence can be seen, and the regression model confirms it.

Several Statisticians state that low coefficient regressions could be normal depending on the type of model that is intended to be explained. In term of human behavior and social science, high R-squared coefficients are not expected because the variables cannot explain some behaviors.

In *Table 3* we can see that the F-statistic is 20,08203 and significant at any significance level. This statistic tests the relevance of all the independent variables at the same time, it means that checks the significance of the estimators (from B0 to B5) at the same time. As we have a large enough t-statistic, we can say that all our variables together explain our dependent variable.

In *Table 4* we observe a description of the statistics used in the analysis (maximum, minimum, median, average, and standard deviation). These descriptive statistics help to understand the common dispersion of the values of the data. In *Table 4* is possible to observe that the median and average of the

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[1] R squared defined as "standardized measure, bounded between Zero and One, of how well a sample regression model fit the data" (Brooks, 2008). It is important not to confuse this measure with Coefficient of variation or Coefficient of correlation.

variables have close values. These are the features of a Gaussian distribution. Therefore, we might assume that the variables in our model are normally distributed.

Table 4 Statistical description of variables in the model

Variables	Mean	Median	Standard Deviation	Minimum	Maximum
Labour Productivity	104,22	102,20	6,87	94,00	141,50
IDI	7,23	7,16	0,86	4,99	8,88
Rule of Law	1,05	1,11	0,79	- 1,90	2,10
FDI/GDP	8,80	2,40	26,14	-43,50	252,30
Education (Government Expenditure)	5,18	5,20	0,99	2,80	7,10
Education Years of Schooling	11,73	12,00	1,10	8,10	14,10
Inflation	1,40	1,29	1,52	- 2,10	6,09

In order to assure the reliability of the model, and therefore, the results, several tests were needed among them, which will be described below:

- Multicollinearity
- Normality
- Breusch –Pagan- Godfrey for Heteroscedasticity

Multicollinearity

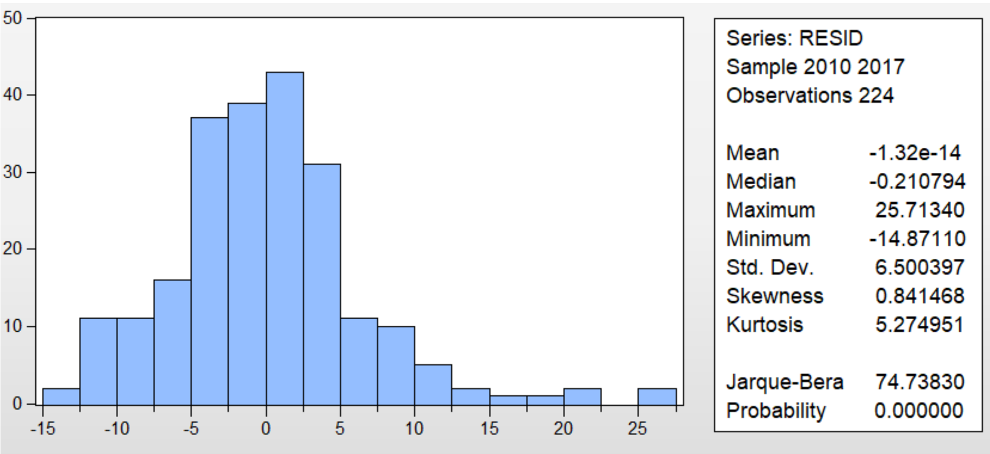
When talking about *multicollinearity*, the purpose is to identify the direct relationship between the independent variables of the model (Brooks, 2008). If the model presents *multicollinearity*, there would not be a real *ceteris paribus* at the regression coefficient, meaning that the independent variables will be related to each other. Therefore, the model will not be accurate because it cannot capture the real effect on the dependent variable. In our results *Table 5*, no correlation larger than 0,8 or smaller than -0,8 was found, so as a Rule of Thumb (i.e., a rough guide) no correlation was found among the independent variables (Investopedia, 2018).

Table 5 Correlation among independent variables

Correlation	IDI	Rule of Law	FDI/ GDP	Education (Gov. Expend.)	Years of Schooling	Inflation
IDI	1					
Rule of Law	0,674	1				
FDI/GDP	0,04	0,139	1			
Education (Government Expenditure)	0,321	0,399	0,042	1		
Years of Schooling	0,408	0,287	-0,016	0,213	1	
Inflation	-0,283	-0,017	0,041	0,061	-0,03	1

Normality

The data was also tested in terms of normality of the errors. Although the result of the normality test is rejected (with a p-value of 0,0000) by the Central Limit Theorem[2], we can assume that our data have a normal distribution, since the number of observations is 224.



[2] Central Limit Theorem refers to the theorem that states that any random phenomenon, being a consequence of a large number of small, independent causes, is described by a Gaussian distribution (Normal Distribution) (Voit, 2005, p. 124)

Breusch –Pagan- Godfrey

One of the final tests made was the one regarding 'Heteroscedasticity' of the model. Baltagi (2005) "*establishes that the regression disturbance of the standard error is homoscedastic with the same variance across time and individuals*" this means that is expected that variance of the data remains uniform along with the sample. When checking for heteroscedasticity, we performed a 'Breusch –Pagan-Godfrey' test manually, running the square residuals of the pooled regression against our independent variables. The result of this makes us not able to reject the Hypothesis of Homoscedasticity. To account for this, we should run our regression with 'White's diagonal', because we have an effect in both dimensions due to Random-Random effects.

6. Analysis and Discussion

In the Correlation Matrix presented in *Table 6*, it can observe that there is no significant correlation among the variables of the study. However, we do not rely on the information of the correlation, but rather in the Panel Data Analysis, that remarks a causal relationship among IDI and Labor Productivity for the studied period (2010-2017).

Table 6 Correlation Matrix

Correlation Probability	LABOUR_P...	IDI	RULE_OF_L...	FDI_GDP	EDUCATION...	EDUCATION...	INFLATION
LABOUR_PRODU...	1.000000 -----						
IDI	-0.040503 0.5465	1.000000 -----					
RULE_OF_LAW	-0.206738 0.0019	0.674121 0.0000	1.000000 -----				
FDI_GDP	-0.020407 0.7613	0.039955 0.5519	0.139080 0.0375	1.000000 -----			
EDUCATION_YEA...	0.166620 0.0125	0.407749 0.0000	0.286978 0.0000	-0.016402 0.8071	1.000000 -----		
EDUCATION_GOV...	-0.363406 0.0000	0.320646 0.0000	0.398831 0.0000	0.041731 0.5344	0.212926 0.0013	1.000000 -----	
INFLATION	-0.181760 0.0064	-0.283004 0.0000	-0.017452 0.7951	0.040755 0.5440	-0.032575 0.6277	0.060756 0.3654	1.000000 -----

The results obtained from the Panel Data Analysis are presented in *Table 3*. Analysis and discussion of Labor Productivity and IDI will be the central focus of this chapter. Moreover, an overall explanation of the control variables will be presented.

This chapter will focus on the interpretation of the Panel Data Results that that can be found below, and that is the same as the ones presented in *Table 3*:

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	84.56516	10.73417	7.878131	0.0000
IDI	2.746499	0.931327	2.949016	0.0035
RULE_OF_LAW	-0.981235	1.543243	-0.635826	0.5256
FDI_GDP	0.010308	0.010383	0.992850	0.3219
EDUCATION_YEARS_OF_SCHOOLING	2.012708	0.814425	2.471322	0.0142
EDUCATION__GOVERNMENT_EXPENDI...	-4.368034	1.196739	-3.649948	0.0003
INFLATION	-0.170709	0.299025	-0.570888	0.5687

Weighted Statistics			
R-squared	0.357022	Mean dependent var	28.36508
Adjusted R-squared	0.339244	S.D. dependent var	4.968020
S.E. of regression	4.038350	Sum squared resid	3538.895
F-statistic	20.08203	Durbin-Watson stat	0.433963
Prob(F-statistic)	0.000000		

6.1. Hypothesis Result

The hypothesis stated previously in the Methodology chapter was the following:

H1- There is a relationship between IDI and labor productivity

The statement was tested and analyzed through a model of Panel Data Analysis. The results described and explained in the previous section, lead us not to reject the hypothesis and therefore confirm a positive causal relationship. Moreover, and after the different analysis is done, it possible to state that the IDI influences the indicator of *Labor productivity.*

6.2. Labor Productivity and ICT Development Index

ICT Development Index shows a significant relevance of **1%** in our model, showing a 2,746499 coefficient of relationship with Labor Productivity.

The way this could be understood is that for each unit that the IDI increase, there will also be an increase of 2.74 USD in the indicator of Labor Productivity (expressed in USD per person employed).

For example, if we take Estonia's IDI index for 2017 and we are expecting a growth of one unit in the index (going from 8.14 to 9.14), the increase in labor productivity expressed in USD per person employed at prices of 2010, will be expected to change from $111.20 to $113.94.

Now well, it is important to take into account that in order to achieve a change of one unit on the IDI index requires the interaction of several factors overall. It will be necessary to achieve a higher value on the infrastructure, this means, increasing the connectivity of the country to almost all the citizens, not only in computers but in bandwidth access and speed. Moreover, the complementarity of skills and use of the ICT tools will have to increase significantly in order to achieve a unit of growth in the index.

On the other hand, it is likely that the investments and increase in the several factors of ICT might not have an immediate impact on Labor Productivity. Our research claims that a causal relationship exists among those two variables, and a change in one will affect the other. However, the model is not designed to evaluate the immediate effect on ICT.

After we ran the model presented to test our hypothesis, it is possible to identify that although there is a causal relationship between the IDI and Labor Productivity, several other variables might interfere on the changes of productivity.

Some comments can be made regarding the variables used. Firstly, for our model and data-sets evaluated, the control variables Rule of Law, Foreign Direct Investment and Inflation are not statistically relevant.

In that case, the variable expected to have a positive and relevant influence on Labor Productivity was FDI and Rule of Law. According to Alcalá and Ciccone (2004), this two variables represent a positive effect on productivity due to institutional quality that promotes the Investment, and therefore, some spillovers product of the FDI effect (Jorgenson & Stiroh, 2000).

In our particular case and under this statement, the authors are aware that the model does not capture the entire dynamic of economic growth, employment and productivity, however, the variables were carefully chosen in order to capture the different inputs and isolate the effect of the value of the index on labor productivity. For example, Irish's economy high value on its Labor Productivity, cannot be easily measured and generalized for the entire sample.

Findings in previous studies performed by Leeuwen and van der Wiel (2003), Armstrong et al. (2002) and (Dahl, et al., 2011) indicate that ICT capital appears to be the most important source of productivity growth.

However, these findings may only measure the ICT infrastructure and not the evolution of the complexity around the ICT (like skills and use dimensions) captured in the IDI. Hence, the motivation to develop the analysis of productivity through this index is becoming relevant.

In *Figure 8*, the progress of labor productivity and IDI is shown as an average of the 28 EU economies from 2010 to 2017. This comparison is as a way to illustrate how these two variables (labor productivity and IDI) are evolving.

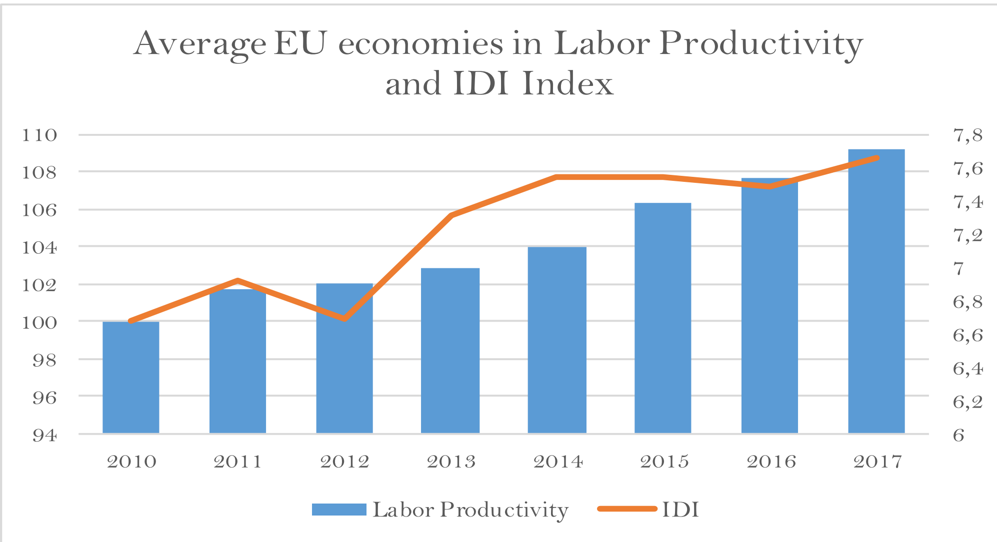


Figure 8 Labor productivity and IDI in European Union Economies

Moreover, as we can see in *Figure 8* and in the Panel Data results both are showing a causal relationship among them.

We acknowledge that the IDI is not the only factor that could explain changes in labor productivity, but we do find that the IDI is statistically relevant. Therefore, any policy that is develop in connection with the *Information and Communication Technologies* is likely to have an impact in the labor productivity; of course, it will depend also in other particular aspects of each economy, and the repercussion could be lower or higher depending on other conditions.

In order to understand the effect in the 28 economies of the European Union and based on the classification made by Mačiulytė-Šniukienė & Gaile-Sarkan *Table 7* (2014), we evaluate the impact of the IDI index according to the classification of labor productivity previously mentioned.

Table 7 Classification of countries according to Labor Productivity. (Mačiulytė-Šniukienė & Gaile-Sarkan, 2014)

High productivity countries cluster	Luxembourg	Austria	Finland	Germany
	Ireland	Sweden	Italy	
	Belgium	Netherlands	Spain	
	France	Denmark	United Kingdom	
Medium productivity countries cluster	Greece	Cyprus	Slovakia	Portugal
	Malta	Hungary	Slovenia	Croacia
Low productivity countries cluster	Czech R.	Estonia	Poland	Lithuania
	Latvia	Romania	Bulgaria	

Figure 9, shows the graphs describing the relationship between Labor productivity and the IDI index following the classification of the countries shown in *Table 7* where labor productivity and IDI is shown as an average of the countries in the cluster from 2010 to 2017.

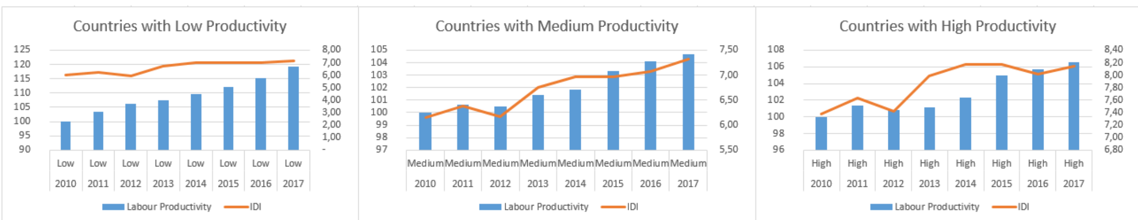


Figure 9 Labor Productivity and IDI index evolution

As can be seen, the graphs confirm the relationship between labor productivity and IDI Index, seen previously in the regression's results.

- Even in Low productivity countries, the IDI Index keeps a low variation during the period studied, providing a positive outcome in terms of labor productivity with an average of 119 in 2017. An overall observation of this results denotes a direct relationship among the two variables, however, with the low productivity countries the evolution of the IDI index is constant, whereas the productivity increase in a positive way.
- For the medium countries, we see a constant growth that is behaving in a similar way between Labor productivity and IDI index. Although it is important to mention that the average Labor productivity for these countries was only 105 for 2017, in contrast with the countries with low productivity.
- Finally, the high productivity countries denote a laggard within the IDI Index and the Labor Productivity growth, as it can be seen in *Figure 9* and *Annex A* in more detail. The pike of IDI Index is not showing an immediate growth of Labor Productivity until a few years later.

In order to understand better the causal relationship of the clusters mentioned above, the panel data analysis was run with the same model proposed in equation **(2)**.

The results of each regression found in *Annex C*, are aligned with the main result in the sense that IDI is statistically relevant with a positive causal relationship. However, it is interesting to observe how the coefficients of the IDI vary for the three cases.

The main conclusion drawn from these results is that for the countries of Low Labor productivity the impact of improving skills, usage, access, and infrastructure is higher, which means that by achieving a further development in technologies, the labor productivity could increase in 5,19 USD when the IDI grow one unit.

Returning to the example of Estonia, a country that was classified in *Table 7* among those with Low Productivity, we could see that the evolution of its IDI in the past eight years has reflected a remarkable increase of its Labor Productivity.

The authors observed that thanks to the development of policies that helped embraced technology, like the implementation of infrastructure, training, and use (Schulze, 2019), the impact in the Labor Productivity was higher. A compelling case of how policies trigger a Digital Society and encourage companies to embrace Digital Transformation.

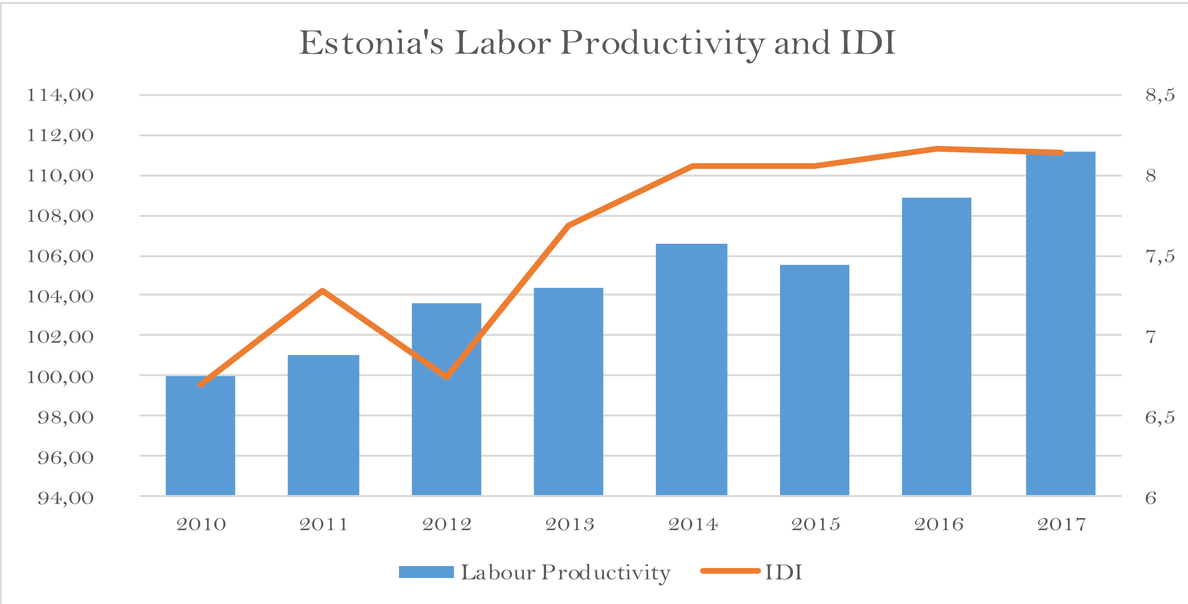


Figure 10 Estonia´s Labor Productivity and IDI

Several authors (Brynjolfsson, 1993), (Stiroh, 2005), (Jorgenson, et al., 2008), (Jorgenson, 2001), (Jorgenson, et al., 2006) have measured the impact of technology in labor productivity. However these studies have followed different ranges on the definition of technology, starting from expenditure in Information Technology (Solow, 1987), to several components of ICT (expenditure, infrastructure, uses, production, trade), showing diverse results (Mačiulytė-Šniukienė & Gaile-Sarkan, 2014).

Some authors concluded that there was no connection between technology and productivity giving place to talk about the Productivity Paradox, but other results have shown a relationship between this two variables supporting the findings where technology, influence the labor productivity and help economies grow.

In this aspect, the task of transforming the European economy into a more productive one is a challenging one when comparing the economies of the EU against the United States, primarily until 1995, where a gap on productivity was evident (Miller & Atkinson, 2014).

The success story of the United States and the increase of their productivity thanks to their investments and spillovers of ICT capital has been studied by several authors (Jorgenson & Stiroh, 2000) (Jorgenson, et al., 2008) and the evidence shows that ICT is one of the key elements that lead the growth on economy.

Consequently, the relevance of ICT and its implementation matters not only to governments and the development of policies, but remarks of these findings could be translated into companies.

When a firm set its strategies, it is important to identify and understand the trends of the market and the industry, to produce a good or provide a service. The development of competitive advantages brings value to the bottom line. Moreover, the way companies choose to adapt to changes will be relevant to maintain these advantages.

In the case of technology, the adoption of Digital Transformation is fundamental to sustain competences among the industry, but this can only be done by understanding the stage of maturity and the core elements on which companies must focus their efforts.

By acknowledging the relationship between IDI and Labor Productivity, we r too, the importance of the elements of the IDI in a more 'simplistic' way. Furthermore, as Porter mentioned, the development of competitive advantages of a nation is directly related to the performance of the firms (strategy). Hence, the result of a country's advantages is the sum up of the competitive advantages of firms.

Under this analysis, it is possible to adapt three elements of IDI within the company's activity:

IDI	Company
Access	Infrastructure
Use	Adoption
Skills	**Capabilities

When companies search to diagnose their stage of technology involvement, it could be a good approach to measure and benchmark their productivity in comparison with the industry.

Considering our previous findings, and division of countries into Low, Medium and High Labor Productivity, a similar proxy could be done at an industry level, with the purpose of understanding, perhaps, how investments in technology topics, could affect the company.

In this scenario, a company with low productivity could consider more in-depth involvement in Digital Transformation, by acknowledging that the improvement in productivity will be higher and the return of the investment could be achieved in a shorter time. Nonetheless, it is important to keep in mind that this adoption has to be framed in long-term plans, and they should bear in mind that the outcomes of these investments will present laggards.

In the case of a company considered in the high end, the adoption of Digital Transformation could follow a different pace. Despite the need to adopt changes, this could relate to diffusion of knowledge and adoption of alternative tools, rather than the development of entire infrastructure to overcome new trends.

Digital Transformation is a topic to consider individually and under different frameworks which are not exposed in this thesis. However, the overall findings of the research regarding the causal relationship among Labor Productivity and IDI (technology) aim to motivate companies to engage in the digital economy.

6.3. Applicability of Results

The discussion around competitive advantages can be taken from different edges, but productivity is one of the central indicators to understand how different economies compete in the market. The efficiency on which each country is capable of producing a good or providing a service is essential to the growth of nations.

The boom of new technologies and the emerging of new business models supported in the Internet and Digital Economy seems to be fundamental to the development of the countries. The success of the economies will be measured in the capacity of adoption and adaptation of ICT and the development of the right capabilities.

IDI is an index that is used for policy adjustments to the growth of a nation ICT sector as well as their country competitiveness. In this sense, by evaluating the impact at a macro-perspective, policy-makers can address better strategies that help to deploy effectively the different components of the ICT, not only in terms of price but also in need and of course the knowledge implicit in the usage of the new technologies.

Policy-makers then, need to develop policies that allow the growth of competitiveness in ICT matters like access (infrastructure), use and skills, allowing and promoting the adaptation of citizens and firms to the Digital Economy.

However, this analysis can be scaled-up to a managerial perspective. Transferring this result, where the IDI is relevant, and breaking it down to the creation and development of competitive advantages, focusing on the development of capabilities that can develop the ICT. Hence, the adoption of new technologies in the core business of firms that seek to be part of the Digital Economy.

Some of the principal remarks of the analysis and the objective of design this model from the IDI, is the inclusion of capabilities to use the current infrastructure, and in that line, to create knowledge that makes possible to evolve the current ICT. This is part of the challenges of Digital Transformation, and by understanding this, companies will focus their activities not only into prepare the needed software and hardware to face transformation but will keep in mind the relevance on creating technical and managerial skills to face the future.

7. Conclusion

Globalization has intensified competition, and Nations role is vital for the generation of competitive advantages since the home base is where the strategy takes place, core products and processes are developed and most importantly is where the skills reside (Porter, 1990). Hence, *"Government Policy at the state and local level has an important role to play in shaping national advantage"* (Porter, 1990).

Digital Transformation should not only be considered as a trend but as a way to generate Competitive Advantages. The development of the right capabilities will allow the transition into a Digital Economy, a relevant topic nowadays thanks to the relevance of connectivity and enhancement on communication since the internet and information are leading the change of current business models and economy.

This research aimed to make a more holistic approach to ICTs where *a causal relationship* was found between IDI and Labor Productivity, involving not only the monetary aspects of development in technology but also taking into account other factors like accessibility, skills, and use. A technological approach should be considered not only in terms of infrastructure but also in developing the necessary capabilities that will allow nations to stay competitive, leading to improve their productivity. Since IDI considers accessibility, skills, and use, a more robust comparison between the variables (dependent and independent) was run through a Panel Data Analysis.

Our findings are aligned with previous researchers (Dedrick, et al., 2003), (Stiroh, 2005) (Draca, et al., 2006) (Karabou & Adeve, 2018) acknowledging the existence of a relationship between technology and productivity. Hence, implying that the Productivity Paradox is no longer applicable.

The results observed in the Panel Data at a macro level perspective with data from the European Union Economies seeks to influence firms, making them realize the importance of the ICTs and capabilities as a source of productivity.

As it can be observed, deployment of capabilities become strategical to achieve better outcomes and keep resilient to constant changes in the economy. This applying not only at a macro level, with the inclusion of policies that enhance the appropriated environment to take advantages of the benefits of technology, but also at a micro-level with companies aiming to keep up with the new trends.

This productivity and the impact of ICTs could be measured not only at a national level but also within firms, leading the path to a Digital Transformation and adoption of a Digital Economy.

In terms of measurement, we are aware that this IDI index might be excluding some factors and could be susceptible to measurement errors. However, this index is more complete since it includes more factors than other measures. For us, the inclusion of capabilities is fundamental to create a relevant differentiation from others, and this helps to develop a more complex a robust database use in our econometric model.

We found that beyond the causal relationship among IDI and Labor productivity, from the strategical management point of view, focus on the development of capabilities and skills should be taken into account when designing strategies. The results at a macro level denote the relevance of the topic that companies should embrace.

7.1. Future Research

The fact that technology and information technologies are becoming so relevant and showing effects on labor productivity and impacting other spheres of the economy might be the door that opens the discussion of ICT as a General Purpose Technology (GPT).

GPT defined as "a new method of producing and inventing that is important enough to have a protracted aggregate impact (…) that transform both household life and the ways in which firms conduct business" (Jovanovic & Rousseau, 2005).

References

Ahmad, N. & Ribarsky, J., 2018. *Towards a Framework for Measuring the Digital Economy*. Paris, s.n.

Alcalá, F. & Ciccone, A., 2004. Trade and Productivity. *The Quarterly Journal of Economics*, 119(2), pp. 613-646.

Aldrich, J., 2004. The Discovery of Comparative Advantage. *Journal of the History of Economic Thought*, 26(3), pp. 379 - 399.

Arellano, M., 2004. *Panel Data Econometrics. Advanced Texts in Econometrics.* First Edition ed. New York: Oxford University Press.

Ark, B. v. & McGuckin, R. H., 1999. International comparisons of labor productivity and per capita income. *Monthly Labor Review*, Volume 122, pp. 32-41.

Armstrong, P., Harchaoui, T., jackson, C. & Tarkhani, F., 2002. *A Comparison of Canada-U.S. Economic Growth in the Information Age,1981-2000: The Importance of Investment in Information and Communication Technologies*, Ottawa: Analytical Studies Branch Statistics Canada.

Ashmarina, S., Mesquita, A. & Vochozka, M., 2019. *Digital Transformation of the Economy: Challenges, Trends and New Opportunities*. First ed. Switzerland: Springer Nature Switzerland AG.

Attewell, P., 1994. Information Technology and the Productivity Paradox. In: D. H.Harris, ed. *Organizational Linkages: Understanding the Productivity Paradox*. Washington, D.C.: National Academies Press, pp. 13-53.

Baily, M. N., 2002. Distinguished Lecture on Economics in Government: The New Economy: Post Mortem or Second Wind?. *The Journal of Economic Perspectives*, 16(2), pp. 3-22.

Baltagi, B. H., 2005. *Econometric Analysis of Panel Data*. Third ed. Chippenham: John Wiley & Sons Ltd.

Barney, J., 1991. Firm Resources and Sustained Competitive Advantage. *Journal of Management*, 17(1), pp. 99-120.

Barro, R. & Lee, J., 2016. *Data set on Educational Attainment.* [Online] Available at: www.barrolee.com [Accessed 8 June 2018].

Barua, A., Kriebel, C. H. & Mukhopadhyay, T., 1995. Information Technologies and Business Value: An Analytic and Empirical Investigation. *Information Systems Research*, 6(1), pp. 3-23.

Belabbes, I., El Moustafid, S. & Oubrich, M., 2015. *ICT Development Index (IDI) as a statistical tool for measuring ICT uptake and assessing ICT policy: Morocco case.* At Saïdia, Mediterranean Conference on Information & Communication Technologies 2015.

Berman, S. J., 2012. Digital transformation: opportunities to create new business models. *Strategy & Leadership*, 40(2), pp. 12-24.

Berman, S. & Marshal, A., 2014. The next digital transformation: from an individual-centered to an everyone-to-everyone economy. *Strategy and Leadership*, 42(5), pp. 9-17.

Berndt, E. & Morrison, C. J., 1995. High-tech capital formation and economic performance in U.S. manufacturing industries. An exploratory analysis. *Journal of Econometrics*, 65(1), pp. 9-43.

Bharadwaj, A. E. S. O. A., Pavlov, P. A. & Venkatraman, N., 2013. Digital Business Strategy: Toward a Next Generation of Insights. *MIS Quarterly*, 37(2), pp. 471-482.

Bharadwaj, A., Sambamurthy, V. & Zmud, R., 1999. IT Capabilities: Theoretical Perspectivse and Empirical Operationalization. *International Conference on Information Systems (ICIS)*, Volume 35, pp. 378-385.

Bharadwaj, A. S., Bharadwaj, S. G. & Konsynski, B. R., 1999. information technology Effects on Firm Performance as MEasured by Tobin's q. *Management Science*, 45(6), pp. 1008-1024.

Biørn, E., 2016. *Econometrics of Panel Data. Methods and Applications.* First ed. Oxford: Oxford University Press.

Boddy, R. & Smith, G., 2009. *Statistical Methos in Practice for scientists and technologists.* 1st ed. Chcichester U.K.: U.K. Wiley .

Bondarenko, P., 2019. *Absolute advantage.* [Online] Available at: https://www.britannica.com/topic/absolute-advantage [Accessed 03 May 2019].

Brooks, C., 2008. *Introductory Econometrics for Finance.* 2nd ed. Cambridge: Cambridge University Press.

Bryman, A. & Bell, E., 2011. *Business Reasearch Methods.* 3rd ed. New York: Oxford University Press Inc.

Brynjolfsson, E., 1993. The Productivity Paradox of Information Technology. *Communication of the ACM*, 36(12), pp. 67-77.

Brynjolfsson, E. & Hitt, L., 1995. Information Technology as a Factor of Production: The Role of Differences Among Firms. *Economics of Innovation and New Technology*, Volume 3, pp. 183-200.

Brynjolfsson, E. & Hitt, L. M., 1998. Beyond the productivity paradox. *Communications of the ACM* , 41(8), pp. 49-55.

Brynjolfsson, E. & Hitt, L. M., 2000. Beyond Computation: Information Technology, Organizational Transformation and Business Performance. *Journal of Economic Perspective*, 14(4), pp. 23-48.

Brynjolfsson, E. & Kahin, B., 2002. *Understanding the Digital Economy. Data, Tools, and Research.* First Edition ed. Massachusets: The MIT Press.

Brynjolfsson, E. & McAfee, A., 2014. *The Second machine Age.* 1st ed. New York: W.W. Norton & Company.

Brynjolfsson, E. & Oh, J. H., 2012. *The Attention Economy: Measuring the Value of Free Digitl Services on the Internet*, Orlando: s.n.

Brynjolfsson, E. & Yang, S., 1996. Information Technology and Productivity: A Review of the Literature. *Advances in Computers*, Volume 43, pp. 179-214.

Callen, T., 2008. What is Gross Domestic Product. *Finance & Development*, pp. 48-50.

Campisi, D., De Nicola, A., Farhadi, M. & Mancuso, P., 2013. Dicovering the impact of ICT, FDI and Human Capital on GDP: A cross-sectional Analysis. *interantionl Journal of Engineering Business Management*, 5(46), pp. 1-10.

Cardona, M., Kretschmer, T. & Strobel, T., 2013. ICT and productivity: conclusions from the empirical literature. *Information Economies and Policy*, 25(3), pp. 109-125.

Ceccobelli, M., Mancuso, P. & Gitto, S., 2012. ICT capital and labour productivity growth: A non-parametric analysis of 14 OECD countries. *Telecommunications Policy*, 36(1), pp. 282-292.

Chakravorti, B. & Chaturvedi, R. S., 2017. *Digital Planet 2017. How Competitivness and trust in Digital Economies Vary Across The World*, s.l.: The Fletcher School, Tufts University.

Coelli, T. J., Prasada Rao, D. S., O'Donnell, C. J. & Battese, G. E., 2005. *An Introduction to effciency and productivity analysis*. 2nd ed. New York: Springer Science + Business Media.

Colecchia, A. & Schreyer, P., 2002. The ocntribuiton of informationand communication technologies to economic growth in nine OECD countries. *OECD Economic Studies*, pp. 153-171.

Creswell, J. W., 2014. *Research Design; Qualitative, Quantitave and Mixed Methods Approaches*. 4th ed. London: SAGE Publications, Inc..

Dahl, C. M., Kongsted, H. C. & Sörensen, 2011. ICT and productivity growh in the 1990s: panel data evidence on Europe. *Empirical Economics*, 40(1), pp. 141-164.

Daveri, F., 2002. The new Economy in Europe 1992-2001. *Oxford Review of Economics*, 18(3), pp. 345-362.

Day, G., 1990. *Market driven strategy: Processes for creating value.* 1st ed. New York: Free Press.

Day, G. S., 1994. The Capabilities of Market-Driven Organizations. *Journal of Marketing* , Volume 58, pp. 37-52.

Dedrick, J., Gurbaxani, V. & Kraemer, K. L., 2003. Information technology and economic performance: A critical review of the empirical evidence. *ACM Computing Surveys (CSUR)*, 35(1), pp. 1-28.

Dimelis, S. P. & Papaioannou, S. K., 2011. Technical Efficiency and the Role of ICT: A Comparison of Developed and Developing Countries. *Emerging Markets Finance and Trade*, 47(7), pp. 40-53.

Draca, M. et al., 2008. *The Economic Impact of ICT: First Interim Report*, London: Centre for Economic Performance, London School of Economics.

Draca, M., Sadun, R. & Van Reenen, J., 2006. *Productivity and ICT: A Review of the Evidence*, London: CEP Discussion Papers.

Encyclopaedia Britannica, 2019. *Comparative advantage.* [Online] Available at: https://www.britannica.com/topic/comparative-advantage [Accessed 15 May 2019].

European Comission , 2019. *Digital Transformation.* [Online] Available at: https://ec.europa.eu/growth/industry/policy/digital-transformation_en
[Accessed 11 May 2019].

European Commission, 2018. *The Digital Economy and Society Index (DESI).* [Online]
Available at: https://ec.europa.eu/digital-single-market/en/desi [Accessed 11 May 2019].

Eurostat metada, 2018. *Nominal unit labour cost.* [Online] Available at: https://ec.europa.eu/eurostat/cache/metadata/EN/tipslm10_esms.htm [Accessed 3 May 2019].

Eurostat, 2019. *Direct investment in the reporting economy (flows) - annual data, % of GDP.* [Online] Available at: https://ec.europa.eu/eurostat/tgm/table.do?tab=table&init=1&plugin=1&language=en&pcode=tipsbp90 [Accessed 7 May 2019].

Eurostat, 2019. *Eurostat Overview.* [Online] Available at: https://ec.europa.eu/eurostat/about/overview [Accessed 3 May 2019].

EViews, 2019. *User's Guide : EViews Fundamentals : Advanced Workfiles : Structuring a Workfile.* [Online] Available at: http://www.eviews.com/help/helpintro.html#page/content%2Fworkadv-Structuring_a_Workfile.html%23ww101489 [Accessed 10 May 2019].

Fortin-Rittberger, J., 2013. *The SAGE Handbook of Regression Analysis and Causal Inference.* First ed. London: SAGE Publications Ltd.

Fransman, M., 1994. technological Capability in the Third World: An Overview and Introduction to some of the Issues raised in htis Book. In: K. KIng & M. Fransman, eds. *Technological Capability in the Third World.* s.l.:Springer, pp. 3-30.

Freeman, R., 2008. *Labour Productivity Indicators: Comparisson of two OECD databases productivity differentials,* s.l.: Organization for Economic Co-Operation and Development .

Gao, Y. & Cowling, M., 2019. *Introduction to Panel Data, Multiple Regression Method, and Principal Components Analysis Using Stata: Study on the Determinants of Executive Compensation—A Behavioral Approach Using Evidence From Chinese Listed Firms,* London: SAGE Publications Ltd.

Gera, S., Gu, W. & Lee, F. C., 1999. Information Technology and Labour Productivity Growth: An Empirical Analysis for Canada and the United States. *The Canadian Journal of Economics/ Revue canadienne d'Economique* , 32(2), pp. 384-407.

Gubbia, J., Buyyab, R., Marusica, S. & Palaniswamia, M., 2013. Internet of Things (IoT): A vision, architectural elements, and future directions. *Future Generation Computer Systems*, 29(7), pp. 1645-1660.

Gutierrez, M. A., Moreno, R. A. & Rebelo, M. D. S., 2017. Chapter 3 - Information and Communication Technologies and Global Health Challenges. In: H. d. F. Marin, M. A. Gutierrez, E. Massad & R. J. Rodrigues, eds. *Global Health Informatics: How Information Technology Can Change Our Lives in a Globalized World.* s.l.:Elsevier Inc., pp. 50-93.

Haskel, J. E., Pereira, S. C. & Slaughter, M. J., 2007. Does Inward Foreign Direct Investment Boost The Productivity of Domestic Firms. *The Review of Economics and Statistics*, 89(3), pp. 482-496.

Herselman, M. & Britton, K., 2002. Anlysing the role of OCT in bridging the digital divide amongst learners. *South Africa Journal of Education*, 22(4), pp. 270-274.

Hill, T. & Westbrook, R., 1997. SWOT Analysis; It's time for a product recall. *Long Range Planning* , 30(1), pp. 46-52.

Holt, L. & Jamison, M., 2009. Broadband and contributions to economic growth: Lessons from the US experience. *Telecommunications Policy*, Volume 33, pp. 575-581.

Hsiao, C., 2007. Panel data analysis—advantages and challenges. *TEST An Official Journal of the Spanish Society of Statistics and Operations Research*, 16(1), pp. 1-22.

IDC- International Data Corporation, 2019. *Global ICT Spending*. [Online] Available at: https://www.idc.com/promo/global-ict-spending/regional-markets
[Accessed 27 May 2019].

ILO, 2015. *Labour Productivity - International Labour Organization - Key Indicators of the Labour Market.* [Online]
Available at:
http://www.ilo.org/global/topics/dw4sd/themes/productivity/lang--en/index.htm
[Accessed 3 May 2019].

IMD World Competitiveness Center, 2018. *IMD World Competitiveness Ranking 2018*, s.l.: s.n.

International Labour Organization, 2010. *A Skilled Workforce for Strong, Sustainable and Balanced Growth: A G29 Training Strategy*, Geneva: International Labour Office.

International Monetary Fund, 2018. *Gross Domestic Product: An Economy's All.* [Online]
Available at: https://www.imf.org/external/pubs/ft/fandd/basics/gdp.htm
[Accessed 10 May 2019].

International Telecommunication Union, 2019. *About International Telecommunication Union.* [Online]
Available at: https://www.itu.int/
[Accessed 1 May 2019].

International Telecommunications Union, 2017. *Measuring the Information Society Report*, Geneva: International Telecommunication Union.

Investopedia, 2018. *What does it mean if the correlation coefficient is positive, negative, or zero.* [Online]
Available at: https://www.investopedia.com/ask/answers/032515/what-does-it-mean-if-correlation-coefficient-positive-negative-or-zero.asp
[Accessed 18 May 2019].

Jalava, J. & Pohjola, M., 2007. ICT as a source of output and productivity growht in Finland. *Telecommunications Policy*, 31(8), pp. 463-472.

Jorgenson, D., Ho, M. S. & Stiroh, K. J., 2006. Potential Growth of the U.S. Economy: Will be Productivity Resurgence Continue?. *Business Economics*, 41(1), pp. 7-16.

Jorgenson, D., Ho, M. S. & Stiroh, K. J., 2008. A Retrospective Look at the U.S. Productivity Growth Resurgence. *The Journal of Economic Perspectives*, 22(1), pp. 3-24.

Jorgenson, D. & Stiroh, K., 2000. U.S. Economic Growth at the Industry Level. *The American Economic Review*, 90(2), pp. 161-167.

Jorgenson, D. W., 2001. Information Technology and the U.S. Economy. *The American Economic Review*, 91(1), pp. 1-32.

Jorgenson, D. W. & Khuong, V., 2005. Information Technology and the World Economy. *Scandinavian Journal of Economics*, 107(4), pp. 631-650.

Jovanovic, B. & Rousseau, P. L., 2005. handbook of Economic Growth. Volume 1B. In: P. A. a. S. N. Durlauf, ed. *General Purpose Technologies*. s.l.:Elsevier B.V., pp. 1181-1221.

Kanwar, S. & Robert, E., 2017. Does Intellectual Property Protection Spur Technological Change?. *Yale Economic Growth Center Discussion* , Volume 831.

Karabou, F. E. & Adeve, K., 2018. ICT and Economic Growth in WAEMU: An Analysis of Labour Productivity. *Economics and Applied Informatics* , Volume 2, pp. 12-20.

Kaufmann, D., Aart, K. & Mastruzzi, M., 2010. *The Worldwide Governance Indicators: Methodology and Analytical Issues*, s.l.: World Bank Policy Research Working Paper N 5430.

Kaufman, R. L., 2014. *(Estimated) Generalized Least Squares Regression Model for Heteroskedasticity*. First ed. Thousand Oaks: SAGE Publications, Inc..

Klevmarken, N. A., 1989. Panel studies: What can we learn from them? Introduction. *European Economic Review*, 33(2), pp. 523-529.

Kreft, I. G. & Leeuw, J. d., 1998. *Introducing Multilevel Modeling*. 1st ed. London: SAGE Publications.

Krugman, P. R., 1997. *The Age of Diminished Expectations: U.S. Economic Policy in the 1990s*. Third Edition ed. Cambridge, Massachusetts: The MIT Press.

Langlois, R. N., 2007. *Dynamics of Industrial Capitalism; Schumpeter, Chandler, and the new economy*. 1st ed. New York: Routledge.

Lanksher, C. & Knobel, M., 2008. *Digital Literacies: concepts, policies and practices*. First ed. New York: Peter Lang Publishing.

Lasi, H., Fettke, P., Feld, T. & Hoffman , M., 2014. Industry 4.0. *Business & Information Systems Engineering*, Volume 4, pp. 239-242.

Laudon, K. C. & Laudon, J. P., 2006. *Essentials of Business information Systems*. 7th Edition ed. Upper Saddle River: Prentice Hall.

Leeuwen, G. & van der Wiel, H., 2003. ICT, Innovation and Productivity. *Starter*, pp. 41-44.

Liu, et al., 2000. Productivity spillover from Foreign Direct investment: Evidence from UK industry Level Panel Data. *Journal of International Business Studies*, 31(3), pp. 407-425.

Loveman, G., 1988. *An Assessment Of The Productivity Impact Of Information Technologies*, Cambridge: MIT Management In The Nineties Working Paper 88-054.

Lu, Y. & Ramamurthy, K. (., 2011. Understanding the Link Between Information Technology Capability and Organziational Agility: An Empirical Examination. *MIS Quarterly*, 35(4), pp. 931-954.

Mačiulytė-Šniukienė, A. & Gaile-Sarkan, E., 2014. Impact of information and telecommunication technologies. *Procedia - Social and Behavioral Sciences*, Volume 110, pp. 1271-1282.

Melville, N., Kraemer, K. & Gurbaxani, V., 2004. Review: Information Technology and Organizational Performance: An Integrative Business Model of IT Business Value. *MIS Quarterly*, 28(2), pp. 283-322.

Miller, B. & Atkinson, R. D., 2014. *Raising European Productivity Growth Through ICT*, s.l.: ITIF.

Nekrep, A., Strašek, S. & Boršič, D., 2018. Productivity and Economic Growth in the European Union: Impact of Investment in Research and Development. *Our Economy*, 64(1), pp. 18-27.

OECD (Organisation for Economi Co-operation and Development), 2017. *Education.* [Online]
Available at: www.oecd-ilibrary.org/education/educa-tion-at-a-glance-2017_eag-2017-en
[Accessed 15 June 2018].

OECD, 1986. OECD Trends in the Information Economy. *Information Computer Communication Policy*, Volume 11.

OECD, 2014. The digital economy, new business models and key futures. In: *Addressing the Tax Challenges of the Digital Economy.* Paris: OECD Publishing, pp. 69-97.

OECD, 2018. *Sweden well ahead in digital transformation yet has more to do.* [Online]
Available at: https://www.oecd.org/sweden/sweden-well-ahead-in-digital-transformation-yet-has-more-to-do.htm
[Accessed 10 May 2019].

OECD, 2019. *Hour worked (indicator).* [Online]
Available at: https://data.oecd.org/emp/hours-worked.htm
[Accessed 7 May 2019].

OECD, 2019. *ICT Investment.* [Online]
Available at: https://data.oecd.org/ict/ict-investment.htm
[Accessed 30 May 2019].

Oliner, S. D. & Sichel, D. E., 2002. Information Technology and Prodcutivty: Where are we now and where are we going?. *Federal Reserve Bank of Atlanta Enconomic Review*, 87(3), pp. 15-44.

Oxford English Dictionary, 2019. *Capability*. [Online] Available at: https://en.oxforddictionaries.com/definition/capability [Accessed 27 May 2019].

Pereira, A. C. & Romero, F., 2017. A review of the meanings and the implications of the Industry 4.0 concept. *Procedia Manufacturing*, Volume 13, pp. 1206-1214.

Piatkowski, M., 2006. Can Information and Communication Technologies Make a Difference in the Development of Transition Economies. *Information Technologies and International Development*, 3(1), pp. 39-53.

Polák, P., 2017. The productivity paradox: A meta-analysis. *Information Economics and Policy*, Volume 38, pp. 38-54.

Porac, M. U., 1977. *The Information Economy: Definition and Measurement*, Washington, DC.: Office of Telecommunications (DOC).

Porter, M. E., 1980. *Competitive Strategy. Techniques for analyzing industries and competitors.* Firs ed. New York: The Free Press.

Porter, M. E., 1990. *The Competitive Advantage of Nations.* First ed. London: The MacMillan Press LTD.

Porter, M. E. & Millar, V. E., 1985. How Information Gives You Competitive Advantage. *Harvard Business Review*, 63(4), pp. 149-160.

Relich, M., 2017. The impact of ICT on labor productivity in the EU. *Information Technology for Development*, 23(4), pp. 706-722.

Roach, S., 1986. *Macrorealities of The Information Economy*, New York: National Academy of Sciences.

Rouse B., W., 2005. A Theory of Enterprise Transformation. *Wiley Inter Science.*

Schulze, E., 2019. *CNBC - Tech.* [Online] Available at: https://www.cnbc.com/2019/02/08/how-estonia-became-a-digital-society.html
[Accessed 25 May 2019].

Seretis, S. A. & Tsaliki, P. V., 2016. Absolute Advantage and International Trade: Evidence from Four Euro-zone Economies. *Review of Radical Political Economics*, 48(3), pp. 438 - 451.

Smith, A., 1776. *An inquiry into the nature and causes of the wealth of nations.* London: W. Strahan and T. Cadell.

Solow, R. M., 1987. 'We'd better watch out' Book Review. *New York Times*, 12 July, p. 36.

Song, M. & Di Benedetto, C. A., 2007. Capabilities and financial performance: the moderating effect of strategic type. *Journal of the Academy of Marketing Science*, 35(1), pp. 18-34.

Stiroh, K. J., 2002. Information Technology and the U.S. Productivity Revival: What do the industry Data Say?. *the American Economic Review*, 92(5), pp. 1559-1576.

Stiroh, K. J., 2005. Reassessing the Impact of IT in the Production Function: A Meta-Analysis and Sensitivity Tests. *ANNALES D' ÉCONOMIE ET DE STATISTIQUE*, Volume 79/80, pp. 529-561.

Strassmann, P. A., 1990. *The Business Value of Computers. An executive's Guide.* New Canaan, Connecticut: The Information Economics Press.

Syverson, C., 2011. What determines productivity. *Journal of economic literature*, 2(49), pp. 326-365.

Sölvell, Ö., 2015. The Competitive Advantage of Nations 25 years – opening up new perspectives on competitiveness. *Competitiveness Review*, 25(5), pp. 471-481.

Tang, C. F., 2014. The effect of real wages and inflation on labour. *interantional Review of Applied Economics*, 28(3), pp. 311-322.

Teece, D. J., 2019. A capability theory of the firm: an economics and (Strategic) management perspective. *New Zeland Economic Papers*, 53(1), pp. 1-43.

The International Bank for Reconstruction and Development, 2002. *Information and Communication Technologies. A World Bank Group Strategy*. 1st ed. Washington DC: The World Bank.

The World Bank, 2019. *Data Bank*. [Online] Available at: https://databank.worldbank.org/data/reports.aspx?source=2&series=FP.CPI.TOTL.ZG&country=
[Accessed 06 May 2019].

The World Justice Project, 2019. *the World Justice Project Rule of Law Index 2019*, Washington: THE WJP Rule of Law Index.

Thurow, L., 1994. New game, new rules, new strategies. *RSA Journal*, 142(5454), pp. 50-56.

Torre-Reyna, O., 2007. *Panel Data Analysis. Fixed and Random effects ussing Stata*. Princeton, Princeton University.

Turban, E., Leidner, D., McLean, E. R. & Wetherbe, J. C., 2008. *Information technology for management: transforming business in the digital economy*. Sixth ed. s.l.:John Wiley & Sons.

UNESCO institute for Statistics, 2018. *Data centre*. [Online] Available at: http://data.uis.unesco.org
[Accessed 15 June 2015].

Unesco Institute for Statistics, 2019. *Education*. [Online] Available at: http://data.uis.unesco.org/
[Accessed 7 May 2019].

UNICEF, 2018. *Multiple Indicator Cluster Surveys*. [Online] Available at: http://mics.unicef.org.
[Accessed 15 July 2018].

United Nations Development Programme, 2019. *human Develpoment Index*. [Online]
Available at: http://hdr.undp.org/en/content/human-development-index-hdi
[Accessed 10 May 2019].

United Nations, 2019. *E-Government Development Index (EGDI)*. [Online] Available at: https://publicadministration.un.org/egovkb/en-us/About/Overview/-E-Government-Development-Index
[Accessed 24 May 2019].

van Ark, B., Inklaar, R. & McGuckin, R. H., 2003. The emplyement effects of the 'New Economy'. A comparison of the European Union and the United States. *National Institute Economic Review*, Volume 184, pp. 86-98.

Watanabe, C. et al., 2018. Measuring GDP in the digital economy: Increasin dependence on uncaptured GDP. *Technological Forecasting & Social Change*.

Westerman, G., Bonnet, D. & McAfee, A., 2014. The nine elements of Digital Transformation. *MIT Sloan Management Review*, 60(2), pp. 8-13.

Willcocks, L. & Lester, S., 1996. Beyond the IT productivity paradox. *European Management Journal*, 14(3), pp. 279-290.

Voit, J., 2005. *The Statistical Mechanics of Financial Markets*. 1st ed. Berlin: Springer.

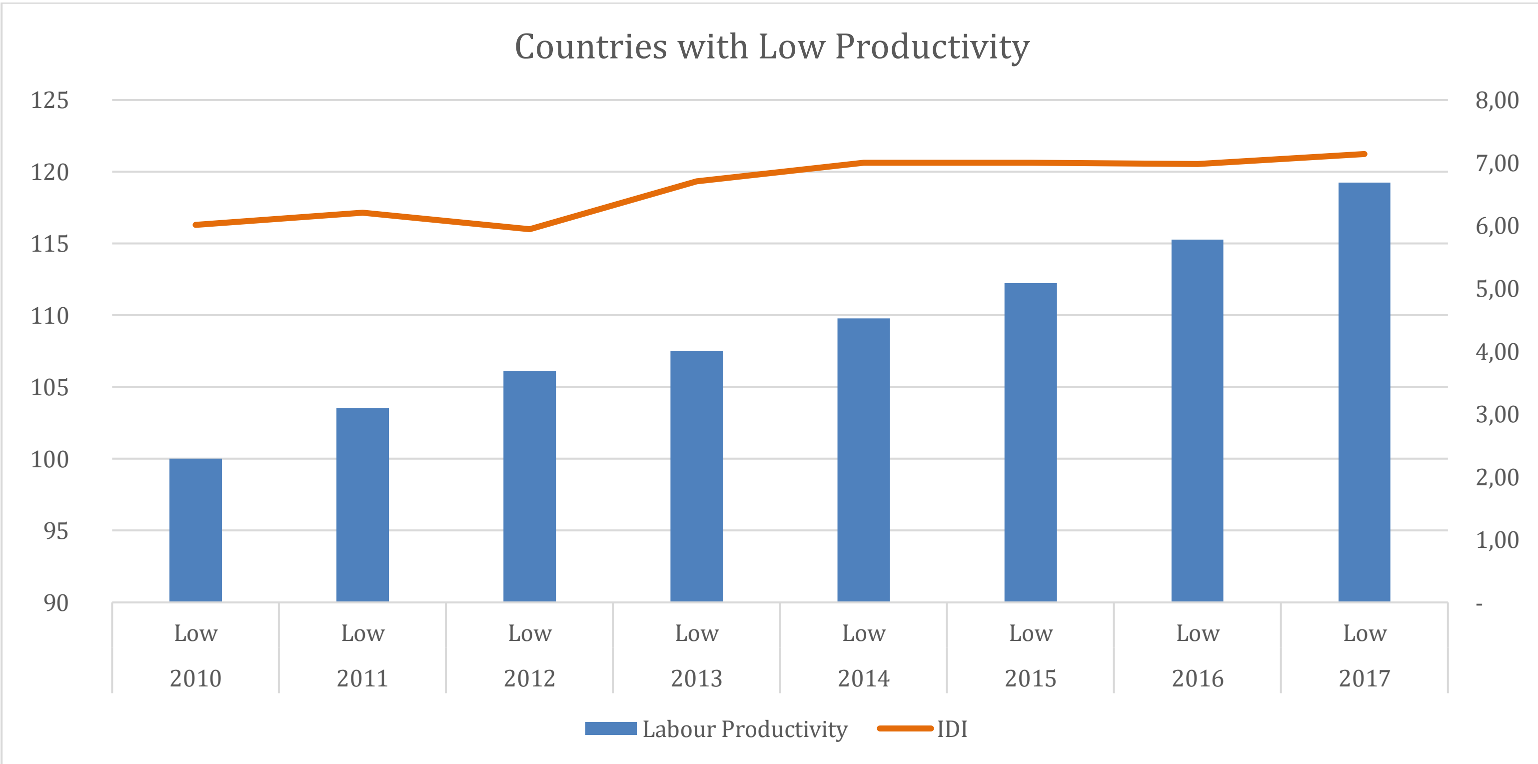
World Economic Forum, 2019. *Global Information Technology Report 2016*. [Online]
Available at: http://reports.weforum.org/global-information-technology-report-2016/?doing_wp_cron=1559065024.1492080688476562500000
[Accessed 15 May 28].

Zins, C., 2007. Conceptual approaches for defining data, information, and knowledge. *Journal of the American Society for Information Science and Technology*, 58(4), pp. 479-493.

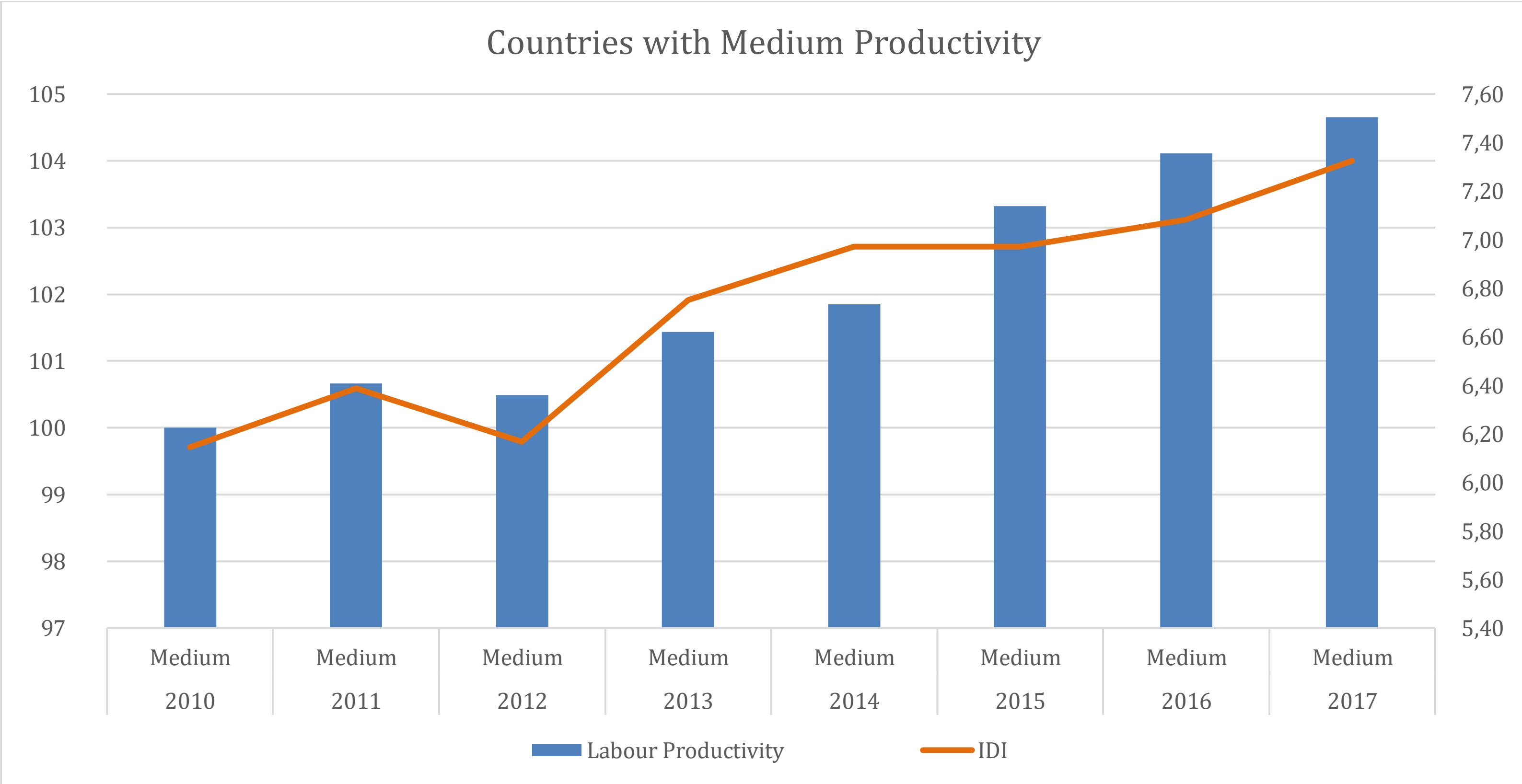
Žmuk, B., Dumičić, K. & Palić, I., 2018. Forecasting Labour Productivity in the European Union Members States: Is Labour Productivity changing as expected?. *Interdiciplinary Description of Complex Systems*, 13(3-B), pp. 504-523.

Annex A

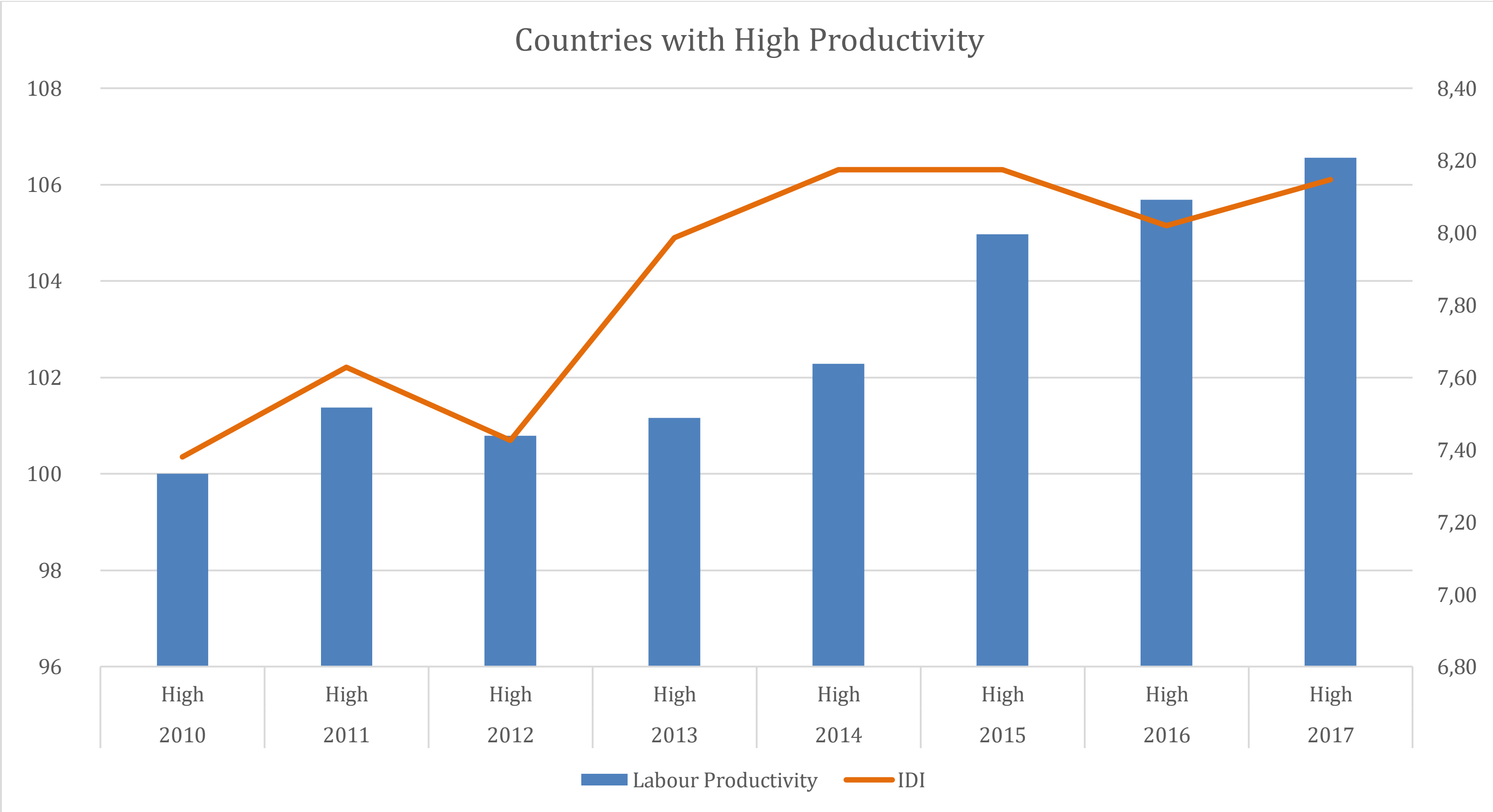
Countries with Low Productivity



Countries with Medium Productivity



Countries with High Productivity



Annex B

Results of the panel data regression

Dependent Variable: LABOUR_PRODUCTIVITY
Method: Panel EGLS (Two-way random effects)
Date: 05/18/19 Time: 18:39
Sample: 2010 2017
Periods included: 8
Cross-sections included: 28
Total panel (balanced) observations: 224
Swamy and Arora estimator of component variances
White diagonal standard errors & covariance (d.f. corrected)

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	84.56516	10.73417	7.878131	0.0000
IDI	2.746499	0.931327	2.949016	0.0035
RULE_OF_LAW	-0.981235	1.543243	-0.635826	0.5256
FDI_GDP	0.010308	0.010383	0.992850	0.3219
EDUCATION_YEARS_OF_SCHOOLING	2.012708	0.814425	2.471322	0.0142
EDUCATION__GOVERNMENT_EXPENDI...	-4.368034	1.196739	-3.649948	0.0003
INFLATION	-0.170709	0.299025	-0.570888	0.5687

Effects Specification	S.D.	Rho
Cross-section random	4.684841	0.6097
Period random	0.000000	0.0000
Idiosyncratic random	3.747954	0.3903

Weighted Statistics

R-squared	0.357022	Mean dependent var	28.36508
Adjusted R-squared	0.339244	S.D. dependent var	4.968020
S.E. of regression	4.038350	Sum squared resid	3538.895
F-statistic	20.08203	Durbin-Watson stat	0.433963
Prob(F-statistic)	0.000000		

Unweighted Statistics

R-squared	0.104698	Mean dependent var	104.2179
Sum squared resid	9422.901	Durbin-Watson stat	0.162981

Annex C

a) Results of the regression of countries with classification "High"

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	94.35527	17.98701	5.245745	0.0000
IDI	5.194862	1.930169	2.691403	0.0097

Weighted Statistics

R-squared	0.474394	Mean dependent var	82.96318
Adjusted R-squared	0.410034	S.D. dependent var	7.372894
S.E. of regression	5.663063	Sum squared resid	1571.444
F-statistic	7.370958	Durbin-Watson stat	0.475151
Prob(F-statistic)	0.000012		

b) Results of the regression of countries with classification "Medium"

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	51.43315	19.89487	2.585247	0.0123
IDI	2.883141	0.998185	2.888385	0.0055

Weighted Statistics

R-squared	0.398009	Mean dependent var	10.79635
Adjusted R-squared	0.334642	S.D. dependent var	2.710824
S.E. of regression	2.211205	Sum squared resid	278.6973
F-statistic	6.280976	Durbin-Watson stat	0.647443
Prob(F-statistic)	0.000041		

c) Results of the regression of countries with classification "Low"

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	80.27166	12.00871	6.684454	0.0000
IDI	3.074003	1.517057	2.026294	0.0455

Weighted Statistics

R-squared	0.428593	Mean dependent var	28.35355
Adjusted R-squared	0.393248	S.D. dependent var	4.787642
S.E. of regression	3.729300	Sum squared resid	1349.045
F-statistic	12.12606	Durbin-Watson stat	0.527948
Prob(F-statistic)	0.000000		