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1. Introduction

Technological development is commonly known as the main driver behind employment and economic growth. Increased innovations for information and communication technologies (ICTs) have, in particular, been discussed to be the primary transformer for economic processes as production and trade during recent decades (World Bank, 2017a). Ever since the growth in productivity rates for many developed countries during the 1990's, the increased utilization of ICT capital has been exceptional (Venturini, 2006). The highest shares of ICT capital investments in 2013 were found in Europe, where OECD (2015) estimates that nearly 4% of GDP in Switzerland and Czech Republic were devoted to these kinds of assets. It might be considered as a low share of total GDP, but when looking at the internet connection globally the usage among the population in 1995 reached 0.78% and increased by 15 percentage points ten years later (World Bank, 2017b). The World Bank estimates that almost half of today's population live in regions provided with internet connection, but only 1 out of 7 inhabitants in least developed countries can use it (2017a). Since many of the ICT related devices are reliant on internet connection, they argue for the expensive access and an underdeveloped infrastructure in developing countries to be the main obstacles in ICT investments (World Bank, 2017a). Although the implementation of digital agendas is becoming a governmental priority worldwide, the use is very dispersed across countries and regions. This is shown by GSMA (2016) which estimates that nearly 85% of the Europeans and almost 79% of the Americans in 2015 did have some sort of mobile subscription, while only 43% of the population in Sub-Saharan Africa had one.

1.1 Problem

Due to these assets' potential and complementary effects on labor and capital, ICT has been a center of dispute among researchers investigating growth of economies during recent decades. A common conclusion is that investments in internet, broadband and infrastructure for telecommunications are significantly correlated with output growth in developed economies (Röller & Waverman, 2001; Wolde-Rafael, 2007). Since ICT tends to be positively correlated with income, there could be reasons for one to expect different effects between developed- and less developed countries. Research stress that income differences across countries could be the

consequences of country-specific characteristics affecting investment decisions (North, 1991). The quality of national policies incentivizing ICT investments can for example influence the contribution to growth by establishing supportive regulations. However, the effect of ICTs on economies at different levels of income has been somewhat overlooked up until recently and the results regarding the effects on low-income countries, where the support for ICT is assumed to be quite low, are split. Although the research within this topic is currently on the rise, attributes affecting ICT's contribution to economic growth have not been scrutinized sufficiently.

1.2 Purpose

The purpose of this paper is to add to the existing literature about the effects ICT investments are having on output growth. We analyze how the contribution to GDP growth differs amongst country groups and try to explain what might causing these potential differences with help from previous research. Our approach is inspired by the earlier studies of Yousefi (2011) and Niebel (2014) and follows the empirical methodologies outlined in their papers. However, this study differs in several aspects. This thesis will analyze a greater amount of countries and an increased timespan consisting of 21 years. The rapid increase in ICT assets during 1995 – 2015 and great variability in the adoption, imply that the period is interesting to investigate. The challenge of finding proper and reliable data for all countries makes it a natural decision to only include countries showing values for ICT capital investments during the period. We will divide all countries into different income groups by using the most recent classification by United Nations (2017) and data primarily collected from a comprehensive database by the Conference Board (2016a). We employ an augmented Cobb-Douglas production function which consists of explanatory variables like ICT capital, non-ICT capital, employment growth and additional variables as exports and labor quality.

1.3 Outline

The organization of this study is as follows: Section 2 defines ICT and discusses the main contributions to the topic so far by presenting previous studies. In the theoretical framework, section 3, we discuss relevant theories that can explain the differences in investments and growth at different stages of development. Section 4 presents data and method used to

accomplish the empirical analysis in section 5. Finally, we interpret the results and present what we conclude from the estimated regression with help from previous literature and theory. In addition, suggestions for further studies will be presented.

2. Background & Related Literature

The common conclusion among previous studies investigating the impact of ICT, is that increased investments in these assets do have positive effects on growth. The contribution to income among countries at different stages of development are however somewhat mixed. We will in this section define the concept of ICT and discuss related literature relevant for our study.

2.1 Definition of ICT

ICT capital are used for many different purposes, not at least for how people communicate and how firms are producing goods and services. The assets permeate the economy through transportations, retail services, educational- and health sectors as well as personal lifestyles. By increased use of automated vehicles and machinery, e-commerce, online classes, healthcare and social networks, ICTs are usually referred to assets such as computers and related hardware, software, communications- and video equipment (OECD, 2017).

2.2 Related Literature

The positive effects of ICTs on economic growth have been confirmed by many members of the OECD and the European Union (Edquist & Henrekson, 2004; Hanclova, Doucek, Fischer & Vltavska, 2015; Falk & Biag, 2015). As suggested by Edquist and Henrekson, with support from Hagsten (2015) who is studying broadband-connection, ICTs have been some of the most important innovations for growth during the past three decades. However, the significant effects of increased ICT capital and e-commerce have not been fully exploited within all countries in the Western World. They stress that countries invested heavily in the production of ICT in the end of the second millennia, experienced higher growth rates in comparison to other countries importing it¹. Hanclova et al. (2015) suggest that growth related to ICT in Eastern Europe, consisting most of emerging economies, is less evident. They on the other hand, suggest that investments should be prioritized by upper middle income countries where higher marginal returns are anticipated. This is consistent with Dimelis and Papaioannou (2009), studying ICTs and productivity on the global level. They suggest developed countries have reached higher

¹ Edquist and Henrekson (2004) give the example of United States and Nordic countries, which invested in ICT during the 1990's and created a comparative advantage within the IT industry.

growth rates due to advantages of higher learning and experience levels, in relation to developing countries. These factors tend to lower the cost of implementation and lead to faster technological distribution in the society. Steinmuller (2001) in contrast, argues that less developed countries can achieve higher growth rates through ICTs. The strategy of *leapfrogging* enables poor economies to skip some steps related to capability building, e.g. historical experience, by bypassing some of the old technologies that developed countries have established. He states that the phenomenon of leapfrogging is possible and almost every country can benefit from it. For countries to overcome obstacles hindering these opportunities, the World Bank (2017a) argues that effective reforms set by governments must be fulfilled. Well-established national strategies for ICTs are crucial for raising private and corporate investments in broadband and telecommunications and make the accessibility less expensive. King et al. (1994) argue that institutions are big influencers that foster a good environment for ICT investments. By supporting e.g. higher education, governments can increase the human capital stock and through this attract more ICT investments.

Several Granger Causality tests, testing the hypothesis whether ICT causes output growth or not, have yet reached somewhat different results. Beil, Ford and Jackson (2005) for example, state that economic growth is causing increased investments in telecommunications. They suggest that policies aiming to stimulate investments and improve GDP growth, could therefore be ineffective. Röller and Waverman (2001) and Wolde-Rufael (2007) argue for a more common conception that investments in ICT instead causes output to grow. Röller and Waverman stress that less developed countries find it harder to achieve higher growth in relation to members of the OECD, due to very low levels of functioning infrastructure in telecommunication. They agree with previous authors that a potential influencer could be the role of institutions. Policies, governmental regulations and corporate incentives should play major roles in developing the infrastructure for telecommunication and thus affect the relationship between ICT and GDP growth.

To shed light on the global impact of ICT, Yousefi (2011) studies the growth across different income groups and finds significant contributions of ICT in most economies, with an exception for the low-income group. However, Dedrick, Kraemer and Shih (2011) argues that developing countries have gained higher productivity rates from ICT investments during recent decades.

Countries having growth of tertiary enrollment above the median today, gain relatively more from IT than countries below the median. They discuss the existence of a potential lag between the time of investments in the 1980's and increased knowledge in how to use different IT assets, to explain the low productivity gains in previous periods. This is in line with the arguments previously mentioned by Dimelis and Papaioannou (2009), which in addition support the fact that less developed countries can gain from ICT investments through the flow of FDI. Furthermore, Yousefi's investigation has been somewhat criticized for the exclusion of heterogeneity effects, contributing to differences in investments of ICT. As being acknowledged by himself, one should need more appropriate data to do comparisons across countries with different economic conditions. Niebel (2014) chose to follow a similar method by adding exports as a measurement for the openness to trade. Even when including the effects from trade, developing countries are according to Niebel positively affected by increased growth of ICT services. Labor service is only significant in developed and emerging economies, while all tests point at the affection of exports only is significant in emerging countries. Although he concludes that ICT capital services contribute positively to output growth, he does not put much emphasis in discussing what might causes the impact differentials on growth between the three stages of development.

3. Theoretical Framework

In this section, we will through economic theory discuss the general impact ICTs are said to have on output growth in different countries. The last paragraph presents the theoretical model used in the empirical part of this study.

Existing theories have for a long time stated capital, labor and technological development to be the main drivers for sustained economic growth. The technology factor is suggested to complement capital and labor in the sense that it brings productivity gains in production by new knowledge and innovations (Solow, 1956; Romer, 1990; Gottfries, 2013). The neoclassical model for growth conceives technology as an exogenous factor. In this case, one should expect income to converge between countries over time because of every economy's constant access to technological progress. On the other hand, endogenous growth theory does not assume convergence since it attempts to explain how the level of technology varies. Both theories do support the characteristics of diminishing marginal returns on investments. Consequently, expectations about higher returns on investment where lower stocks of capital and labor are anticipated (Gottfries, 2013).

Investments in ICT have not for that long, as the case for other types of non-ICT related capital, been evident to affect economic growth of countries. According to Venturini (2006), the effects could not be realized until the late 1990's, after the impressive increase of productivity in the United States. He explains that countries' growth rates today are driven by the process of learning-by-doing, determined by increased usage of ICT in both industries and households. The consumption and investment behaviors of ICT are complementary factors and the spillover effects occurring between households and firms are determined by the social value of capital. He suggests that households own firms and can thus allocate the investment and consumption behavior by existing externality effects. However, Venturini's model is solely based on the development of a high-income country and might not capture the investment behavior in lower income countries. Avgerou (2003) argues that ICT investments are only successful in those economies that have the prerequisites for implementing and efficiently use the assets. She argues that it should not be surprising if ICT capital can affect economies differently in terms of growth. According to her, economic development is a *context-specific process* and related to market efficient policies and historical consequences of institutions. Developed countries

should therefore hold better technologies in form of ICT, due to their level of prior experience and established infrastructure suitable for efficient use. Glaser, La Porta, Lopez-de-Silanes and Shleifer (2004) argue for human capital to have a greater impact on growth and poverty reduction. They stress that societies are built upon a collection of individual characteristics largely determined by the knowledge and the social capital of its citizens.

Waverman, Meschi and Fuss (2005) stress that demand elasticity for mobile phones in developing countries are significantly above 1. This implies that demand is rising much more in comparison to income. However, they argue that developing countries too often find it difficult to experience growth related to ICT investments due to a so called *low telecoms trap*, implying an unrealistically high cost which reduces the opportunities for raised productivity. They stress that these consequences are mainly affected by the lack of efficient networks and accessibility of good infrastructure supporting these types of assets. Romer (1990) suggests that countries can access new technologies through the knowledge spillovers occurring through trade. The diffusion of technological factors across countries and companies implies a high importance of a country's magnitude of exports and imports. He argues that countries with relatively low human capital stocks should benefit more from trade due to the external sources of knowledge, research and new innovations. In other words, for less developed countries to achieve higher productivity gains from new technologies, they should focus on integrating with economies with relatively higher stock of human capital. Dollar & Kraay (2002), agrees upon the statement that trade induce countries to grow faster. They stress that trade liberalized economies often tend to have better constitutions supporting commercial exchange and grow more rapidly. A country's openness to the World should therefore always be taken into consideration when analyzing the growth differentials across countries.

Dimelis and Papaioannou (2009) agree upon the statements mentioned by previous authors - technological progress cannot be the same for all countries around the globe. Every economy is holding different policies and prerequisites e.g. human capital, supporting the implementation of new technologies. North (1991) and Acemoglu, Johnson and Robinson (2001) are suggesting that historical consequences such as colonization, could be a factor of why some countries still find it difficult to reach higher growth rates in relation to others. Time-invariant factors such as institutional climate, should in other words have plausible effects in the

development and human capital of countries. Economies that early established solid property rights and governmental structures are today investing more in both capital and education, leading to the development of a larger output stock. United Nations (Information Economy Report, 2006) confirm that governmental actions aiming to invest in ICT capital, should have plausible effects for developing countries to reach higher levels of income. They conclude that ICT adoption can make positive impacts on per capita income even in low-income countries, by raising the human capital endowment and thus raise the efficient use of ICT assets.

A common model used in previous studies investigating the effects of ICT investments on output growth, is the neoclassical model by Solow (1956). In this model the technological factor, or Solow residual², is a parameter of great matter. It includes all other factors of production that cannot be explained by capital and labor alone. Since growth is discussed to be influenced by technology, which often is determined by factors such as new innovations, externalities, human capital and investment decisions, there are reasons to believe upon a positive relationship between the Solow residual and the capital variable for ICT (Stiroh, 2002), making the neoclassical model suitable to use in this context. Although Stiroh finds little evidence of the positive relationship, he argues that one should not drop the framework of the neoclassical concept since there are strong reasons to believe GDP growth in the digital era is in favor of technological factors. The production function outlined by Solow includes the three following factors of production:

$$Y = AK^{\alpha}L^{1-\alpha}$$

where Y is output stock, K and L is the stocks of capital and labor respectively. A is the technological parameter affecting the productivity of K and L . In addition, the function represents constant returns to scale, implying that 1 unit increase in both capital and labor will contribute to 1 unit increase in the level of output. The values of α and $(1 - \alpha)$ will therefore sum up to one.

² Solow residual is often known as total factor productivity (TFP).

4. Empirical Framework

This section describes the practical approach chosen to analyze the problem of this thesis, where we put ICT capital as explanatory variable to GDP growth. We begin by describing the data selected for this study followed by a classification of countries. Finally, a presentation of the production function used to analyze our problem and some descriptive statistics, are examined.

4.1 Data

For us to analyze the impact of investments in information and communication technologies to output growth, we need a comprehensive dataset consisting of variables measuring economic inputs of several countries globally. National statistical offices most often estimate domestic values in their own national currencies and are therefore not directly internationally comparable. Fortunately, the Conference Board³ has conducted a great database for this type of study by collecting economic data for 123 countries worldwide, during the period of 1950 - 2016. The dataset we are ought to use is the Total Economy Database (TED) (2016a) and includes variables for two sources of capital, output growth, labor and human capital. Due to limited data accessibility of ICT capital for developing countries, we end up with a total number of 101 countries. As mentioned in the theoretical part, ICTs have only been considered to affect productivity for several years due to the rapid growth during the 1990's, after the so-called *IT boom* (Venturini, 2006; Edquist & Henrekson, 2004). The great increase in these kinds of investments during the past three decades, therefore makes up an interesting period for us to investigate. In accordance with Niebel (2014), we start in 1995 but add another twenty years to gather the impact up until recently. Thus, we end up with a total number of 21 years during the period 1995 - 2015. Additional data which is not covered by the TED, is accessed from the World Bank (2017c).

Since previous empirics have found support for the relationship between ICT and GDP, we assume this relationship to flow from ICT investments to output growth (Röller & Wavermann, 2001; Wolde-Rafael, 2007) and have, just as Niebel (2014), Yosefi (2011) and Hanclova et al. (2015), put ICT as an independent variable explaining GDP. To distinguish for growth in ICT

³ The Conference Board is an independent, non-profit research association working with issues regarding public interest by reporting economical values (2016a).

investments, TED is dividing capital into two categories; growth of ICT capital services and non-ICT capital services. ICT capital services are provided by assets as telecommunication materials, computer hardware and software, while the non-ICT capital services are referred to the growth in the services provided by transports, machinery, buildings, construction and other types of non-ICT assets. Hence, the empirical part is based on capital services instead of capital stocks. According to OECD (2001), Inklaar and Timmer (2013) and Niebel (2014), this measure is more appropriate since it reflects upon the assumption that short-lived assets (computers, phones, etc.) are having greater impact in production, as indicated by user cost of capital. ICT as well as non-ICT capital services, are thus calculated as the growth of stocks in single ICT assets weighted by the share in total ICT capital compensation. As theory suggests, we expect both types of capital services to contribute to the growth of GDP. ICT services are however expected to have relatively greater marginal impacts in the lower income groups, due to the law of diminishing returns on investments (Solow, 1956; Romer, 1990; Gottfries, 2013). Since developed countries are assumed to hold better prerequisites, they should in general also be regarded as more efficient users and eager to invest in new technologies. We have therefore reason to believe that the impact of ICT could be high in the high-income group as well (Avgerou, 2003)

We include labor quality as one of the control variables since we assume human capital to influence the level of production (Glaeser et al., 2004). Labor quality consists of three levels of skills; low, medium and high, and is a composition of data sources from different origins⁴ (The Conference Board, 2016b). Since these sources are set up differently in terms of definitions, time and countries, TED has estimated the relationship between them using a seemingly unrelated regression (SUR) model. The employment data covers all employees, including self-employed, apprentices and the military, engaged in productive activities within the country's border. The data is gathered from different sources by the Conference Board⁵. The level of employment and human capital are vital factors for raising output and this study will thus expect positive effects on GDP growth in most of the income groups (Solow, 1956; Romer, 1990; Gottfries, 2013).

⁴ Cohen & Soto (2007), Barro & Lee (2012), EU KLEMS and Wittgenstein Centre for Demography and Global Human Capital (2015).

⁵ The main sources are Eurostat, OECD, Groningen Growth and Development Center and Asian Productivity Organization.

From World Development Indicators, we add export as a measure for a country's openness to the rest of the world (World Bank, 2017c). In addition to labor quality, we follow Niebel and assume that the level of trade and export are important factors for GDP growth. Theory suggests that the more globalized a country is, the easier it is to accumulate capital and access new technology through the exchange of knowledge across borders (Romer, 1990; Dollar and Kraay, 2002). The expectations about exports having positive effects on GDP growth are therefore present in our empirical analysis.

4.2 Country Classification

To grasp potential disparities between countries, especially different income levels, we separate them in accordance to their level of development. We classify these as different income groups rather than dividing them into developing-, emerging- and developed economies. We follow the country classification table drawn by the World Economic Situation and Prospects, WESP (United Nations, 2017), where each country is categorized into the low-, lower middle, upper middle or the high-income country group. The classification is dependent on each country's gross national income (GNI) per capita. Countries having a GNI less than \$1.025 per capita are drawn under the category of low-income countries, countries between \$1.026 and \$4.035 are classified as lower middle income, upper middle income countries between \$4.036 and \$12.475 and high-income countries for those with more than \$12.475 per capita. All countries can be found in table A1.1 in Appendix 1.

4.3 Empirical Model

The empirical model in this study is based on the neoclassical Solow model, presented in the theoretical framework. The analytical framework follows the methodologies outlined by Yousefi (2011) and Niebel (2014) in their studies. We put GDP growth as dependent variable by having capital, labor and technology on the right-hand side of the equation, without the assumption of constant returns to scale. The contribution of capital to GDP is measured by having two capital variables; ICT and non-ICT capital services. In addition, we augment the production function by including two control variables, export and labor quality, since those

are considered to affect the level of production as well. We end up with the following augmented production function:

$$gY_{i,t} = \beta_{li} + \beta_{ICT} gK^{ICT}_{i,t} + \beta_{NICT} gK^{NICT}_{i,t} + \beta_E gE_{i,t} + \beta_X X_{i,t} + \varepsilon_{i,t}$$

$$\begin{aligned} i &= \text{country } 1, 2, 3 \dots \\ t &= \text{period} \end{aligned}$$

where $gY_{i,t}$ is the annual growth rate of GDP, $gK^{ICT}_{i,t}$ and $gK^{NICT}_{i,t}$ are the growth rates of ICT and non-ICT capital services respectively, and $gE_{i,t}$ is the growth rate of employment. Finally, $X_{i,t}$ stands for the additional variables for export and growth of labor quality. All variables apart from exports, are presented in annual growth rates as the log change of previous year's value and are measured in terms of 2015 US Dollars purchasing power parities (PPP).

We run panel estimations for the four different country groups by using two types of models; pooled ordinary least square (OLS) and fixed effect models (FEM). We cut off the 5% highest and lowest observations and replace them with the 5th and 95th percentile value, to avoid problems of extreme outliers in the data. The process is called *Winsorising* and is a more robust method to correct for outliers, in comparison to trimming (IHS EViews, 2010). To avoid problems of non-stationarity, a Fisher Augmented Dickey-Fuller test for panel data analysis is conducted (Appendix 3). The ADF results do not find any problems of non-stationarity in the aggregated sample, nor in the high-income group. Problems of unit roots are solved among the other three groups by differencing the affected time-series. The drawback is that we end up with less number of years. Consequently, for all groups except the most developed we can only estimate the period 1996 - 2015. It should be noted that the Jarque-Bera normality tests indicate non-normal distributions among residuals in the highest income and lower middle income countries, as well as for the total sample (Appendix 4).

The OLS regression is used as a benchmark for the analysis, where the assumption about no individuality among countries is present. They are all having the same intercept and the same slope. The assumption that all countries are holding the same characteristics is somewhat unrealistic (Gujarati & Porter, 2009) and not the purpose of this study. Countries should not

hold similar prerequisites for using factors efficiently in production, due to differences in investments behavior (Avgerou, 2003). We will therefore adopt a FE model to control for unobserved heterogeneity across countries, by letting all nations to have individual intercepts and control for time-invariant qualities to not affect GDP growth. The difference between the two models will show if some constant variables omitted from the model, affect the contribution of ICT to GDP growth. Both models are estimated with robust standard errors, using Whites period coefficient covariance estimator to remove potential problems with heteroscedasticity (Eviews, 2016).

4.4 Descriptive Statistics

Below, there are four tables reporting summary statistics for each income group. Every table gives an overview of the statistical nature in each subgroup by presenting the values of the mean, median, maximum, minimum and standard deviation for each variable. The summary statistics for the full sample can be found in table A2.1 in Appendix 2.

As can be seen in table 4.1 - 4.4, the mean value for the annual change in ICT capital investments are presented for each income group. As expected, the highest growth rate is reached within the high-income group. This observation is consistent with previous literature and implies that the richer an economy is, the more it tends to invest in ICT due to the knowledge and experience in how to use and implement these assets (Avgerou, 2003; Beil, Ford & Jackson, 2005; Venturini, 2006). The highest maximum value of 65.2% is presented in the low-income group, indicating that the largest investments are not placed in any of the top-three highest income groups. The change in non-ICT investment is still relatively high in the most developed countries, yet not as large as the investments for ICT in any of the four income groups. This implies that some of the less developed countries have invested heavily in ICTs during the past two decades. This is in accordance with the findings of Niebel (2014) and Dedrick et al. (2013) and might display the realization of the so called *leapfrogging* effect discussed by Steinmuller (2001).

Another main variable in focus for the empirical part is the annual growth rates for GDP. In accordance with the neoclassical theory, the highest rate is reached in the low-income group followed by the lower middle income group. The same relationship can be noticed for the mean

value of employment growth, as the highest value comes from below and ends with the lowest mean in the high-income economies. These recognitions display the observations by Dedrick et al. (2013) and Niebel (2014), about the rise in income among less developed countries during the past two decades. Furthermore, the rise might represent the success from increased investments in ICT and non-ICT capital as well as increased employment rate which should have a plausible effect on output growth (Solow, 1956; Romer, 1990; Gottfries, 2013). Although the highest average values for GDP are reached for the low-income group, the highest minimum values are reached for the upper middle and in the lower middle income group for the employment rate.

For labor quality and exports, higher rates are explored in the high-income group. The unrealistically low median as well as the relatively lower mean value for the upper middle income group, might indicate that there could be some biasedness or measurement errors in the data for export. However, the tables give an overview about the relatively lower rates in the low-income groups in comparison the developed.

Table 4.1 - Descriptive Statistics: High-Income Countries 1995-2015

	gGDP	gICT	gNICT	gEmployment	gLabor Quality	Export % of GDP
Mean	3.012433	15.91900	3.355078	1.274806	0.395945	52.96728
Median	2.857492	14.79699	2.880083	1.345245	0.310951	43.42753
Maximum	8.740070	32.04962	9.094110	5.534577	1.115487	160.3446
Minimum	-2.450791	3.823758	0.255046	-1.958880	0.022180	16.92983
Std. Dev.	2.749152	7.525781	2.175520	1.760511	0.285414	34.75061
Observations	836	836	836	836	836	836

Source: The Conference Board (2016) and the World Bank (2017)

Table 4.2 - Descriptive Statistics: Upper Middle Income Countries 1995-2015

	gGDP	gICT	gNICT	gEmployment	gLabor Quality	Export % of GDP
Mean	3.942654	13.19339	-0.027561	1.982523	-0.003785	-0.028340
Median	4.015630	12.16439	0.044870	2.141071	0.003667	0.000000
Maximum	10.53673	35.96643	3.845262	6.108792	0.504177	24.07263
Minimum	-4.120802	-4.874120	-7.431728	-2.735221	-0.580911	-21.41074
Std. Dev.	3.499686	9.233922	1.372037	2.164911	0.078683	4.083994
Observations	407	407	407	407	407	407

Source: The Conference Board (2016) and the World Bank (2017)

Table 4.4 - Descriptive Statistics: Lower Middle Income Countries 1995-2015

	gGDP	gICT	gNICT	gEmployment	gLabor Quality	Export % of GDP
Mean	4.955204	15.11854	0.048224	2.410774	0.003804	28.66016
Median	5.046018	14.92673	0.050294	2.493957	0.003002	24.86869
Maximum	9.546127	39.52879	5.418834	6.488618	0.370544	62.84007
Minimum	-1.679405	-5.457444	-6.152139	-2.880427	-0.404322	11.51269
Std. Dev.	2.252047	10.65957	1.038844	2.041554	0.050776	13.56161
Observations	339	339	339	339	339	339

Source: The Conference Board (2016) and the World Bank (2017)

Table 4.3 - Descriptive Statistics: Low-Income Countries 1995-2015

	gGDP	gICT	gNICT	gEmployment	gLabor Quality	Export % of GDP
Mean	5.256713	-0.414414	0.171651	3.146388	0.005343	20.48802
Median	5.400000	1.166639	0.171829	3.322903	0.003401	20.75642
Maximum	10.55441	65.16451	4.377003	4.794707	0.123903	30.66378
Minimum	-0.728816	-53.08947	-8.105458	0.588888	-0.092569	9.830083
Std. Dev.	2.881087	17.43820	1.713302	1.132137	0.021098	5.881081
Observations	125	125	125	125	125	125

Source: The Conference Board (2016) and the World Bank (2017)

5. Empirical Analysis

In this section, a presentation and analysis of the main findings from the regressions will be presented. We investigate whether ICT capital investments and their impact on GDP growth differ between countries at four levels of income.

5.1 Results

Table 5.1 examines the results from the regression for the aggregated sample in period 1995 – 2015. The growth in ICT capital services is insignificant for the two models with only a few percentage points (0.012% and 0.014%) differing the output elasticities. For the non-ICT capital services, the elasticities range from 0.479% to 0.437%, indicating a higher importance in relation to ICT. The growth of employment seems to have somewhat higher importance for economic growth when accounting for country-specific effects (0.521%) compared to the OLS (0.458%). When controlling for labor quality and export in the regression, we only find significant results for the labor variable. When we exclude the control variables, we find that ICT capital has a significant effect in both models, as can be seen in table A5.1.

Table 5.1 - All countries – Dependent Variable: *gGDP* - 1995 – 2015

Variables	OLS	FEM
gICT Capital Serv.	0.011591	0.014488
gNICT Capital Serv.	0.479263***	0.436616***
gEmployment	0.458463***	0.521142***
gLabor Quality	-0.646490*	1.022370**
Export %	0.001090	-0.001133
Constant	1.138814***	0.683452
Adjusted R ²	0.346677	0.443701

* $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$. All standard errors are estimated with Whites period coefficient covariance estimator

Since the purpose of this study is to compare the contribution of ICT growth across different countries, the output in table 5.2 presents the results for each subsample for the same period. When including exports and labor quality, the low-income group do not find ICT contributing to GDP growth at all. In this group, we also find the only significant export coefficient. On the other hand, in the FE model for high-income countries the labor quality seems to find its only significant impact on GDP. Although insignificant results, the control variables seem to affect the impact of ICT on GDP positively for the lower middle income group, where the coefficient increase from 0.0405% and 0.014% to 0.044% and 0.027% in OLS and FEM respectively. For the high-income group, the impact from the control variables are mixed, with a slight increase in OLS for ICT and a decrease in FEM. In the other two groups, when including exports and labor quality, we get lower elasticities of ICT capital.

When we exclude labor quality and export, ICT capital is significant in the three highest income groups with an exception for FEM in the lower middle income group. The elasticities reveal somewhat higher values in all subgroups in comparison to the aggregated sample. The magnitude of the non-ICT capital services is considerably higher for all subsamples, in comparison to the ICT services. It is surprising to see is the elasticity in the upper middle income countries is around 1.3. This is a remarkably high value in relation to the other groups. The variable suggests a 1% increase in growth of non-ICT capital services would affect growth of GDP with 1.3%.

Table 5.2 - Dependent Variable *gGDP* - 1995 –2015

Group	Variables	OLS	FEM
High-Income	gICT Capital Serv.	0.056954***	0.057382***
	gNICT Capital Serv.	0.321397***	0.219719**
	gEmployment	0.588300***	0.737138***
	gLabor Quality	0.044218	0.660441**
	Export %	0.001552	-0.017498
	Constant	0.177795	1.087396
	Adjusted R ²	0.372632	0.469352
Upper Middle Income	gICT Capital Serv.	0.048142**	0.006591
	gNICT Capital Serv.	1.242143***	1.313912***
	gEmployment	0.385873***	0.398522***
	gLabor Quality	1.582198	1.183480
	Export %	0.002612	0.005554
	Constant	2.582792***	3.106468***
	Adjusted R ²	0.378176	0.578190
Lower Middle Income	gICT Capital Serv.	0.044418**	0.026961
	gNICT Capital Serv.	0.574419***	0.566220***
	gEmployment	0.112611	0.198684**
	gLabor Quality	1.600055	0.458789
	Export %	0.017584	0.012898
	Constant	3.474450***	3.669914***
	Adjusted R ²	0.135205	0.303499
Low-Income	gICT Capital Serv.	-0.007542	-0.004736
	gNICT Capital Serv.	0.521802**	0.488911**
	gEmployment	0.509946**	0.478445*
	gLabor Quality	1.327520	-8.755657
	Export %	-0.110056***	0.020872
	Constant	5.807270***	3.284623***
	Adjusted R ²	0.141420	0.226006

* $p < 0.1$

** $p < 0.05$

*** $p < 0.01$

All standard errors are estimated with Whites period coefficient covariance estimator

5.2 Analysis & Discussion

The output from the empirical part presents interesting results. As expected, the result for the full sample in table A5.1 shows a positive relationship between ICT capital services and GDP growth rate, supporting previous work made by both Niebel (2014) and Yousefi (2011). The values of capital services provided by non-ICT assets are considerable higher, implying that classical assets like buildings, cars and machinery should still be more important for the global growth in relation to new technologies within the ICT sector. Increased coefficients are observed when including export and labor quality as control variables. However, there are no longer any evidence for ICT capital services affecting growth. Consistent with Gottfries (2013) and Glaeser et. al (2004), labor quality seems to have an important role for growth in the full sample. Since traditional theory is predicting exports to have a positive effect on growth (Romer, 1990; Dollar and Kraay, 2002), it is surprising to see the opposite in our empirical findings. The insignificant results might however indicate that there could be some measurement errors. Since these results are aggregations of countries with different income levels, we should not assume that these values are true for all countries globally (Avgerou, 2003; Dimelis & Papaioannou, 2009). Again, all economies do not share the same prerequisites for investing and using new technologies, one should therefore not rely on the results based on an aggregated sample of different countries.

The impact of ICT on GDP growth affects the four subgroups in the output differently. Regarding ICT capital services in the high-income group, there are no differences in the significance level between the two models, nor any remarkable changes in the contributions to GDP growth. This could suggest that there are not many unobserved heterogeneity effects, constant over time, that affect the impact on the contribution of ICT to GDP growth rate. The significance levels are in line with both Yousefi and Niebel as well as theory; high-income countries should have a high stock of ICT capital and historical experience in how to efficiently use these assets. When allowing every country to have its own intercept we notice that labor quality becomes significant to GDP growth. This might partially support the statement by Avgerou about context-specific characteristics and that these could affect the educational contribution to GDP. In addition, it is expected that these countries have developed appropriate infrastructures supporting these types of assets. Our results somewhat contradict the statements made by Edquist and Henrekson as well as Venturini, stressing that growth in high income

countries are today driven by investments and usage of ICT capital. The contributions of non-ICT related capital shown in our output, seem to still be relatively more important in relation to ICT capital services.

In the upper middle income group, the results show reduced importance of ICT capital services in relation to the high-income group. This is not in favor of previous research and theory studying upper middle economies, which shows that these countries should have higher elasticities of ICT compared to higher income economies (Yousefi, 2011; Hanclova et al., 2015). On the other hand, the results about relatively lower contributions in this income group are in line with the findings of Niebel, if one consider the upper middle income group as ‘emerging’ economies. Interestingly, when including both control variables, the significant contribution of ICT investments to GDP growth in FEM disappears. The result estimated by the fixed effects model now suggests that ICT capital services no longer is contributing to the growth of GDP. Non-ICT capital services however shows increased importance when controlling for omitted variables. Our results also show that labor qualities are insignificant in this group. This could be another explanation why ICTs do not affect GDP growth in these countries. Researchers argue that the labor force in low-income countries do not have the required education, nor skills, to handle these technologies efficiently and are thus not able to benefit from high-tech investments of ICT (North, 1991; Acemoglu, Johnson & Robinson, 2001). This could also be a consequence of low institutional qualities, since King et al. (1994) and Glaeser et al. (2004) state that institutions have a major role in the development of human capital and vice versa. However, these results measure the growth in labor quality and the effects on growth in GDP from one year to another, implying that the change in human capital does not contribute to the change in GDP output. This could mean that the change in labor quality are time-invariant over the years and is therefore not contributing to the change in GDP growth rate.

The contribution of ICT capital services in the lower middle income countries is like the results found in the upper middle income group. When controlling for fixed effects the variable is no longer contributing to growth of GDP. As in the upper middle income economies, a potential reason for this could be the impact of low quality institutions. The results for the non-ICT capital however, show much less importance in explaining the GDP growth in relation previous

group. This is not consistent with the theory presented by the neoclassical model about the law of diminishing marginal return on capital, which states that countries with relatively lower stocks of capital should have higher elasticities. On the other hand, the contribution seems to be higher in this group in comparison to the high-income group.

For low-income countries, we do not find any significant contribution from the growth in ICT capital to GDP growth. Here, the growth of non-ICT capital services seems to be of higher importance. This might be explained by the suggestion of Wavermann, Meschi and Fuss (2005) about the fact that lower income countries seem to hold less incentives to invest in infrastructure for new technologies. The explanation to this is that country-specific characteristics and established infrastructure, do not support these kinds of investments. This could imply that lower income countries in general suffer from lower contributions of ICT in relation to other types of capital that meet more primary needs. Wavermann et al. also argue that another explanation for why less developed economies exhibit insignificant contributions from ICT capital could be the consequence of the so-called telecom income trap. This implies that the cost of ICTs exceeds the gains in productivity. The lower levels of income might also affect the support for building efficient infrastructures for telecommunications, as stressed by Röller and Waverman (2001). In comparison to the lower middle income group, the growth in employment seem to be of much higher importance in these types of countries. This could partially be explained by the lower stocks of capital making labor more important in the production. In addition, one might also assume higher unemployment rates in low-income countries, making the growth of employment a much more important variable to GDP growth in relation to previous group.

Overall, the results show that ICT capital still has a more important role among the World's richest countries. In contrast to Niebel, we do not find any significant impact of ICT in the three lower income groups when accounting for country-specific effects. Interestingly, both middle-income groups exhibit significant impacts of ICT in the OLS model. It can however, be noticed that the fixed effect model fails to support the effects of ICT capital on growth in most countries. One could therefore assume there is some time-invariant heterogeneity aspect that rendering ICT negligible when accounting for it. Many less developed countries are today affected by current or historical consequences of war, famine and poverty and might therefore find it hard

to establish stable economies and increased growth. This is in line with the research of North (1991) and Acemoglu et al. (2001), which arguing that historical aspects still influence the configuration of institutions today.

6. Conclusion

The purpose of this study was to investigate how growth in ICT investments affect output growth differently at four levels of income and what possibly can affect the levels of contribution. By employing a panel dataset consisting of 101 countries, the investigation covers the effects during 1995-2015, which was a period of increased investments in ICT.

According to the outcome in this paper, it seems like non-ICT related capital services e.g. buildings, classical machinery, transports etc., are more important in explaining the growth of GDP in relation to ICT capital services. In both models for the high-income group, we find significant support that growth in ICT capital services explains the growth of GDP. With support from related literature this might be the consequence of historical economic stability and high experience levels of using technologies prior to ICT, since exports do not have any impact on the economies. Less importance is found in the low-income group where none of the two regressions point at significant contributions of ICT capital services to growth. Low stocks of human capital and exports could play major roles for the unsupportive environment. Previous studies also suggest that lower contributions to growth could be explained by the fact that less developed countries usually are having unstable policies, acting as barriers for the ability to use ICT capital efficiently. The two middle income groups exhibit the same pattern for the two models regarding the growth of ICT capital services. Interestingly, the variable is having a significant impact on output growth when not controlling for country-specifics effects while in the fixed effects models, ICT becomes insignificant. In contrast to the high-income group, this might be explained by relatively lower qualities of institutions as suggested by North (1991). On the other hand, these countries are having higher income levels than the low-income group and might therefore show significant contributions to growth in the OLS model, implying that heterogeneous characteristics e.g. policies supporting ICT investments might be on the rise. This could in time bring the contribution from ICT capital to higher levels like those experienced in high-income countries.

This paper adds contradicting results regarding positive impact on *all* countries globally and support the fact that there is something apart from labor quality and exports, that affects the contribution of ICT. For future research to investigate the impact on GDP growth, effort should be devoted to examining if institutions are having an impact on the contribution from ICT

investment, by including variables explaining the quality of these. The impact on economic growth should also be examined e.g. by studying a more disaggregated dataset. This could be done by dividing the period into smaller segments and use more country groups. One will then be able to see the effects of ICT in a narrower perspective and the changing effects over time.

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Appendix 1 – List of Countries

Table A1.1 – List of Countries

High-Income		Upper Middle	Lower Middle	Low-Income
Australia	New Zealand	Algeria	Armenia	Burkina Faso
Austria	Norway	Angola	Bangladesh	Ethiopia
Bahrain	Oman	Argentina	Bolivia	Madagascar
Belgium	Poland	Belarus	Cambodia	Malawi
Canada	Portugal	Brazil	Cameroon	Mali
Chile	Qatar	Bulgaria	Egypt	Niger
Cyprus	Saudi Arabia	China	Guatemala	Tanzania
Czech Republic	Singapore	Colombia	India	
Denmark	Slovak Republic	Costa Rica	Indonesia	
Estonia	Slovenia	Dominican Republic	Kenya	
Finland	South Korea	Ecuador	Morocco	
France	Spain	Georgia	Pakistan	
Germany	Sweden	Iran	Philippines	
Greece	Switzerland	Jamaica	Sri Lanka	
Hong Kong	Taiwan	Jordan	Sudan	
Hungary	Trinidad Tobago	Malaysia	Syria	
Ireland	United Kingdom	Mexico	Tajikistan	
Israel	United States	Peru	Tunisia	
Italy	Uruguay	Romania	Ukraine	
Japan		Russian Federation	Uzbekistan	
Kuwait		Serbia & Montenegro	Vietnam	
Latvia		South Africa	Yemen	
Lithuania		Thailand	Zambia	
Luxembourg		Turkey		
Malta		Turkmenistan		
Netherlands		Venezuela		

Source: United Nation (2017)

Appendix 2 – Descriptive Statistics

Table A2.1 Descriptive Statistics: All countries - 1995 – 2015

	gGDP	gICT	gNICT	gEmployment	gLabor Quality	Export % of GDP
Mean	3.814260	15.34089	3.848440	1.795926	0.329436	39.27439
Median	3.815707	14.35705	3.508448	1.799598	0.298725	32.21320
Maximum	9.848467	36.83021	9.966584	5.821805	0.827041	96.64283
Minimum	-2.714485	-1.684516	-0.484032	-2.352787	0.004595	12.79590
Std. Dev.	3.007628	9.436000	2.584943	1.973105	0.222375	22.50627
Observations	1751	1751	1751	1751	1751	1751

Source: The Conference Board (2016) and the World Bank (2017)

Appendix 3 – Augmented Dickey-Fuller unit root tests

Results for the Augmented Dickey-Fuller unit root tests.

H₀: There is unit root (non-stationarity)

Table A3.1 ADF Unit Root test: All countries

		gGDP	gICT	gnICT	gEmpl	gLQ	Export %
ADF - Fisher Chi-sq.	Stat.	551.545	448.945	291.451	707.906	208.836	263.663
	Prob.	0.0000	0.0000	0.0000	0.0000	0.0367	0.0002
ADF - Choi Z-stat	Stat.	-12.5979	-8.89219	-3.87246	-15.6283	-0.09509	-2.53528
	Prob.	0.0000	0.0000	0.0001	0.0000	0.4621	0.0056

Table A3.2 ADF Unit Root test: High-Income Countries

		gGDP	gICT	gNICT	gEmpl	gLQ	Export %
ADF - Fisher Chi-sq.	Stat.	266.633	240.770	173.518	272.433	135.331	110.443
	Prob.	0.0000	0.0000	0.0000	0.0000	0.0002	0.0282
ADF - Choi Z-stat	Stat.	-9.61196	-7.39645	-4.78965	-9.73005	-3.40136	-1.64727
	Prob.	0.0000	0.0000	0.0000	0.0000	0.0003	0.0498

Table A3.3 ADF Unit Root test: Upper Middle Income Countries

		gGDP	gICT	gNICT	gEmpl	gLQ	Export %
ADF - Fisher Chi-sq.	Stat.	125.228	123.970	50.1017	231.648	22.4037	54.8466
	Prob.	0.0000	0.0000	0.5489	0.0000	0.9943	0.2310
ADF - Choi Z-stat	Stat.	-5.35900	-5.09437	-0.10529	-10.4292	2.11633	-0.67519
	Prob.	0.0000	0.0000	0.4581	0.0000	0.9828	0.2498

Table A3.4 ADF Unit Root test: Lower Middle Income Countries

		gGDP	gICT	gNICT	gEmpl	gLQ	Export %
ADF - Fisher Chi-sq.	Stat.	102.620	64.8666	47.2447	188.696	23.6132	65.6534
	Prob.	0.0000	0.0347	0.4215	0.0000	0.9442	0.0300
ADF - Choi Z-stat	Stat.	-4.31373	-2.32728	-0.01291	-7.94839	1.89526	-0.62916
	Prob.	0.0000	0.0100	0.4948	0.0000	0.9710	0.2646

Table A3.5 ADF Unit Root test: Low-Income Countries

		gGDP	gICT	gNICT	gEmpl	gLQ	Export %
ADF - Fisher Chi-sq.	Stat.	64.6905	21.8151	20.7948	39.6908	3.04607	24.4221
	Prob.	0.0000	0.0825	0.1070	0.0003	0.9990	0.0407
ADF - Choi Z-stat	Stat.	-5.86386	-1.24403	-1.13450	-3.45277	2.46762	-1.51607
	Prob.	0.0000	0.1067	0.1283	0.0003	0.9932	0.0648

Table A3.6 ADF Unit Root test after differencing: Upper Middle Income Countries

		gGDP	gICT	gNICT	gEmpl	gLQ	Export %
ADF - Fisher Chi-sq.	Stat.	125.228	123.970	155.152	231.648	181.318	204.198
	Prob.	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
ADF - Choi Z-stat	Stat.	-5.35900	-5.09437	-8.09301	-10.4292	-10.1463	-10.3126
	Prob.	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000

Table A3.7 ADF Unit Root test after differencing: Lower Middle Income Countries

		gGDP	gICT	gNICT	gEmpl	gLQ	Export %
ADF - Fisher Chi-sq.	Stat.	102.620	64.8666	191.570	188.696	149.893	65.6534
	Prob.	0.0000	0.0347	0.0000	0.0000	0.0000	0.0300
ADF - Choi Z-stat	Stat.	-4.31373	-2.32728	-9.71971	-7.94839	-8.77278	-0.62916
	Prob.	0.0000	0.0100	0.0000	0.0000	0.0000	0.2646

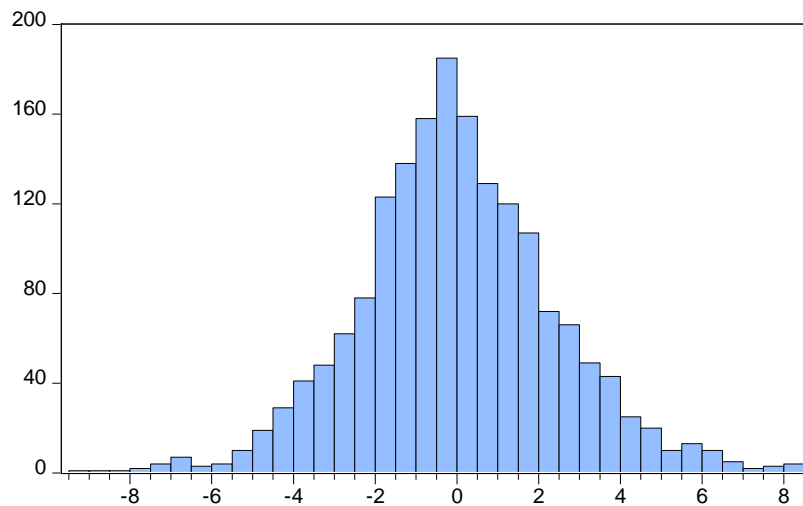
Table A3.8 ADF Unit Root test after differencing: Low-Income Countries

		gGDP	gICT	gNICT	gEmpl	gLQ	Export %
ADF - Fisher Chi-sq.	Stat.	64.6905	61.0251	53.6703	39.6908	59.1908	24.4221
	Prob.	0.0000	0.0000	0.0000	0.0003	0.0000	0.0407
ADF - Choi Z-stat	Stat.	-5.86386	-5.82998	-4.19703	-3.45277	-5.76712	-1.51607
	Prob.	0.0000	0.0000	0.0000	0.0003	0.0000	0.0648

Appendix 4 – Jarque-Bera Normality Test

H₀: Residuals are normally distributed

Table 4.1 Full Sample (All Countries).

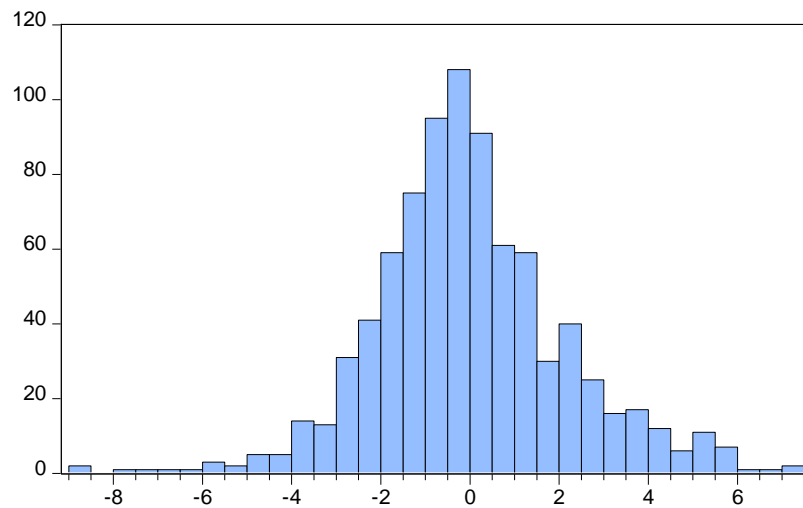


Series: Standardized Residuals
Sample 1995 2015
Observations 1751

Mean	1.63e-15
Median	-0.114663
Maximum	8.197447
Minimum	-9.297405
Std. Dev.	2.427543
Skewness	0.105282
Kurtosis	3.752990

Jarque-Bera	44.60176
Probability	0.000000

Table 4.2 High-Income countries.



Series: Standardized Residuals
Sample 1995 2015
Observations 836

Mean	-7.21e-16
Median	-0.147892
Maximum	7.190385
Minimum	-8.914543
Std. Dev.	2.170980
Skewness	0.124410
Kurtosis	4.255440

Jarque-Bera	57.05847
Probability	0.000000

Table 4.3 Upper Middle Income countries.

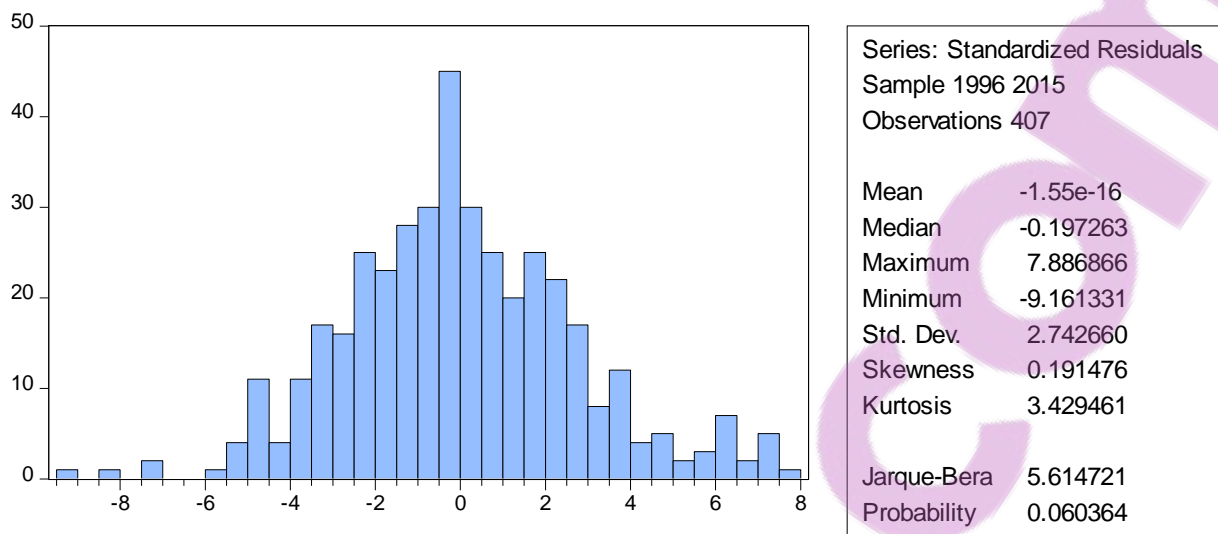


Table 4.4 Lower Middle Income countries.

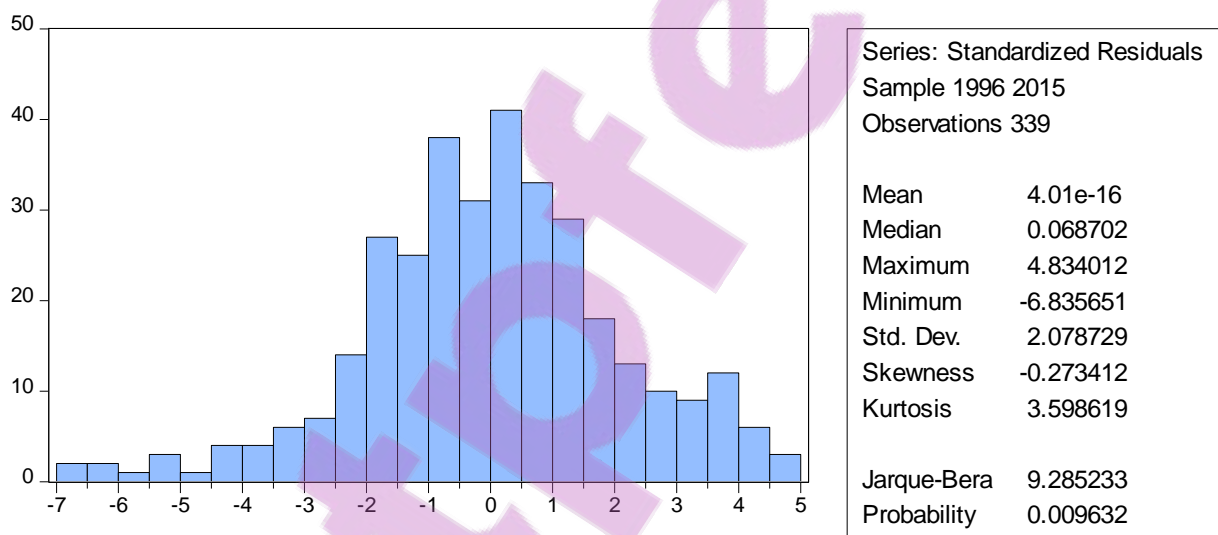
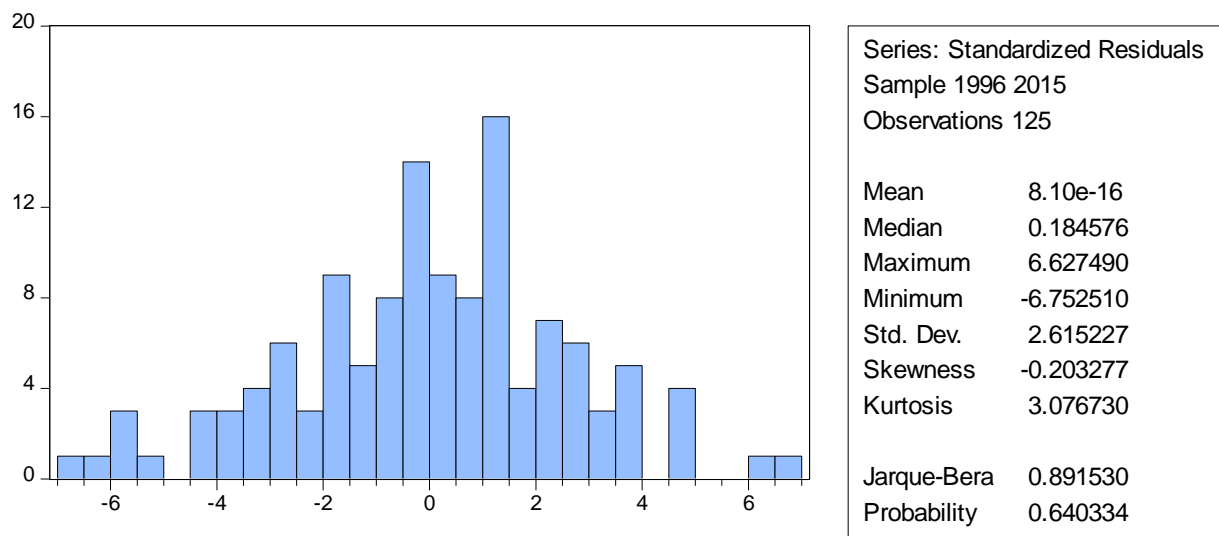


Table 4.5 *Low-Income countries.*



Appendix 5 – Regression Output

Table A5.1. Dependent Variable: gGDP - 1995 – 2015

Variables	OLS	FEM
gICT Capital Serv	0.020813**	0.022027**
gNICT Capital Serv	0.413037***	0.408713***
gEmployment	0.393381***	0.501715***
Constant	1.329270***	1.133286***
Adjusted R2	0.284039	0.415708

** $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$. All standard errors are estimated with Whites period coefficient covariance estimator*

Table A5.2. Dependent Variable: gGDP - 1995 – 2015

Group	Variables	OLS	FEM
High-Income	gICT Capital Serv.	0.055399***	0.058714***
	gNICT Capital Serv.	0.295426***	0.237978***
	gEmployment	0.559976***	0.714838***
	Constant	0.367899	0.293007
	Adjusted R ²	0.361622	0.453729
Upper Middle Income	gICT Capital Serv.	0.063687***	0.038003**
	gNICT Capital Serv.	1.299726***	1.307815***
	gEmployment	0.333807***	0.361461***
	Constant	2.634779***	2.944011***
	Adjusted R ²	0.357884	0.529958
Lower Middle Income	gICT Capital Serv.	0.040524**	0.014102
	gNICT Capital Serv.	0.784174***	0.744913***
	gEmployment	0.136332	0.236370**
	Constant	4.073894***	4.251202***
	Adjusted R ²	0.177185	0.354946
Low-Income	gICT Capital Serv.	-0.003823	0.003882
	gNICT Capital Serv.	0.508169**	-0.003882*
	gEmployment	0.693652**	0.688068**
	Constant	3.090505***	3.114454***
	Adjusted R ²	0.113361	0.196339

* $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$ All standard errors are estimated with Whites period coefficient covariance estimator