Information and Communication technology and its effect on productivity growth in seven European countries

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ABSTRACT

Productivity is an important factor in determining a nation's wealth, successfulness and long-run economic growth. As such it is of interest to determine what affects productivity and during the last couple of decade's information and communication technology has been seen as the next innovation to have a widespread impact on productivity growth. This paper empirically examines the impact of investments in information and communication technology on productivity growth in Austria, Denmark, Finland, Italy, Spain, the Netherlands and the United Kingdoms. Furthermore is the theory of ICT being a general purpose technology examined. The econometrical study is done by examining harmonized panel data for each country consisting of 22 different sectors during the period 1970-2007. Investments in labor, ICT capital and non-ICT capital are used as explanatory variables for value added which acts as a proxy for productivity. The study shows that investments in ICT capital has only had a significant impact on productivity growth for Austria, Finland and the United Kingdoms which raises the question whether ICT truly is a general purpose technology. The results differ from previous research and brings into question the validity of those studies, the methods used and the data that has been analyzed.

Keywords: ICT, GPT, Productivity growth, Panel data, Europe

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1. INTRODUCTION

Countries wealth is largely dependent on how productive they are. The ability to produce more goods at lower prices influences income differences across the globe and as such it is of interest to determine what affects productivity. An important part of being, and remaining productive, is the ability to develop and use new technology and innovations.

During the last couple of decade's information and communication technology[1] has been identified as one of the most important new innovations in the hunt for increased productivity, profitability and long-term economic growth and has been predicted to have a significant impact on all parts of the economy (Cardona, M., et al. 2013, p 109). It all started with the development of the microprocessor which allowed for a wide range of further innovations, applicable within different sections of the economy (van der Wiel, H. and G van Leeuwen, 2004, p 95). From when it first made an appearance in the 1970s ICT seemed destined to increase productivity and some even believed that it would usher in an economic era of high productivity growth, free from cyclical fluctuations and inflation (van der Wiel, H. and G van Leeuwen, 2004, sid 93).

Despite all this positivity economists initially struggled to find clear evidence of ICT having any impact at all on productivity. In 1987 Robert Solow described this phenomenon in the New York Times with the words "You can see the computer age everywhere but in the productivity statistics" (Solow, R. in Gregor, S. et al., 2006, p 250). He effectively described the fact that during the latter part of the 20th century when ICT became more common in the United States productivity slowed down. This productivity paradox, as it became called, puzzled many and led the importance of ICT to be questioned (Brynjolfsson, E., 1993, p 67). Since then many studies have been conducted to determine whether or not ICT does in fact have a significant effect on productivity in different countries or sectors but with mixed results (van der Wiel, H. and G van Leeuwen, 2004, p 94). One thing that may have hampered such studies is the general lack of comparable and reliable data on ICT (O`Mahoney, M and M Timmer, 2009, p 374).

[1]Information and communication technology will from now on be referred to using the acronym ICT.

The goal of this paper is to help determine whether or not investments in ICT has had a positive impact on productivity in various European countries by analyzing panel data from the relatively new EU-KLEMS database. The data consists of 22 different sectors for each country and covers the period 1970-2007. Due to restrictions in data availability only seven countries are studied. Panel data studies on ICT and its effect on productivity, covering European countries and using harmonized data on investments in ICT are rare and the author's ambition is that this study will help discerning the true impact of ICT in this part of the world.

1.1 Purpose of this study

The purpose of this study is to determine whether or not investments in ICT has significantly affected the productivity growth rates in seven[2] of EU-15s[3] member states.

The paper aims to answer the following questions using panel data analysis:

- Has investments in ICT capital had a significant effect on the growth of productivity in Europe and if so to what extent?
- Should ICT be classified as a general purpose technology?

1.2 Theory

The main theory of this paper is that investments in ICT, as a general purpose technology, has had a significant and positive impact on the growth of productivity. By applying a panel data analysis on productivity growth with ICT capital as one of the explanatory variables the hope is to find proof of it having a significant impact on productivity in Europe. The reasoning behind this theory is further expanded in chapter two.

[2]Austria, Denmark, Finland, Italy, Spain, the Netherlands and the United Kingdoms.

[3]Austria, Belgium, Denmark, France, Finland, Germany, Greece, Ireland, Italy, Luxembourg, the Netherland, Portugal, Spain, Sweden and the United Kingdoms.

1.3 Disposition

The disposition of the paper is as follows. In chapter two the concept of ICT is defined and the reasons why it has become of interest to study its effect on productivity is explained. In chapter three previous studies, what methods have been employed and their findings are presented. In the fourth chapter the econometric method used in this paper and how it may differ from previous studies is explained. In chapter five the source of data and the variables used are presented. In chapter six the econometric results are presented and discussed and in the final seventh chapter conclusions are drawn.

2. INFORMATION AND COMMUNICATION TECHNOLOGY

In the following chapter the term information and communication technology is presented and why it has become of interest to examine and determine its impact on productivity.

2.1 The components of ICT

Information and communication technology has three different components, as defined by the EU-KLEMS project. These are computing equipment, such as computers and other types of hardware, communication equipment, such as radio or television transmitters and receivers, and software (Timmer, M., et al., 2007, p 34-38).

2.2 ICT as a general purpose technology (GPT)

ICT has been hailed as a general purpose technology (van der Wiel, H. and G van Leeuwen, 2004, p 95). That is a technology which is not the finished article but acts as the means for further innovations and further productivity gains. Historic examples of such innovations are electricity, the steam engine and railways (David, P. and G. Wright, 1999, p 5-6). Three criteria's to be fulfilled has been suggested by Bresnahan and Trajtenberg in order to determine if an innovation is to be considered as a GPT (in Jovanovic, B. and P. Rosseau, 2005, p 1185). These are:

1. "Pervasiveness – The GPT should spread to most sectors."
2. "Improvement – The GPT should get better over time and, hence, should keep lowering the costs of its users."
3. "Innovation spawning – The GPT should make it easier to invent and produce new products and processes."

(Bresnahan, T. and M. Trajtenberg in Jovanovic, B. and P. Rosseau, 2005, p 1885)

As pointed out in the introduction the invention of the microprocessor has allowed for a large number of further innovations, such as the computer, the costs of producing ICT equipment has continuously fallen and by all accounts ICT in different forms has spread into different sectors of the economic system. For example has computers gone from being simple word-processing equipment in the 1970s to being platforms for an enormous amount of different application used for a wide array of tasks, allowing for reductions in resource costs (David, P. and G. Wright, 1999, p 17-19).

By the aforementioned criteria's ICT should be considered as a GPT and as such be an important component in driving productivity growth.

In an effort to determine whether this is true Jovanovic and Rosseau has compared the implementation of electricity, one of the most important innovations of the 20th century (Jovanovic, B and p. Rosseau, 2005, p 1182), in the United States economy to the implementation of ICT. Jovanovic and Rosseau come to the conclusion that ICT indeed is a GPT technology and that productivity improvements are to be expected because of it (2005, p 1221). However one important fact they point out is that the effects of a new GPT often does not show immediately and that it takes some time for it to have full effect (Jovanovic, B. and P. Rosseau, 2005, p 1182). In a historical comparison of various GPTs David and Wright compare the effects of the electrification on the economy in the United States and the United Kingdoms. This is done in order to determine if electricity had a similar impact as a GPT in the two countries or if it was an effect limited to the United States. Their study concludes that the effects where in fact similar (David, P. and G. Wright, 1999, p 11). However David and Wright (1999, p 13-14) also point out that even if ICT appears to fulfill the criteria's to be classified as an GPT it is no guarantee that its effects will mimic those of earlier ones, such as the electricity. If anything what their historical comparison suggests is a more careful optimism regarding ICT. The effects of it may not yet be fully visible but that is not to say they will not show in time.

As ICT shows the signs of being a GPT and as such has the ability to significantly affect economic growth across the world it has become an interesting field of study subject to a number of different approaches and methods, as will be discussed in the following chapter.

3. LITERATURE REVIEW

This chapter aims to present and discuss some previous studies of ICT and its effect on productivity and the methods that have generally been applied.

Studies on the effect of ICT on productivity can be divided into two separate groups in terms of the methods used. The first group of studies are those that have applied the non-econometric method called growth accounting. Growth accounting is used in order to determine how important capital, human capital and other inputs are to growth as well as to measure multifactor productivity (Timmer, M., et al., 2010, p 5-6). These studies have generally been conducted to determine the effect of ICT on different industries or countries. The second group of studies are those that have applied econometric methods primarily using industry-level data (Draca, M., et al., 2008, p 4-6).

The majority of studies on ICT and productivity have either tried to distinguish the difference between how Europe and the United States have been able to implement ICT or how ICT has affected individual countries (Draca, M., et al., 2008, p 57-59). The ones that focus on the differences between Europe and the United States have generally decided to treat and report the study results of Europe as a group rather than as individual countries.

Two examples of such studies are the fairly well known articles "The productivity gap between Europe and the United States: Trends and Causes" by O`Mahoney, Timmer and van Ark (2008) and "Does information and communication technology drive EU-US productivity growth differentials" by Timmer and van Ark (2005). These studies examines the phenomenon that productivity levels in Europe where converging to the levels of the United States for much of the 20th century only to fall behind during the second half of the 90s and beginning of the 21st century. Using growth accounting and looking at, amongst other things, investments in ICT the study by O`Mahoney, Timmer and van Ark (2008, p 26) attempts to answer why this has happened. The results show that the United States managed to increase their productivity through investments in ICT producing industries during the 90s and then reaped the rewards of further innovations within other sectors during the following decade. Europe on the other hand, says O`Mahoney et al. (2008, p 41), has failed to adopt new innovations into its economy and face great difficulties modernizing its institutions, labor market and how companies are run in order to once again catch up to the productivity levels of the United States.

In the article “ICT and productivity” Henry van der Wiel and George van Leeuwen applies both the growth accounting approach and the econometric one in an effort to examine the effect of ICT on Dutch labor productivity (2004, p 94). Productivity in the Netherlands where almost at the levels of the United States during the 1990s but has since fallen behind. They come to the conclusion that ICT has provided a significant boost to productivity growth on an aggregate level. The positive effect however is only seen in ICT producing and ICT intensive sectors while others have not benefitted from it. Looking ahead however they claim that ICT has the ability to enhance productivity growth rates across the board due to spillovers from productive, ICT intensive, sectors to those less productive (van der Wiel, H. and G. van Leeuwen, 2004, p 109-110).

There are not very many studies comparing the effect of ICT on productivity between different European countries, especially not using econometric methods. One such study is the article ”Information-communication technology impact on labour productivity growth of EU-developing countries” by Ljiljana Lovrićs (2012) in which the author attempts to determine the effects of ICT in the newest members of the European Union. By dividing European countries into two groups of developed and developing countries she concludes that there is a positive and significant effect for developed countries but that the results for developing countries are more ambiguous (Lovrić, L., 2012, p 239).

4. ECONOMETRIC METHOD

In this chapter the general model used to estimate the effects of investments in ICT on productivity is derived. The approach of similar studies are also discussed as well as the potential pitfalls when conducting a panel data analysis and how to avoid them. Lastly the final model used in the panel data analysis is presented and how the combined effect of the lagged and non-lagged variables is calculated.

4.1 General model

The aim of this paper is to analyze how investments in ICT have affected productivity, on an aggregate level, in seven different European countries. In order to conduct an empirical study a basic Cobb-Douglas production function model, similar to the one used by van der Wiel and van Leeuwen (2004, p 97) is constructed where Value added (VA) acts as a measurement of productivity and is explained by three different inputs, labor (L_{HW}), ICT-capital (K_{ICT}) and non ICT-capital (K_{NONICT}).

$$VA_{it} = AL_{HW_{it}}^{\beta_1} K_{ICT_{it}}^{\beta_2} K_{NONICT_{it}}^{\beta_3} e^{\varepsilon_{it}}$$

VA_{it} denotes gross value added value added, in real 1995 price levels, for each sector and time period, $L_{HW_{it}}$ the total amount of hours worked in each sector and time period, $K_{ICT_{it}}$ the amount of ICT specific capital in each sector and time period and $K_{NONICT_{it}}$ all other capital in each sector and time period. The model is linearized by taking logarithms.

$$\ln VA_{it} = \ln A_{it} + \beta_1 \ln L_{HW_{it}} + \beta_2 \ln K_{ICT_{it}} + \beta_3 \ln K_{NONICT_{it}} + \varepsilon_{it}$$

As the countries are similar in the sense that they all are industrialized countries from Europe it is assumed that they all have access to the same level of technology. It (A) varies over time (A_t) but not from sector to sector (A_i) and not between different countries. Because of this and in order to simplify the model the level of technology is therefore excluded.

$$\ln VA_{it} = \beta_1 \ln VA_{it-1} + \beta_2 \ln L_{HW_{it}} + \beta_3 \ln L_{HW_{it-1}} + \beta_4 \ln K_{ICT_{it}} + \beta_5 \ln K_{ICT_{it-1}} +$$
$$\beta_6 \ln K_{NONICT_{it}} + \beta_7 \ln K_{NONICT_{it-1}} + \varepsilon_{it}$$

4.2 Previous studies

Other studies conducted in the same vein as this one, such as "Information-communication technology impact on labor productivity growth of EU-developing countries" by Ljiljana Lovrić (2012, p 228), have generally applied lagged versions of the included variables in order to account for the possibility that previous periods affect current variables. The inclusion of a lagged dependent variable transforms the model into a dynamic one. Apart from being a logical inclusion, the lagged variables also help remedy problems with autocorrelation that otherwise would affect the model (Asteriou, D and S Hall, 2011, p 223).

What some other studies, such as "ICT and Productivity" by van der Wiel and van Leeuwen (2004), seemingly does not do is to apply fixed effects for cross-sections and variables, account for heteroskedasticity and check for unit-roots in variables and residuals. This may cause several serious problems. Not including fixed effects could cause problems with wrongly excluded variables as industry- and time specific properties, which otherwise would be included in the model, are not accounted for. Not accounting for heteroskedasticity by, for example, estimating the model with one of the White-estimators for robust coefficient standard-errors may result in the model underestimating coefficient variances and standard-errors leading wrongful rejection of the null hypothesis (Asteriou, D and S Hall, 2011, p 113). Not checking for unit-roots in variables and residuals effectively ignores the potential problems of estimating a model containing one or several non-stationary variables. This may cause the model, if it contains non-stationary variables, to give faulty estimates of the t-statistic making explanatory variables appear to be significant when in truth they are not (Westerlund, 2005, p 206).

4.3 Final model and econometric approach

As other studies have done lagged variables for VA, L_{HW}, K_{ICT} and K_{NONICT} are included in the model to take into account delayed effects and autocorrelation. Furthermore dummy-variables for cross-sections and periods are included to avoid wrongly excluded variables which otherwise could cause the OLS-estimator to become biased (Dougherty, C., 2011, p 518-519). As heteroskedaticity is commonly found in time-series data, and consequently in panel data (Asteriou, D och S Hall, 2011, p 110), the "White-diagonal" method is used to create robust coefficient standard-errors. The White estimator does not transform heteroskedastic variables into homoscedastic ones but adjust the variance matrix so that the problems associated with heteroscedasticity are minimized. The "White-diagonal" method is chosen because of the similar amount of periods and cross-sections within the panel data. Testing the included variables for unit-roots using the LLC (Levin, Lin and Chu) and IPS (Im, Pesaran and Shin) tests reveals that a large number where in fact non-stationary. Further testing of the regressions residuals also revealed that the variables where, in almost all cases, not cointegrated. This was done by unit-root testing the respective regression residuals, thus finally rejecting the use of the standard level-model. In order to address the issue of non-stationary variables the model is instead calculated using the first differences of all included variables.

Taking the first difference converts non-stationary variables in stationary ones, at a loss of some degrees of freedom, which allows for the OLS-method to be used (Westerlund, 2005, p 207). However using first differences changes the regression into one that describes growth rates rather than the level effects.

The fully expanded model, using lagged variables, fixed effects for cross-sections and periods, the White-diagonal method for robust coefficient standard errors and first differences of the included variables to handle non-stationarity, used in this study is defined as follows:

$$(\ln VA_{it} - \ln VA_{it-1}) = \beta_{1i} + \beta_{2t} + \beta_3 (\ln VA_{it-1} - \ln VA_{it-2}) + \beta_4(\ln L_{HW_{it}} - \ln L_{HW_{it-1}}) + \beta_5(\ln L_{HW_{it-1}} - \ln L_{HW_{it-2}}) + \beta_6(\ln K_{ICT\,it} - \ln K_{ICT\,it-1}) + \beta_7(\ln K_{ICT\,it-1} - \ln K_{ICT\,it-2}) + \beta_8(\ln K_{NONICT\,it} - \ln K_{NONICT\,it-1}) + \beta_9(\ln K_{NONICT\,it-1} - \ln K_{NONICT\,it-2}) + \varepsilon_{it}$$

4.4 Combined effects

As the effect of each variable is calculated both in its current and lagged state it is of interest to determine the combined effect and whether or not it is significant. In order to determine this the Wald-test of joint significance is applied to for each set of variables. In practice the effects of both explanatory variables, such as lagged labor and non-lagged labor, are combined and tested against the null hypothesis that they have an insignificant combined effect.

$$h_0: C(\beta_n) + C(\beta_{n+1}) = 0$$
$$h_1: C(\beta_n) + C(\beta_{n+1}) \neq 0$$

5. DATA AND RESTRICTIONS

The following chapter presents the source of the data material, the variables used in the analysis are presented and the restrictions in terms of available data are discussed.

5.1 Source of data

The data used in this paper comes from one source, the EU-KLEMS database. It is the result of a project, funded by the European Union, with the aim to collect harmonized data on capital, labor, energy, material and services over the period 1970 to 2007 for the member states of the EU as well as some additional OECD countries. The availability of comparable data between countries on, amongst other things, investments in ICT has generally been poor and this project, which ran from 2003 to 2008, was an attempt to address this issue (O'Mahoney, M. and M. Timmer, 2009, p 374-375). The lack of data has generally forced early studies on ICT and productivity to use the Structural Analysis database (STAN), released by the OECD, which was never intended to be used in productivity analysis. As a result researchers have been forced to apply different adjustments to their data which has resulted in poor comparability between different studies (O'Mahoney, M. and M. Timmer, 2009, p 381-382).

The data on value added and labor comes from the March 2011 update of the dataset on standard industry aggregate released in November 2008. The data on ICT- and non-ICT capital comes from the March 2011 update of the dataset on capital inputs released in 2008. All datasets used in this paper are available from the EU-KLEMS homepage (www.euklems.net).

5.2 Variables

The variables used in the analysis are value added, labor, ICT-specific capital and non ICT-specific capital for 22 different sections of the economy during the period 1970-2007. Value added is calculated at current basic prices in millions of euros and then deflated to real prices using the year 1995 as base. Labor is expressed as total hours worked by all persons engaged. ICT-capital and non ICT-capital are both expressed as the real fixed capital stock of each type, using 1995 as base. Together ICT capital and non-ICT capital account for the entire capital stock in each sector and time period. The 22 different sections of the economy, as defined by the EU-KLEMS database, are: Agriculture, hunting, forestry and fishing (1), Mining and quarrying (2), Food, beverages and tobacco (3), Textiles, textile, leather and footwear (4), Wood and of wood and cork (5), Pulp, paper, printing and publishing (6), Chemical, rubber, plastic and fuel (7), Other non-metallic mineral (8), Basic metals and fabricated metals (9), Machinery, NEC (10), Electrical and optical equipment (11), Transport equipment (12), Manufacturing NEC; recycling (13), Electricity, gas and water supply (14), Construction (15), Wholesale and retail trade (16), Hotels and restaurants (17), Transport and storage (18), Post and telecommunications (19), Financial intermediation (20), Real estate, renting and business activities (21) and Community, social and personal services (22).

5.3 Balanced and unbalanced data sets

For one country included in the analysis, namely Finland, the reported value of ICT-capital was zero for sector (1) during period 1970-1974, sector (2) during period 1970-1974, sector (4) during period 1970-1974, sector (5) during period 1970-1971, sector (8) during period 1970-1971, sector (13) during period 1970-1973, sector (15) during period 1970-1971 and sector (17) during period 1970-1971. In order to circumvent the problem of having one unbalanced dataset the earliest, and lowest, reported value was used to replace those missing in the affected sectors. For all other countries the data sets are fully balanced.

5.4 Restrictions

Despite the projects efforts data on investments in ICT-capital is still limited and only available to the public for seven European countries, for the full 1970-2007 period. These are Austria, Denmark, Finland, Italy, the Netherlands, Spain and the United Kingdoms. For some European countries such as Sweden and Germany data on investments in ICT is available for a shorter time period but for others such data is still not available at all or of restricted access. The limited availability of data places restrictions on the possible scope of this paper. Instead of comparing all EU-15 countries the analysis is only applied to those countries for which full, or in the case of Finland nearly full, datasets are available in order to conduct a comparable study of the included countries.

6. ECONOMETRICAL RESULTS AND DISCUSSION

In this chapter the results from the econometrical tests are presented and discussed.

6.1 Unit root and cointegration tests

Table 1: Unit root tests

	Variables							
	VA		L_{HW}		K_{ICT}		K_{NONICT}	
Test type / Country	IPS	LLC	IPS	LLC	IPS	LLC	IPS	LLC
AUT	0.0173*	0.3324	0.7883	0.4056	0.0107*	0.4012	0.6958	0.2319
DNK	0.0423*	0.2125	0.4633	0.4458	0.0009**	0.4092	0.9259	0.9076
ESP	0.1033	0.4827	0.9045	0.6132	0.2221	0.4267	0.0000**	0.0000**
FIN	0.0002**	0.0005**	0.0186*	0.0044**	0.0000**	0.0000**	0.0014**	0.0000**
ITA	0.0132*	0.0303*	0.6838	0.1046	0.2507	0.0036**	0.0000**	0.0000**
NLD	0.0000**	0.0004**	0.0572	0.0007**	0.0001**	0.0003**	0.9708	0.8249
UK	0.0012**	0.0240*	0.0004	0.0432*	0.3544	0.1231	0.4845	0.0203*

Notes 1: Tests against the null hypothesis of a unit root.

**=rejects the null at the 5 % level.*

***=rejects the null at the 1 % level.*

Testing whether the variables are stationary reveals that almost all countries have several non-stationary variables. Testing the residuals reveals that they are, for the most part, non-stationary as well and thus not cointegrated. The one exception is Finland but in order to conduct a comparable study all panel data regressions are calculated using the first-differences of all variables in order to avoid nonsensical results and ensure stationary variables. The tests used in order to determine the presence of a unit root in variables and residuals are the ones by Im, Pesaran and and Shin (IPS), which assumes a individual unit roots, and Levin, Lin and Chu (LLC), which assumes common unit roots.

Table 2: Cointegration tests

	Test type	
Country	IPS	LLC
AUT	0.8555	0.3276
DNK	0.4698	0.3507
ESP	0.0197*	0.2144
FIN	0.0003**	0.0000**
ITA	0.3721	0.0017**
NLD	0.1721	0.0296*
UK	0.3250	0.2076

Notes 2: Tests against the null hypothesis of a unit root.

**=rejects the null at the 5 % level.*

***= rejects the null att the 1 % level.*

6.2 Panel data regression

The panel data regression is conducted using balanced data sets for all seven countries over the 1970-2007 period. Separate estimations of all coefficients and their respective P-values are obtained for all countries in order to determine their significance and effect.

Table 3: Regression results using panel data

	Explanatory variables						
Country	VA(-1)	L_{HW}	L_{HW}(-1)	K_{ICT}	K_{ICT}(-1)	K_{NONICT}	K_{NONICT}(-1)
AUT	-0.037020 (0.4971)	0.144035 (0.1689)	0.148108 (0.1160)	0.055200 (0.0483)*	0.043732 (0.3983)	0.253838 (0.0599)	-0.319614 (0.0502)
DNK	-0.060068 (0.4117)	0.612857 (0.0000)**	-0.036085 (0.7599)	-0.007167 (0.8934)	0.055666 (0.1995)	0.370079 (0.3372)	-0.163929 (0.5449)
ESP	0.100792 (0.0611)*	0.516617 (0.0000)**	-0.040433 (0.5019)	0.003033 (0.9388)	-0.033275 (0.4533)	0.188750 (0.0723)*	0.142462 (0.1670)
FIN	0.033287 (0.5288)	0.743904 (0.0000)**	-0.191456 (0.0174)*	0.028779 (0.0439)*	0.008894 (0.5142)	-0.053328 (0.5941)	0.138331 (0.1630)
ITA	0.076043 (0.1318)	0.281110 (0.0000)**	-0.142685 (0.0292)*	0.012639 (0.7679)	-0.017146 (0.7085)	0.150897 (0.4542)	0.110979 (0.5732)
NLD	0.183800 (0.0063)**	0.046011 (0.7106)	-0.271644 (0.0064)**	0.043966 (0.2414)	-0.052690 (0.1511)	0.393263 (0.0006)**	-0.051348 (0.6830)
UK	0.152074 (0.0075)**	0.279003 (0.0000)**	-0.159562 (0.0038)**	0.064010 (0.0447)*	0.017491 (0.6044)	0.124260 (0.2419)	-0.131315 (0.1658)

Notes 3: Coefficient values and P-values. P-values are given within parenthesis.

**= significant at the 5% level.*

***= significant at the 1 % level.*

The panel data regression reveals that investments in ICT capital does not have an as widespread impact on productivity growth in the studied countries as was expected. A significant effect on productivity growth can only be proven for three countries, Austria, Finland and the United Kingdoms.

The regression results for Austria reveals that only one of the included variables, K_{ICT}, have a significant impact on productivity growth. Neither lagged value added, the two labor variables, lagged ICT capital nor non-ICT capital has a significant effect. The positive impact of ICT is not very large, a 1 % increase in ICT capital only yields roughly a 0.06 % increase in productivity growth.

In Denmark investments in ICT capital does not have any statistically significant impact on productivity growth at all. The only variable which provides an impact is the growth of labor. On the other hand the positive impact of more labor is fairly large. Increasing hours worked by 1 % yields a 0.6 % increase in overall productivity.

The model for Spain shows that lagged value added, labor and investments in non-ICT capital are the variables with a significant and positive effect. Increases in productivity growth in previous periods has a positive impact of 0.1 %, growth in human capital has a strongly significant effect and increases productivity growth by 0.5 % and increased growth in non-ICT capital has a positive effect of 0.2 %.

Finland is one of the few countries in which investing in ICT capital has had a positive impact on productivity growth. On top of that increases in labor capital has a positive impact on productivity growth while lagged labor has a negative impact. Growth in ICT capital provides a small but positive impact on productivity growth of 0.03 % for each 1 % growth in ICT capital. Increasing labor by 1 % in the current period provides a positive impact of 0.74 % while the previous period provides a negative impact of 0.2 % to productivity growth.

In Italy the only variable with a positive impact on productivity growth is labor. Human capital in its non-lagged state is strongly significant and yields a 0.3 % increase in productivity growth for each 1 % increase while the lagged version of labor provides a negative impact of 0.15 %.

The results for the Netherlands show that the lagged version of value added, lagged labor and non-ICT capital have significant effects on productivity growth. Lagged value added has a strongly significant effect and provides 0.2 % increased productivity growth. Lagged labor has a negative impact of 0.3 % while non-ICT capital has a positive effect of 0.4 %.

In the regression results for the United Kingdom it becomes clear that lagged value added, labor, lagged labor and ICT capital has a significant effect on productivity growth. Lagged value added provides a 0.15 % increase in productivity growth. The impact of labor is strongly significant and provides a 0.3 % increase in productivity growth while lagged labor has a negative effect of 0.15 %. Lastly ICT capital has a positive effect of 0.06 % on productivity growth per 1 % increase in ICT.

The most surprising results, apart from the lack of impact from ICT capital, is that lagged value added does not provide a significant impact on productivity growth in more countries. One could expect that growth would drive itself in the sense that positive growth during one year would allow for further expansions on industry, sector and national level, thus providing an impact on future periods as well. The closest thing to a pattern within the studied countries, as to what drives productivity growth, is that growth in labor provides a significant effect in all countries but Austria and the Netherlands.

The genuine lack of impact on productivity growth from ICT both in terms of its effect being visible in very few countries as well as the modest contribution in those countries where it has an effect may be cause for worry in terms of ICT being classified as a GPT.

6.3 Wald-test of joint significance

The Wald-test is used for each pair of lagged and non-lagged variable in order to determine their joint effect and significance.

Table 4: Wald-test of joint significance

	Explanatory variables		
Country	L_{HW}+L_{HW}(-1)	K_{ICT}+K_{ICT}(-1)	K_{NONICT}+K_{NONICT}(-1)
AUT	0.292143 (0.0206)*	0.098932 (0.0291)*	-0.065776 (0.6651)
DNK	0.576772 (0.0002)**	0.048500 (0.3342)	0.206151 (0.4119)
FIN	0.552448 (0.0000)**	0.037673 (0.0521)	0.085003 (0.3430)
ESP	0.476184 (0.0000)**	-0.030241 (0.4537)	0.046288 (0.5905)
ITA	0.138425 (0.0572)	-0.004507 (0.9076)	0.261877 (0.0508)
NLD	-0.225633 (0.1547)	-0.008724 (0.8288)	0.341914 (0.0065)**
UK	0.119441 (0.1510)	0.081501 (0.0032)**	-0.007055 (0.9269)

Notes 4: Joint coefficient values and P-values. P-values are given within parenthesis.

**= significant at the 5 % level.*

***= significant at the 1 % level.*

The joint significance tests shows some different results. Both labor and ICT capital are now statistically significant in Austria albeit non-ICT capital is not. The results for Denmark are not different, it is still only growth in labor that provides a significant effect on productivity growth. ICT capital no longer provides a significant effect on productivity growth in Finland, only labor. The combined effect of non-ICT capital is not significant for Spain while labor still is. None of the combined variables is significant for Italy while only the combined effects of non-ICT capital is significant for the Netherlands. For the United Kingdom only the combined effects of ICT capital provides a significant effect on productivity growth.

These results further downplays the impact of ICT on productivity as only two countries can be said to have been benefited in terms of increased productivity growth because of investments in ICT.

7. CONCLUSION

The purpose of this study has been to determine the effect of investments in information and communication technology on productivity growth in seven different European countries in an effort to compare which countries have been the most successful in adopting this new innovation and if ICT has had a widespread impact in Europe as a whole. Additionally the argument whether ICT is a general purpose technology is examined.

The basic model used to conduct the analysis is similar to previous studies and attempts to explain value added by including three inputs which are labor, ICT capital and non-ICT capital. Additionally the variables are lagged, transforming the model into a dynamic one, and calculated using first differences in order to account for the probability that previous periods affects current results and the fact that most variables are non-stationary. What sets the study apart from others is that it examines several European countries using an econometrical analysis of panel data instead of growth accounting and uses harmonized data on labor and capital. The panel data consists of data on total hours worked, ICT capital and non-ICT capital for 22 different sectors. To the authors knowledge there has to date been no study of this kind.

Two main conclusions can be drawn from the econometrical results. The first is that investments in ICT capital has not had a particularly widespread effect on productivity growth in Europe. The panel data analysis shows that only in three countries, Austria, Finland and the United Kingdoms, is there a signs of it having a significant and positive impact. On top of that the boost to productivity growth is not very large in those countries, ranging from 0.03 to 0.06 % per 1 % growth in ICT capital. Instead what appears to be the main source of productivity growth in the analyzed countries is growth in labor, represented as hours worked. It has a significant effect in a majority of the panel and by far outshines the effect from investing in ICT capital.

These results are opposite from what other studies on countries in Europe such as the ones by van der Wiel and van Leeuwen and Ljiljana Lovrić, which are presented in the literature review, have shown. Why the results differ may depend on the choice of, or availability of, data. As described earlier in this paper the availability of data on different aspects of investments in ICT has been lacking and has forced researchers to construct their own which may or may not be perfectly suitable to the task.

The second main conclusion is that ICT does not appear to have the impact one would associate with an innovation described as a GPT. Despite the fact that ICT seems to fulfill all the criteria associated with a GPT this study shows that the actual impact on productivity growth has not appeared, at least not in the countries studied in this paper. As the dawn of ICT was back in the 1970s one could argue that if it was going to significantly impact productivity growth across the world the effects of it would be more apparent by now. It might be time to question whether it actually is a mistake to describe ICT as a GPT, and by extension expect it to have such an overwhelming impact on productivity growth and that previous studies may have given false results due to the poor availability of data.

On the other hand it could be, as argued, that the effects of any GPT takes time to show and that ICT might just be a bit slower to be adopted into the economies of Europe or that European countries have not invested enough in ICT to be able to reap the benefits in the same way as the United States where able to in the beginning of the 21st century, as some studies have claimed. Additional possibilities is that the model used in this study contains errors or that the analyzed countries are exceptions rather than the norm for European countries. Unfortunately the kind of data used in this study is still only available for a few countries and it might be that future studies, with better access to comparable data for a longer period, shows different results.

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8.1 Other sources

Data for value added, total hours worked, ICT capital and non-ICT capital are available at www.euklems.net, 2015-05-25