The economic impact of digital technologies in Europe

Rinaldo Evangelista

University of Camerino, School of Law

Piazza Cavour 19, 62032 Camerino, Italy

Tel.: +39-0737-4043074; Fax: +390737 402812

e-mail: rinaldo.evangelista@unicam.it

Paolo Guerrieri

University of Rome "La Sapienza"

Via Del Castro Laurenziano 9, 00161, Roma

e-mail: paolo.guerrieri@uniroma1.it

and

Valentina Meliciani

University of Teramo

Campus di Coste S. Agostino, 64100 Teramo, Italy

e-mail: vmeliciani@unite.it

Paper prepared for the SIE meeting, October 2014, Trento

Abstract

This paper analyses the economic impact of digital technologies in Europe distinguishing between different stages/domains of the digitalization process. A set of composite ICT indicators is used capturing the access to ICTs, the ability to use them and the digital empowerment of individuals in key social and economic domains. We argue that the mere accessibility to ICT facilities is only a pre-condition for moving towards a digitalized society, while the "level" and the "quality" in the *use* of these technologies, as well as the conditions facilitating or hampering digital empowerment, play a much more important role. Several transmission mechanisms from ICT access, usage and digital empowerment to key macroeconomic variables (namely labor productivity, GDP per capita, employment growth and the employment rate) are identified. The econometric evidence supports our hypotheses showing that the usage of ICT, and mostly digital empowerment, exert the major economic effects, especially on employment also favoring the inclusion of "disadvantaged" groups in the labor market. We conclude that digitalization may drive productivity and employment growth and that inclusive policies may effectively contribute to bridge the gap between the most favoured and the disadvantaged parts of the population, thus helping achieving the 2020 Europe targets.

Keywords:

Digitalization, economic performance, e-inclusion, ICT empowerment, ICT usage

Journal of Economic Literature classifications:

O30 – General: Technological Change; Research and Development; Intellectual Property Rights

O33 - Technological Change: Choices and Consequences; Diffusion Processes

1. Introduction

Over the last two decades the pervasive role played by Information and Communication Technologies (ICT) in our economies and societies has been investigated by a massive amount of literature and has originated an entirely new stream of theoretical and empirical research. A large section of this literature has tried to assess the economic impact of ICT, in particular on key performance variables such as output and productivity growth, at any possible level of aggregation (firms, sectors, regions and countries). The most common approach used to measure the economic impact of ICT has consisted of incorporating this new technological input within a typical production function setting (OECD 2004; van Reenen, Draca and Sadun 2007). This implies that ICT has been assimilated to any other traditional production factor, in this way dismissing the general purpose nature of these technologies and the variegated channels through which they affect the economic and social landscape.

In the last decade a more complex and holistic way of looking at ICT, and at their potential contribution to economic and social life, has progressively emerged. The recent literature on digital inclusion and exclusion, as well as the concepts of e-inclusion and e-exclusion (Guerrieri and Bentivegna 2011) reflect this enlarged perspective and ask for the adoption of a more complex and multidimensional view on the relevant dimensions and mechanisms governing the relationship between ICT and the economy. In this enlarged perspective, the relationship between ICT and the economy becomes less strictly technological in nature, less linear and deterministic, and mediated by a variety of contextual (economic, social and cultural) factors affecting the ways, and the extent to which, the new opportunities offered by ICT can be actually appropriated and exploited by individuals, organizations, economies and societies at large.

The move towards a different view on ICT and their effects stands out clearly also in the current policy agenda of EU as visible in the RIGA targets as well as in the policy guidelines contained in

the EU i2010 policy framework (CEC, 2007). The move towards a digital society does not consist much in "getting people using technology" but rather "it is about the uses of technology to impact on and transform people lives". Individuals and their social and economic behaviours, rather than firms and production activities, become the relevant policy targets and objects of the analysis in an e-inclusion perspective. Dealing with digitalization, and assessing its socio-economic impact, requires therefore first and foremost to overcome the traditional and narrow infrastructural, supply-side, and technology based perspective of ICT as well as using more comprehensive indicators on the diffusion and use of ICT in the economy and society at large. As it will be discussed in the next section, the need of moving in such a direction has been put forward by the most recent development of the literature on digital divide and digital exclusion/inclusion. This multidisciplinary stream of contributions has clearly highlighted that the presence of an ICT infrastructure and the mere accessibility to ICT facilities are only a necessary pre-condition for moving towards a digitalized society and that the "level" and the "quality" in the *use* of these technologies, as well as the conditions facilitating or hampering such "digital empowerment", are likely to play a much more important role.

As it will be highlighted in the following section, despite this change of perspective, the economic impact of ICT continues to be assessed (especially at a macro and cross-country level) adopting an "infrastructural/access view", with little attention to the extent to which, how and in which socio-economic domain, ICT are used. This is largely due to data constraints. In fact, despite in most countries the collection of data on ICT has over the last decade progressively expanded, national surveys provide a rather heterogeneous array of data difficult to be standardized and synthesized in a manageable set of internationally comparable indicators.

This paper aims at exploring the macro-economic impact of ICT in a comprehensive way, overcoming the supply-side and infrastructural perspective of most of the existing empirical

literature. This will be done by using a new set of macro-level indicators of digitalization provided by a recent EU study.[1] A major research task of this project has consisted of surveying and collecting data from the most relevant international data-sets on ICT and synthesising the latter into three composite indicators of digitalization broadly referring to: a) the level of ICT *infrastructure*; b) the actual *usage* of internet services; c) the *impact* of these technologies and services in key socio-economic domains and the associated process of digital *empowerment*. The main value added of this paper consists of having clearly distinguished between these three dimensions or stages of the digitalization process, and in having assessed whether they exert a different impact on key macro-economic variables, focusing in particular on the contribution they provide to employment growth and to the employability of "disadvantaged" groups. The econometric analysis will consist of relating the three composite indicators of digitalization to three sets of aggregated economic variables and namely to: a) labour productivity and per capita GDP growth; b) employment growth (total employment, manufacturing and services employment); c) growth in employment rates referred to specific "disadvantaged" groups (women, older and long term unemployed people).

The paper is structured as follows: the next section contains a review of the relevant literature. Section 3 describes the dataset and the three composite indicators of digitalization that will be used in the econometric analysis. In section 4 the theoretical framework and the possible transmission mechanisms between each of the different stages and dimensions of digitalization and the country level performance variables used in the empirical analysis will be presented, while section 5 contains the results of the econometric estimations. The final section summarizes the main results of this contribution and discusses possible future developments and policy implications.

2. A review of the literature

As already mentioned, the move toward a more complex and multifaceted perspective of ICT and their impact on the economy and society owes very much to the literature on digital inclusion and exclusion. In fact, also this literature started adopting a strict infrastructural/access perspective, the digital divide phenomenon being defined as a gap between those "who have" access to ICT and those "who have not". However, this approach has progressively evolved towards a more complex and multifaceted perspective on both ICT and the dimensions and factors characterizing the process of ICT diffusion and use. The terminological shift from the term "digital divide" (implying a binary vision of the digitalization processes) to terms such "digital inclusion/exclusion", "digital inequality" (Di Maggio and Hargittai 2001; Hargittai 2003) up to the formulation of concepts such as "e-inclusion/exclusion" further synthesize this change of perspective. As pointed out by DiMaggio and Hargittai (Di Maggio and Hargittai 2001) the term "digital inequality" describes not just differences in access (labeled as the first-level, or basic digital divide), but autonomy of use, skill, social support and the purposes for which the technology is employed (labeled as the second-level digital divide).

Also the evolution of the empirical literature on digital inequality reflects this change of perspective. It has in fact advanced from examining the extent and causes of differences in the mere access to ICT to differences in the intensity and types of use of the new technological platforms. While early research studied digital divides by sex, race, and income in computer ownership and Internet access (Hoffman and Novak 1998; Ono and Zavodny 2003), subsequent studies have emphasized differences in frequency of use, types of applications used, and access to emerging technologies such as broadband (Robinson, DiMaggio and Hargittai 2003; OECD 2007).

In most of this literature human capital plays a key role for explaining phenomena of digital

inclusion and exclusion. The main argument is that skilled (i.e. educated) workers are more capable of learning how to use new technologies and that they are more flexible with respect to their job assignment. The adoption of ICT often requires a reorganization of the firm, and a firm with a high percentage of skilled workers can implement information technologies more easily. However, when tested in a macro cross-country framework the empirical evidence has not produced univocal results. Those authors who analyze samples including both developed and developing countries find mixed evidence (Baliamoune-Lutz 2003; Chinn and Fairlie 2007), whereas those who analyze OECD countries find a significant influence of the level of human capital on ICT adoption and use (Hargittai 1999; Guerrieri, Luciani and Meliciani 2011; Lera-López, Billon and Gil, 2011; Cette and Lopez, 2012).

Demographic factors such as the age structure of the population and the size of urban population have also been identified as key factors associated to the level and quality of digitalization processes. The idea is that ICT have larger diffusion among younger people[2] and that urban population tends to adopt more ICT (internet and computer) because of network economies. Several studies, as well as the recent figures released by OECD and EUROSTAT, show that the shortage of ICT skills is concentrated among the old generations (Miniaci and Parisi, 2006; OECD 2008).

The literature analyzing the new phenomena of digital inclusion and exclusion tends to focus more on the determinants and obstacles in the use of ICT rather than on their economic effects. In fact, the economic impact of ICT constitutes the specific object of the analysis of another major stream of empirical (largely econometric) literature. Results and methodologies, as well as strengths and limitations of this stream of literature, have been effectively synthesized by several reviews (OECD 2004; van Reenen, Draca and Sadun 2007). What is important to point out here is that, when compared to the literature on ICT diffusion and digital divide, the econometric literature estimating the economic impact of ICT has adopted a rather supply-side, linear and deterministic view of the

economic effects of digitalization. Regardless of the variables being examined (internet, broadband, telecommunication, hardware, software, ICT) these studies have focused on the mere presence of ICT infrastructures or the mere use of ICT equipments with no (or little) attention to the capability to use them and to the associated process of digital empowerment.

While the majority of these studies converge in finding positive growth effects of the new technologies (Oliner and Sichel 2000; Czernich et al. 2011),[3] there are also studies which find more ambiguous and counter-intuitive evidences showing that ICT have not prevented the productivity slowdown in Europe (Inklaar, O'Mahony and Timmer 2005; van Ark, O'Mahony and Timmer 2008; Brasini and Freo, 2012) or questioning the idea that ICT will exert the same productivity enhancing effects as past technological revolutions (Linstone and Devezas 2012) or even finding a negative relationship between broadband deployment and economic output (Thompson and Garbacz 2007). Possible explanations of these puzzling results include the so called "delay hypothesis" (existence of time lag between the introduction of ICT and the time the economic effects show up), the presence of a negative time-wasting effect on labor productivity accompanying the first introduction of these technologies, the presence of thresholds effects.

In the light of the literature reviewed above, among the factors explaining the "puzzle" one might also consider that, at least as far as the effect of ICT on (labor) productivity is concerned - what really matters is not just the availability of the ICT infrastructure but the extent and ability to use it in an effective or creative way by individuals and organizations[4].

Most of the econometric estimates of the economic impact of ICT have focused on the growth and productivity effects of these technologies somehow downplaying the effects of digitalization on other relevant phenomena of social and economic inclusion. The impact of digitalization on employment and on the demand and supply of labour represent in this respect critical areas of

investigation and social concern. As far as the employment impact of ICT most of the literature has debated around the supposed skill biased nature of these technologies. The main hypothesis is that not only the use of digital technologies tends to substitute low-qualified labour routines but also that labour (or total factor) productivity gains can be obtained only if the adoption and use of ICT are complemented with qualified skills and competencies (Autor and Murnane 1998; Machin and Van Reenen 1998). The increase of wage differentials (more pronounced in the USA and UK then in continental Europe) has in fact been often associated to the widespread diffusion of digital technologies and interpreted as the result of a strong increase in the demand of qualified (digitally skilled) labour which has not found in the labour market, and in the education system as whole, a corresponding capacity of supplying these set of competencies and skills (Krueger 1993; Spitz-Oner 2006). The implication of such paradigmatic change in the organization of production systems is that old generations and digitally unskilled labour represent the most vulnerable component of the labor force which is more likely to risk of getting laid off during periods of downturn and of experiencing long-lasting periods of unemployment (Codagnone 2009). More in general, it has been shown that the access and ability to use ICT affects employability conditions along the entire long life cycle of individuals, being able to influence the decision to enter the labor market (the labor participation decision), the likelihood of getting a job (the transition from unemployment to employment) (Codagnone 2009), the likelihood of losing a job (the transition from employment to unemployment) (Friedberg 2003; Aubert, Caroli and Roger 2006) as well as decisions of early retirement (Bartel and Sicherman 1993; Schleife 2006).

Despite the dispute about the skill biased nature of ICT is still at the centre of a lively debate (Di Nardo and Pischke 1997; Dolton and Pelkonen 2008), the empirical research produced over the last two decades seems to provide an overall support to the idea that ICT produce both positive and negative effects on employment, working conditions and wages, and that such positive and negative

effects are unevenly distributed across the different sections of the economy and the labour force. That being said, what is the net aggregate impact of ICT on employment? This is the most difficult question to be answered. The difficulty arises from the necessity of taking jointly into account both the direct (negative-labour saving) effects of ICT in most scale-intensive manufacturing and service industries and the numerous indirect (largely positive) effects ICT are likely to produce in the rest of the economy through the creation of new industries and markets, the reduction of prices and the increase of income (Evangelista and Savona 2003). In fact, the theoretical and empirical debate on the relative importance of positive and negative effects of technological change on employment has a long tradition in economics and after two centuries it has not produced any conclusive answer (Pianta 2005). The net aggregate employment impact of technological change becomes even more difficult to be determined in the case of ICT. This is because of the pervasiveness of these technologies and their widespread impact on almost any domain of our economic and social life. In the light of these difficulties it does not come as a surprise that the overall employment impact of ICT has been so far seldom investigated. In absence of substantiated empirical analyses an optimistic vision of the long term effects of ICT on the economy and society tends to prevail. Also the literature on the skill bias nature of ICT suggests that the net employment impact of ICT is positive, especially in the case of economic systems able to exploit the opportunities offered by ICT in sectors where international demand is rapidly growing and specialized in manufacturing and services industries where ICT do not have a dominant labour saving effect (OECD 2012).

All in all, we conclude this brief literature review by pointing out that despite the important steps ahead made towards a more complex and less deterministic view of the digitalization process, most of the empirical analyses assessing the aggregate socio-economic impact of ICT fails to incorporate this broader perspective. In fact, while most of the contributions reviewed above seem to be aware of the importance of the qualitative dimension of the processes of ICT diffusion and

use, as far the empirical assessment of the economic impact of digitalization, the (potential) different role played by the ICT infrastructure, the actual use that firms and individuals make of it and the areas where the beneficial effects are likely to be expected remains a largely under investigated topic, especially with regard to the impact on employment. The empirical analysis contained in this paper aims precisely at overcoming these caveats through the use of a new and more comprehensive set of indicators on ICT *infrastructure*, *use* and *empowerment*.

3. A new set of composite indicators of digitalization of economies and societies

The empirical exercise proposed in this article is based on the use of new data on digitalization provided by a EU project funded by the DG Information Society titled "Analysis of e-Inclusion impact resulting from advanced R&D based on economic modeling in relation to innovation capacity, capital formation, productivity, and empowerment (Guerrieri and Bentivegna, 2011). The data-set was built screening, selecting and merging data on ICT drawn from several international sources. Eurostat, and more in particular the data collected by the harmonized EU surveys on information society, constitutes the major information source used in the project. The other two main information sources used are the World Development Indicators (WDI) and the International Telecommunication Union (ITU). The data-set covers the all EU27 area over the period 2004-2009 and contains a very large number of ICT variables reflecting the different dimensions of digitalization of society and economy.[5]

All the variables contained in the data-set have been used to compute one composite overall digitalization index (European Digitalization Development Index - EDDI), and three sub-indicators grasping the different stages of the digitalization process, measuring respectively a) the level of ICT infrastructure (ICT *access* dimension), b) the level and quality in the use of ICT by individuals

and firms (ICT *usage* dimension), c) the personal and social empowerment of digitalization in key socio-economic areas: Education, Labour, Health, Government, Economy, Culture and Communication (ICT *empowerment* dimension).

Table I contains a detailed description of the variables used to compute the three indicators of digitalization (which are incorporated into the global EDDI index) as well as the original statistical source of each variable. EDDI and the three synthetic indicators have been computed as simple averages of a large number of ICT variables which have been previously normalized within a "zero to one" range. As a consequence also EDDI and the three sub indicators (*Access, Usage, Empowerment*) vary (across country) within the same range. Detailed information on the methodology used for the computation of composite indicators can be found in Guerrieri and Bentivegna (2011). For the purpose of our empirical analysis it is important to note that the Infrastructure digitalization index measures quantitative and qualitative aspects of the national ICT "network" as well as the "affordability" and "quality" of internet services available in each country. The usage digitalization index captures the level, quality and intensity in the use of internet services as well as the skills implied in the use of these services. Finally, the empowerment indicator captures personal and social empowerment resulting from Internet take-up in various spheres (Education, Labour, Health, Government, Economy, Culture and Communication) of people's daily lives. The different indicators should, therefore, capture different stages of the digitalization process starting from the mere availability of digital technologies, moving to the quality and skills in their use and to their diffusion in key socio-economic areas thus changing people's everyday life.

(Table I about here)

Figures 1 to 3 report the values of the ICT access, usage and empowerment indexes for European countries in 2004 and in 2008.

(Figures 1, 2 and 3 about here)

In the case of infrastructure we can notice slight increases over the period 2004-2008 for most countries with the exception of Italy where the index decreases. Taking the EU 27 as an average, the ICT infrastructure index increases only three points in five years (from 0.24 to 0.27). This means that overall in Europe the very basic conditions for accessing internet facilities have not changed much over the period considered in our analysis. This in turn might reflect the fact that ICT infrastructures require time and large investments in order to be enlarged. Figure 1 also shows a clear-cut country ranking in the EU 27 area, which appears rather stable over time. Although the coefficient of variation of the index decreases (from 0.40 in 2004 to 0.32 in 2008), due to the behaviour of some catching up countries (mostly East European countries), the infrastructural gap between the countries at the frontier and those lagging behind remains large.

The indicator measuring the actual use of internet facilities (Figure 2) shows a greater dynamism (the EU 27 average increases from 0.30 to 0.46) signalling that in most countries both individuals and firms are getting more and more familiar with ICT facilities, intensifying the use of the network. Starting from large differences between countries in usage (larger than the ones referring to the mere presence of ICT infrastructures), such gaps decrease between 2004 and 2008 so that in 2008 differences across countries in the use of ICT are similar to those registered in terms of access (the coefficient of variation of the usage index is 0.48 in 2004 and decreases to 0.31 in 2008). More in general Figure 2 hints at the presence of different country specific patterns differing in terms of the starting position and the dynamic performances as far as the use ICT is concerned. More in particular, three different behavioural patterns (and country groups) can be identified:

"consolidating behaviours" manifested by countries which have a solid technological tradition and continue to preserve it (such as Denmark, Finland, Luxembourg, the Netherlands, Sweden and the UK), "virtuous behaviours" manifested by countries which are trying to quickly recover lost ground in the country's digitalization process (such as Austria, Czech Republic, France, Hungary and Lithuania) and "resigned behaviours" manifested by countries which are stuck in a situation of technological backwardness (such as Cyprus, Italy and Malta).

Finally, looking at the empowerment dimension we observe the largest increases when compared to the other two indexes (the EU 27 average level of the index increases from 0.16 to 0.28) and the largest differences across countries (the coefficient of variation is 0.53 in 2004 and 0.38 in 2008). This evidence confirms on the one hand that the process of empowerment allowed by the use of ICT in many economic and social domains is rapidly progressing in the EU area but, at the same time, that this process is very uneven across the EU members. There is a group of countries which shows a very rapid growth pattern, higher than the average increase, this group includes many Northern European countries (Denmark, Sweden, Latvia, Finland) plus Slovenia, France, Luxembourg, the Netherlands, and UK. On the other hand, there is a group of countries that is lagging behind in terms of progresses in the implementation of the new technologies in many domains of the society and that is in a position of not being able to take the possible full economic benefits of digitalization. This group includes Italy, Bulgaria, Greece, Romania, and Cyprus.

Overall, moving from the access dimension, to usage and empowerment we can notice an increase in the differences between countries that are at the frontier and those that are lagging behind as far as the capability of taking advantage from the opportunities offered by ICT. Moreover, although we observe a process of convergence across countries in the three indexes (particularly in the usage of digital technologies), the ICT gap remains quite large between leaders and followers.

4. The economic effects of digitalization: mechanisms and areas of impact

The main value added of this paper consists of distinguishing between three key dimensions or stages of the digitalization process (access, usage and empowerment) and in assessing their different effect on macro-economic performances. The basic research hypothesis of this empirical exercise is that these effects are likely to differ in terms of strength (with usage and empowerment being more important than access), areas of impacts (efficiency, employability, growth) and more specifically in terms of economic variables affected (labor productivity and GDP per capita, employment growth (total, manufacturing and services) and the growth in the employment rate of "disadvantaged groups". A major focus of our empirical analysis is the estimation of the effects of digitalization on the level of economic and social inclusion. This explains our emphasis on employment. These hypotheses are explained in more detail below.

The ICT-Infrastructure is expected to be a precondition for any impact of digitalization on the economy to take place. However, the mere availability of digital technologies may prove insufficient in the lack of individuals' abilities to use the new technologies and to exploit their potential in different areas of the economy and society. The descriptive analyses carried out in Section 3 have shown that European countries differ especially in their capability to use and to exploit the new technologies in the different domains of the society rather than in the availability of ICT infrastructure. For this reason we expect that the major economic impacts of digitalization stem from differences across countries in the ICT-usage and ICT-empowerment dimensions rather than in the level of the ICT-infrastructure.

ICT-usage and ICT-empowerment may well impact differently on economic variables. The "usage" index, by capturing the autonomy, intensity and skill in the use of the new technologies, conveys information on both the intensity and the competence with which individuals master the new

technologies. For the same level of infrastructure (as captured by the "infrastructure" index) a more intense use is expected to have a positive impact on labour productivity through the increasing competence of individuals and as a consequence of the labour force.

A higher usage of ICT can also affect employment. The overall employment impact of a more intensive use of ICT by individuals, and by the labour force as a whole, is however not predictable both in terms of its size and sign. The digitalization process is in fact usually associated (directly or indirectly) to an increase in the level of labour productivity. If the direct labour saving effects brought about by a more intensive use of ICT are not counterbalanced by a sufficiently strong growth of the economic output the result might be an overall reduction of employment. This is likely to occur in all sectors where ICT tend to substitute labour intensive and routine tasks (as in many service sectors and potentially also in many public sector areas).

Finally, a higher usage of the new technologies especially by "disadvantaged" groups might have important consequences on social inclusion. The Riga Ministerial Declaration stresses the importance of the use of ICT and identifies a set of well-defined parameters that can help monitoring the state of progress of the digital inclusion process. In particular it focuses on reducing to a half the differences in Internet usage between the current average use by the EU population and the use by older people, people with disabilities, women, lower education groups, unemployed and 'less-developed' regions (CEC, 2007). We will, therefore, focus our attention on the impact of usage on some of these disadvantaged groups, namely women, old workers and long-term unemployed people. For these groups in particular, a higher ICT usage is expected to favour a higher participation in the labour market and a higher employment rate.

Finally the "empowerment" dimension captures the Internet presence in everyday life including several domains namely economic, employment and labour, educational, health, government,

culture, communication and entertainment (see Table I). This index aims therefore at capturing the positive effects of individual and social empowerment resulting from the appropriation of the new technologies.

How is digital empowerment expected to affect economic performance variables? Table II summarises some possible transmission mechanisms and the main economic variables that are likely to be affected by a widespread use of digital technologies in the various social domains indicated in Table I.

In the case of the economic dimension the use of the Internet changes everyday life. In particular the use of internet banking, the use of internet for buying and selling goods and for travel and accommodation are just three examples where the use of Internet might increase competition, reduce costs and the time needed to purchasing products and services, and by these channels, also stimulate economic growth. It is rather difficult to make clear-cut ex-ante hypotheses regarding the overall employment impact linked to these cost savings and the to the growth of new ICT-Internet related economic activities. In general, the growth of internet-related activities and jobs are expected to have a positive impact on employment, provided that they do not phase out pre-existing services, goods and intermediate inputs. In the same vein, efficiency and productivity gains obtained through the use of ICT (in areas such as internet-banking, e-commerce) although might have a direct negative impact on employment in specific areas and sectors might activate "compensating mechanisms" offsetting the initial labour-displacing effects of these technologies. As already discussed in section 2, most of the literature on ICT and its economic impact tends to privilege a positive and optimistic view on the overall employment effects of digitalization.

The second sub-dimension that we have selected comprises indicators which are connected to the broad and variegated area of labour. In this area we can distinguish the impact of digitalization on

people that are already in the labour market and on those who seek employment. For those who have already a place in the labour market, Internet represents an instrument which becomes part of the work routine, changing the organization of the work and introducing a higher level of flexibility with possible positive effects especially on labour productivity. An increase in labour flexibility might also favour inclusion in the labour market of women and of the older part of the population. For those who seek a job, especially the young ones, Internet could represent an opportunity for research and application. As a consequence digitalization can favour a better matching between employers and employees thus reducing the frictional rate of unemployment. Overall the use of the Internet in the labour market area can change significantly the quality of the work performed allowing for new forms of more flexible jobs with possible consequences on the employment rate in particular of disadvantage people (women, old workers). Also in this case, despite the literature tends to underline the positive effects of the diffusion of ICT and internet on the functioning of labour markets, there are also studies that emphasise some negative sides of the new ICT-internet based jobs and models of labour organization, with evidences showing increasing levels of work-load, labour distress and exploitation (Green and Tsitsianis 2004; Askenazy and Caroli 2006; Chesley 2010).

The education sub-dimension comprises all the indicators which contribute to enhance “human capital”, that is, that valuable asset which is becoming increasingly significant for the development of the Information Society. Digitalization in the domain of education increases the opportunities for accumulating human capital making it possible to attend specific courses from distant places and also encouraging long life learning (professional courses, post educational programs, etc.). The main expected economic consequence are increases in labour productivity and in employment (total and of “disadvantaged” groups).

In the case of the Health and the Government areas the use of the Internet is likely to lead to efficiency gains, cost savings and, therefore, to an increase in labour productivity and in Total Factor Productivity.

Finally the Cultural, communicative and recreational areas comprises the most common communication opportunities, such as electronic mail and chat rooms, the consumption of radio and television on alternative platforms, downloading of games, music, magazines and software, and the reading of newspapers free of charge or on payment. These are just some examples of the many activities that Internet users carry out over the web, and which constitute the contemporary forms of communication and cultural consumption. The main economic impact of these activities is expected to be the creation of new markets and, consequently, economic growth. Once again the net aggregate economic and employment impact of these changes in the models of consumption and demand depends on the existence and relevance of crowding-out effects produced by the emergence of these new markets with respect to pre-existing economic fields and activities (Evangelista and Savona 2010).

Overall, the complex and variegated dimensions captured by the "empowerment" index should capture the extent to which the use of ICT leads to paradigmatic changes of the economy and society. In this respect, if the opportunities offered by these changes are appropriately exploited, increases in empowerment should favour a higher growth à la Schumpeter, i.e. involving a process of structural change.

Summarising, we expect that "usage" should mainly impact on labour productivity and eventually also on the employment rate, while we expect the main economic effects of "empowerment" to be found in stimulating total factor productivity, economic and employment growth. Finally, both usage and empowerment are expected to favour economic and social inclusion by improving the

employability of "disadvantaged" groups (women, old people, long-term unemployed). These hypotheses are tested in the next section.

(Table II about here)

5. The empirical analysis

5.1 Estimated equations

The econometric analysis presented in this section aims at assessing how different stages of digitalization (infrastructure, usage and empowerment) affect countries' economic performance and to test the research hypotheses discussed in the previous section. In particular, in the light of the causation mechanisms and areas of impact described above, and recalling our focus on the impact of digitalization on the level of social and economic inclusion, we estimate the effects of digitalization on three sets of economic variables and namely on: a) labour productivity and per capita GDP growth; b) employment growth (total as well as in manufacturing and service industries); c) growth in employment rates referred to specific "disadvantaged" groups (women, older and long term unemployed people)[6].

When estimating the impact of digitalization on the rate of growth of labour productivity, we control for human capital and for the investment rate:

$$LPROD_{it}=a_0+a_1HC+a_2INV+ a_3INFRA+ a_4USAGE+ a_5EMPO+ e_{it} \quad (1)$$

where $LPROD_{it}$ is the rate of growth of labour productivity (measured as the ratio of GDP at constant prices to the number of employees), HC are changes in human capital (measured by two indicators: the change in the percentage of the population aged 25 to 64 having completed at least

upper secondary education and the change in the percentage of persons aged from 25 to 64 who stated that they received education or training in the four weeks preceding the survey on total population of the same age group), INV is the share of gross fixed capital formation on GDP and INFRA, USAGE and EMPO are yearly changes in our indicators of digitalization (respectively "infrastructure", "usage" and "empowerment").

When estimating the impact of digitalization on the rate of growth of per capita GDP, we control for human capital, for the investment rate and for the rate of growth of population:

$$GDPPC_{it}=a_0+a_1HC+a_2INV+a_3POP+a_4INFRA+ a_5USAGE+ a_6EMPO+ e_{it} \quad (2)$$

where GDPPC denotes the rate of growth of per capita GDP (measured as the ratio between GDP at constant prices and total population) and POP denotes the rate of growth of total population.

Finally, when estimating the impact of digitalization on employment growth and on the growth of the employment rate of "disadvantaged" groups we control for labour costs (that are expected to negatively affect employment), human capital (that should have a positive impact), the rate of growth of demand (also with an expected positive sign) and the rate of growth of population (with a positive expected sign on the rate of growth of employment and an ambiguous sign on the rate of growth of the employment rate). The estimated equation is, therefore, the following:

$$EMP_{it}=a_0+a_1LC+a_2HC+a_3DEM+a_4POP+ a_5INFRA+ a_6USAGE+ a_7EMPO+ e_{it} \quad (3)$$

where EMP_{it} denotes the rate of growth of employment (or the employment rate) of country i at time t, LC is the rate of growth of labour costs (measured as total remuneration per employee in constant prices), DEM is the rate of growth of demand (measured as the rate of growth of GDP at constant prices).

Data for all these variables are obtained from Eurostat and cover 27 EU countries over the period 2004-2008 for a total of 108 observations (one time period is lost due to the computation of growth rates). Due to the short time span of the data-set our estimates are based on a repeated cross-section (pooled estimates) using Generalised Least Squares with heteroschedastic robust standard errors.

This exercise should be seen as a first attempt to assess whether and how differently ICT infrastructure, usage and empowerment are linked to aggregate performance variables. We are aware that the empirical strategy adopted in the paper does not make justice to the complexity of the causation mechanisms possibly running from the different stages of digitalization to performance variables. In particular, simultaneity could occur between investment and education variables in the per capita GDP and labour productivity equations and between wages and demand variables in the employment growth equation. In an attempt of (partly) dealing with these issues, and of strengthening the econometric robustness of our empirical exercise, in the Appendix we will report results based on Generalised Method of Moments estimates allowing for the endogeneity of education and investment in equations (1) and (2) and of wages and demand in equation (3). In particular we will estimate equations (1), (2) and (3) in (logs) levels introducing a lag of the dependent variable and adopting the Arellano-Bond dynamic panel-data estimator[7].

5.2 Regression results

Tables III, IV and V report the results of the estimation of equations (1), (2) and (3) using GLS on pooled cross-section time-series. Table III reports the results of the impact of digitalization variables on the growth of labour productivity and per capita GDP; Table IV allows us to verify if and the extent to which the different stages of digitalization are able to provide a contribution to employment growth in total and in the two major branches of the economy (manufacturing and services). Table V reports the estimates of the impact of the different stages of digitalization on the employability of disadvantaged groups (the female employment rate, the employment rate of people aged between 55 and 64 and the unemployment rate of long-term unemployed).

Overall, some interesting messages can be drawn from the results of the empirical analysis that are in line with our research hypotheses.

First, our results show that in order to disentangle the effects of ICT on aggregate performance it is important to distinguish between different stages/dimensions of digitalization since they exert different impacts on macroeconomic variables. In particular the results show that only ICT usage and empowerment are significantly related to the three sets of economic performance variables taken into account in this study, while ICT infrastructure does not appear to discriminate (the only exception being increases in services' employment). This may depend on the low variability of indicators of ICT infrastructure across countries and over time. Our interpretation of this result is not that ICT infrastructure is not important but that the level reached by advanced countries in this respect is sufficient to allow more sophisticated dimensions of digitalization to play their positive role. This is further confirmed by the fact that the interaction between the ICT access variable with the other two ICT indicators does not produce any visible effect on our performance aggregate indicators[8] .

Secondly, macroeconomic variables respond differently (and in line with what expected) to ICT usage and ICT empowerment. In particular the usage dimension appears to be the strategic one when we look at the rate of growth of labour productivity, while the empowerment dimension is what really matters for the rate of growth of the economy and more importantly for creating new jobs. This is consistent with our expectations and also confirms what argued by the most recent strands of literature on the socio-economic impact of ICT, and in particular by the literature on digital inclusion (see literature review in section 2). In fact, the "usage" index captures diffusion, autonomy, intensity and skills in the use of the new technologies, all aspects that are expected to change the familiarity with the new technologies, and, therefore, to make individuals more productive for the same amount of infrastructure provided. On the other hand, as we have stressed in Section 4, the "empowerment index" contains various dimensions that capture the capability of ICT to transform modes of production and consumers' everyday life in a Schumpeterian fashion. The expected consequence is the creation of new markets, higher rate of growth and higher employment. It is interesting to notice in Table IV that only in the case of services the ICT infrastructure indicator has a positive impact on employment. This might reflect the important role that the ICT-network plays in the tertiary sector and more in particular the fact that the emergence and growth of markets for intangibles commodities is heavily dependent on the level and quality of the ICT infrastructure.

The use of Arellano-Bond estimates broadly confirms these results (see table in the Appendix). The access dimension of ICT has no effect on per capita GDP, labour productivity and employment (with the only exception of employment in services where it has a positive impact). ICT empowerment matters for per capita GDP and job creation (aggregate and in the two macro sectors of manufacturing and services) but not for labour productivity. Finally, the results on the positive

impact of usage on labour productivity are confirmed only when allowing for one period lag in the ICT indicators.

Looking at the impact of the different dimensions/stages of digitalization on the employment opportunities of "disadvantaged" groups (Table V), we find differentiated patterns. Our estimates show that ICT empowerment is important not only for increasing the overall level of employment in the economy but (and more importantly) for allowing women and long-term unemployed to get a job. This is consistent with the fact that this is the part of the population that benefits the most from the increases in labour flexibility brought about by the take up of the Internet in some dimensions such as education and labour. On the other hand, when the focus is on people aged between 55 and 64 what really matters for their inclusion in the labour market is their ability to use the new technologies. This might depend on the fact that, among older people "usage" is still relatively low and, therefore, becomes a conditioning variable to grasp the inclusive benefits of the new technologies. Somehow surprisingly a higher "empowerment" of elderly people is associated to a lower employment of this part of the population while, once again, ICT infrastructure does not appear to have any effect on the employability of "disadvantaged" groups.

As far as the role played by the other explanatory variables included in our econometric estimates the results are consistent with the findings of previous empirical research, and in particular: that labour productivity increases with the investment rate although, somehow surprisingly, decreases with long life learning (it appears that continuous education increases employment more than it is able to stimulate production); that the rate of growth of per capita GDP increases with the investment rate and with the share of educated people and decreases with the rate of growth of population; that total employment decreases when wages rise[9] while it increases with increases in demand and in the level of education. These results are confirmed also when allowing for the endogeneity of investment and education in the per capita GDP and labour productivity equations

and of demand and wages in the employment equation (see Appendix). When distinguishing between manufacturing and services it is interesting to observe that education plays a significant role only in the case of services; moreover while for services employment increases with population, in the case of manufacturing increases in population lead to decreases in manufacturing employment. This result may capture the shift from manufacturing to service employment that is occurring in industrialised economies.

Finally, looking at the regressions for the employment rate of "disadvantaged" groups, we find again a positive impact of demand and a negative impact of wages for all groups but older people while, among education variables, long life learning appears to be more important than secondary education.

(Tables III, IV and V about here)

6. Conclusions

In this paper we have argued that dealing with digitalization, and assessing its economic impact, requires to overcome the traditional and narrow infrastructural, supply-side, and technology based perspective of ICT. This change of perspective asks for the adoption of a more complex and multidimensional view on the relevant dimensions and mechanisms governing the relationship between ICT and the economy. In order to assess the economic impact of ICT in this broad perspective we have used three composite indicators measuring respectively three different dimensions/stages of digitalization and namely one synthesizing access conditions to the ICT infrastructure, one reflecting the actual usage of ICT facilities and internet and one measuring the ICT empowerment of individuals and firms in day to day life in key social and economic domains. One of the research hypothesis of this study was that that the presence of an ICT *infrastructure* and

the mere accessibility to ICT facilities are only a necessary pre-condition for moving towards a digitalized society while the "level" and the "quality" in the *use* of these technologies, as well as the conditions facilitating a proper *digital empowerment*, are likely to play a much important role, especially for generating new employment opportunities. Both the descriptive and econometric evidences presented in the previous sections seem to support this hypothesis.

The descriptive analysis presented in section 3 has shown the presence of relevant disparities across European countries in the various dimensions of digitalization with cross-country distances becoming larger and larger passing from the mere presence of infrastructure, to the level and quality in the use of ICT facilities, to the actual empowerment allowed by these technologies. We have also put forward the hypothesis that these three dimensions of digitalization differ in terms of areas of impact and macro-economic variables affected. In line with this working hypothesis, we have identified different possible transmission mechanisms between digitalization and major macroeconomic variables and namely growth in per capita GDP, labor productivity and employment. The identified transmission mechanisms have been explored in an empirical analysis covering the EU 27 countries over the period 2004-2008.

Some interesting results have emerged from the econometric estimates presented in section 4. First, digitalization matters for the all three sets of economic performance variables taken into account in this study; second, usage and (even more) empowerment exert the major economic effects while infrastructure does not appear to discriminate; third, the usage dimension of digitalization is more relevant for labor productivity while digital empowerment is more important for GDP growth, for employment growth, to increase the employment rate of women and to reduce long term unemployment, while usage has been found to positively affect the employment rate of the older part of the population.

The results of the empirical analysis suggest that digitalization may represent a major driver of labour productivity, economic and employment growth and that inclusive policies may effectively contribute to bridge the gap between the most favoured and the disadvantaged parts of the population, thus helping achieving the 2020 European targets. This is particularly important for those countries, such as the Mediterranean and some of the new EU entrant countries, where these gaps are still very large. This is a result broadly supported by most of the literature reviewed in section 2. However a specific indication emerging from our empirical analysis is that efforts in EU 27 countries should be devoted particularly to promote those policies that allow the new technologies to fully exert their potential.

All in all our study tends to provide a positive scenario on the effects of ICT (and related policies) on the economy and society, and this especially with respect to a critical variable such as employment. Despite this view is broadly in line with most of the existing literature on the economic effects of ICT we are fully aware of the very differentiated effects ICT might have on employment. In fact, there are various studies emphasising the negative impact of ICT on the quantity and quality of jobs in many economic and productive contexts and our exercise does not have the ambition of capturing the aggregate net long term employment effects of digitalization. Nonetheless, it is important to highlight some peculiar features of our exercise that could qualify and justify the positive employment scenario emerged from this study. The first peculiarity (and value added) has to do with the broad and composite nature of the indicators used to measure the level of digitalization of the economies and societies. Along with (and beyond) the mere use of ICT facilities in the business sector our indicator tends to cover a much wider set of economic and social domains in which digital technologies are used and exert their effects. In other words, rather than capturing the use of ICT as a mere production factor our indicators reflect the process of digitalization at a much larger economic and social scale. Recalling the “classical” distinction

between the direct and indirect effects of technology on employment, we might say that our analysis is clearly oriented to capture the indirect and deeper effects produced by ICT on labour, through the emergences of new markets and paradigmatic changes in consumption models, learning processes, human capital formation and labour searching procedures. Second, our analysis, and the indicators used, depart from the strictly technological and supply-side perspective of the relationship between ICT and employment that still dominates the current literature. Our analysis focuses on the role that ICT might play in empowering the capability of social systems to take advantage of this digitalization in a variety of social and economic domains beyond the production boundaries of the business sector. Probably the main and most important message stemming from our study is precisely that what really matters for giving better employment perspectives to people is not a more intensive use of ICT facilities within firms (i.e. the variable dimension mostly taken into account by existing studies) but rather a more complex process of digital empowerment, that is a process through which individuals, private organizations and public institutions become fully aware of, and are able to, exploit the wide range of social and economic opportunities offered by digital technologies. This study represents only a first step in the direction of relating different dimensions/stages of digitalization to different economic performance variables, and in particular to employment and other indicators of economic and social inclusion. We are aware that such an exercise does not make justice of the all set of complex transmission mechanisms running from digitalization to macroeconomic performance. Future studies, possibly with longer time series, should better explore the relevance of these mechanisms and the significance of the interaction of digitalization with other factors (such as education, structural change, institutions) possibly amplifying/reducing the economic impact of digital technologies in line with what suggested by the recent literature on e-inclusion.

References

Askenazy, P. and E. Caroli. 2006. "Innovative work practices, information technologies and working conditions: evidence from France." *IZA Discussion Paper*, No 2321.

Aubert, P., Caroli, E. and M. Roger. 2006. "New technologies, organization and age: firm level evidence." *The Economic Journal*. 116: 73-93.

Autor, D.H., Levy, F. and R.J. Murnane. 1998. "The skill content of recent technological change: an empirical exploration." *Quarterly Journal of Economics*. 118 (4): 1279-1333.

Baliamoune-Lutz, M. 2003. "An analysis of the determinants and effects of ICT diffusion in developing countries." *Information Technology for Development*. 10(3): 151-169.

Bartel, a. And N. Sicherman. 1993. "Technological change and retirement decisions of older workers." *Journal of Labor Economics*. 11 (1): 162-183.

Barth, M.C., McNaught, W. and P. Rizzi. 1993. "Corporations and the aging workforce." In *Building the Competitive Workforce: Investing in Human Capital for Corporate Success*, P.H. Mirvis (Ed.), New York: John H. Wiley & Sons.

Bikson, T.K. and C.W.A. Panis. 1999. *Citizens, computers, and connectivity: a review of trends*. Santa Monica: RAND.

Brasini S. and M. Freo. 2012. "The impact of information and communication technologies: an insight at micro-level on one Italian region." *Economics of Innovation and New Technology*. 21 (2): 107-123.

Bresnahan, T.F., Brynjolfsson, E. and L.M. Hitt. 2001. "Information technology, workplace organization and the demand for skilled workers: a firm level analysis." *Quarterly Journal of Economics.* 117 (1): 339-376.

Brynjolfsson, E. and L.M. Hitt. 2000. "Beyond computation: information technology, organizational transformation and business performance." *Journal of Economic Perspectives*. 14 (4): 23-48.

CEC. 2007. *European i2010 initiative on e-Inclusion "To be part of the Information society" Impact Assessment*, SEC 1469.

Cette G. and J. Lopez. 2012. "ICT demand behaviour: an international comparison." *Economics of Innovation and New Technology*. 21 (4): 397-410.

Chesley, N. 2010. "Technology use and employee assessments of work effectiveness, workload, and pace of life." *Information, Communication & Society*. 13 (4): 485-514.

Chinn, M.D. and R.W. Fairlie. 2007. "The Determinants of the global Digital divide: a cross-country analysis of computer and internet penetration." *Oxford Economic Papers*. 59 (1): 16-44.

Codagnone, C. 2009. *Vienna Study on Inclusive Innovation for Growth and Cohesion: Modelling and demonstrating the impact of eInclusion*, DG Information Society and Media, ICT for Inclusion Unit.

Crandall, R.W., Lehr, W., and R. Litan 2007. "The Effects of Broadband Deployment on Output and Employment: A Cross-sectional Analysis of US Data". *Issues in Economic Policy*. The Brookings Institution. 6.

Crespi, G., Criscuolo, C., Haskel, J. and M. Slaughter. 2007. "Productivity Growth, Knowledge Flows and Spillover." *CEP Discussion Paper*. 785.

Czernich, N., Falck, O., Kretschmer, T. and L. Woessmann. 2011. "Broadband infrastructure and economic growth." *Economic Journal*. 121 (552): 505-532.

Di Maggio, P.J. and E. Hargittai. 2001. "From the 'digital divide' to 'digital inequality: Studying Internet use as penetration increases." Working Paper 19, Center for Arts and Cultural Policy Studies,Woodrow Wilson School, Princeton University, Princeton, NJ.

Di Nardo, J. and J. Pischke. 1997. "The returns to computers revisited: have pencils changed the wage structure too?" *Quarterly Journal of Economics*. 112 (1): 291-303.

Dolton, P. and P. Pelkonen. 2008. "The wage effects of computer use: Evidence from WERS 2004." *British Journal of Industrial Relations.* 46 (4): 587-630.

Entorf, H. and F. Kramarz. 1997. "Does unmeasured ability explain the higher wages of new technology workers?" *European Economic Review*. 41 (15): 1489-1509.

Evangelista, R. and M. Savona. 2003. "Innovation, employment and skills in services. Firm and sectoral evidence." *Structural Change and Economic Dynamics*. 14 (4): 449-474.

Evangelista, R. and M. Savona. 2010. "Innovation and employment in services." In *The Handbook of Innovation and Services*, F. Gallouj and F. Djellal (Eds), Cheltenham, UK and Northampton MA USA: Edward Elgar.

Fornefeld, M, Delaunay, G. and D. Elixmann. 2008. "The impact of broadband on growth and productivity." MICUS management consulting GMBH.

Friedberg, L. 2003. "The impact of technological change on older workers: evidence from data on computer Use." *Industrial and Labor Relations Review*. 56 (3): 511-529.

Green, F. and N. Tsitsianis. 2004. "Can the changing nature of jobs account for national trends in job satisfaction?" Department of Economics Discussion Paper, University of Kent, 04-06.

Guerrieri, P. and S. Bentivegna (Eds.). 2011. *The Economic Impact of Digital Technologies*. Cheltenham (UK): Edward Elgar.

Guerrieri, P., Luciani M. and V. Meliciani. 2011. "The determinants of investment in Information and Communication Technologies." *Economics of Innovation and New Technology*. 20 (4): 387-403.

Gust, C. and J. Marquez. 2004. "International comparisons of productivity growth: the role of information technology and regulatory practices." *Labour Economics*. 11 (1): 33-58.

Hargittai, E. 1999. "Weaving the Western Web: explaining differences in Internet connectivity among OECD countries." *Telecommunication Policy*. 23 (10-11): 701-18.

Hargittai, E. 2003. "The Digital Divide and What To Do About It." In *New Economy Handbook,* D.C. Jones (Ed.), 822-841. San Diego: Academic Press.

Hoffman, D.L. and T.P. Novak. 1998. “Bridging the racial divide on the Internet.” *Science*. 280 (17): 390-391.

Inklaar, R., O’Mahony, M. and M. P. Timmer. 2005. “ICT and Europe’s productivity performance, industry-level growth account comparisons with the United States.” *Review of Income and Wealth*. 51 (4): 505-536.

Jorgenson, D.W. 2001. “Information technology and the U.S. economy.” *American Economic Review.* 91 (1): 1-32.

Jorgenson, D.W. 2007. “Industry Origins of the american productivity resurgence.” *Economic Systems Research.* 19 (3): 229-252.

Jorgenson, D.W., Mun, S.H., and K.J. Stiroh. 2008. “A retrospective look at the U.S. productivity growth resurgence.” *Journal of Economic Perspectives.* 22 (1): 3-24.

Koellinger, P. 2008. “The relationship between technology, innovation, and firm performance: empirical evidence on E-Business in Europe.” *Research Policy*. 37 (8): 1317-1328.

Krueger, A.B. 1993. “How computers have changed the wage structure: evidence from microdata, 1984-1989.” *Quarterly Journal of Economics*. 10 (1): 1215-1244.

Lera-López, F., Billon M. and M. Gil. 2011. “Determinants of Internet use in Spain.” *Economics of Innovation and New Technology*. 20 (2): 127-152.

Linstone, H.A. and T. Devezas. 2012. “Technological innovation and the long wave theory revisited.” *Technological Forecasting and Social Change.* 79 (2): 414-416.

Machin, S. and J. Van Reenen. 1998. “Technology and changes in skill structure: evidence from seven ORCD countries.” *Quarterly Journal of Economics*. 113 (4): 33-60

Miniaci, R. and M.L. Parisi. 2006. “Social interactions and the Digital divide: identification and policy implication.” *Contributions to Economic Analysis & Policy.* 5 (1).

Moyer, J.D. and B.B. Hughes. 2012. “ICTs: Do they contribute to increased carbon emissions?” *Technological Forecasting and Social Change*. 79 (5): 919-931.

NTATREP (National Technical Assistance, Training, Research, and Evaluation Project). 2006. "Measuring Broadband's Economic Impact." Final Report Prepared for the U.S. Department of Commerce, Economic Development Administration Project #99-07-13829, February.

OECD. 2004. *The Economic Impact of ICT: Measurement, Evidence and Implications*. Paris: OECD.

OECD. 2007. *Broadband and ICT access and use by households and individuals*. DSTI/ICCP/IE(2007)4. Paris: OECD.

OECD. 2008. *Developments in fibre technologies and investment*. DSTI/ICCP/CISP(2007)4. Paris: OECD.

OECD. 2012. *ICT Skills and Employment*, OECD Digital Economy Papers, 198. Paris: OECD.

Oliner, S.D., and D.E. Sichel. 2000. "The resurgence of growth in the late 1990s: is information technology the story?" *Journal of Economic Perspectives*. 14 (4): 3-22.

Oliner, S.D., Sichel, D.E. and K.J. Stiroh. 2007. "Explaining a productive decade." *Brookings Papers on Economic Activities.* 1: 81-137.

Ono, H. and M. Zavodny. 2003. "Gender and the Internet." *Social Science Quarterly*. 84 (1): 111-121.

Pianta, M. 2005. "Innovation and employment." In *The Oxford Handbook of Innovation*, J. Fagerberg, D. Mowery and R. Nelson (Eds.). Oxford: Oxford University Press.

PriceWaterhouseCoopers. 2009. *Champion for digital inclusion*, PriceWaterhouseCoopers.

Robinson, J.P., DiMaggio, P. and E. Hargittai. 2003. "New social survey perspectives on the Digital divide." *IT & Society* 1 (5): 1-22.

Schleife, K. 2006. "Computer use and employment status of older workers. An analysis based on individual data." *Labour*. 20 (2): 325-348.

Skirbekk, V. 2004. "Age and individual productivity: a literature survey." In *Vienna Yearbook of Population Research*, G. Feichtinger (Ed.). Vienna: Austrian Academy of Sciences.

Spitz-Oner, A. 2006. “Technical change, job tasks and rising educational demands: looking outside the wage structure.” *Journal of Labour Economics*. 24 (2): 235-270.

Stiroh, K.J. 2002. “Information technology and the U.S. productivity revival: what do the industry data say?” *American Economic Review* 92 (5): 1559-1576.

Thompson, H.G. and C. Garbacz. 2007. “Mobile, fixed line and Internet effects on global productive efficiency.” *Information Economics and Policy*. 19: 189-214.

van Ark, B., O’Mahony, M. and M.P. Timmer. 2008. “The productivity gap between Europe and the United States: trends and causes.” *Journal of Economic Perspectives*. 22 (1): 25-44.

van Reenen, J., M., Draca, M. and R. Sadun. 2007. “Productivity and ICTs: a review of the evidence.” In *The Oxford handbook of information and communication technologies*, R. Mansell, C. Avgerou, D. Quah, R. Silverstone (Eds.), 100-147. Oxford: Oxford University Press.

Figure 1: ICT access across European countries: 2004 and 2008

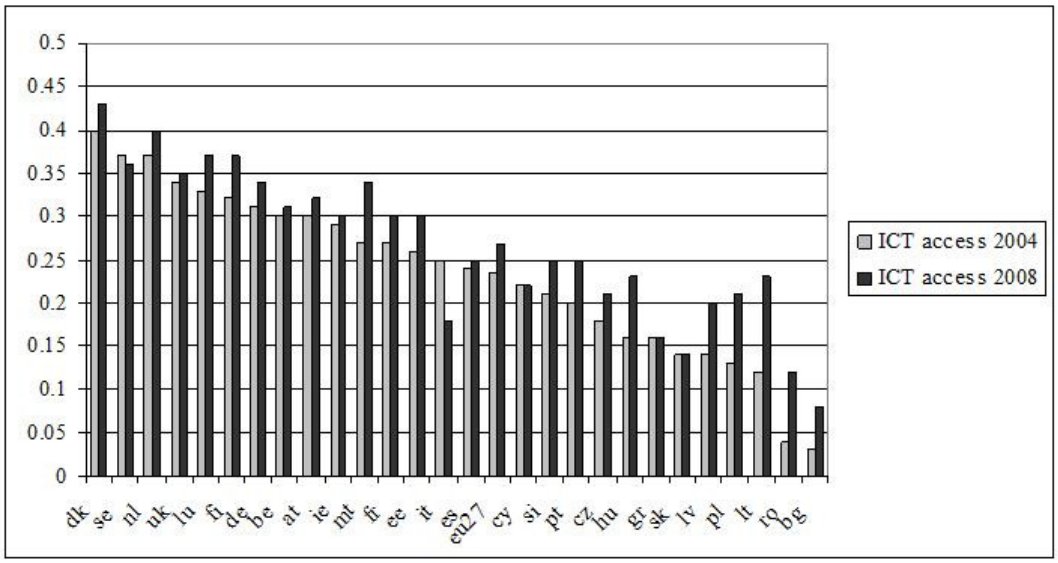

Figure 2: ICT usage across European countries: 2004 and 2008

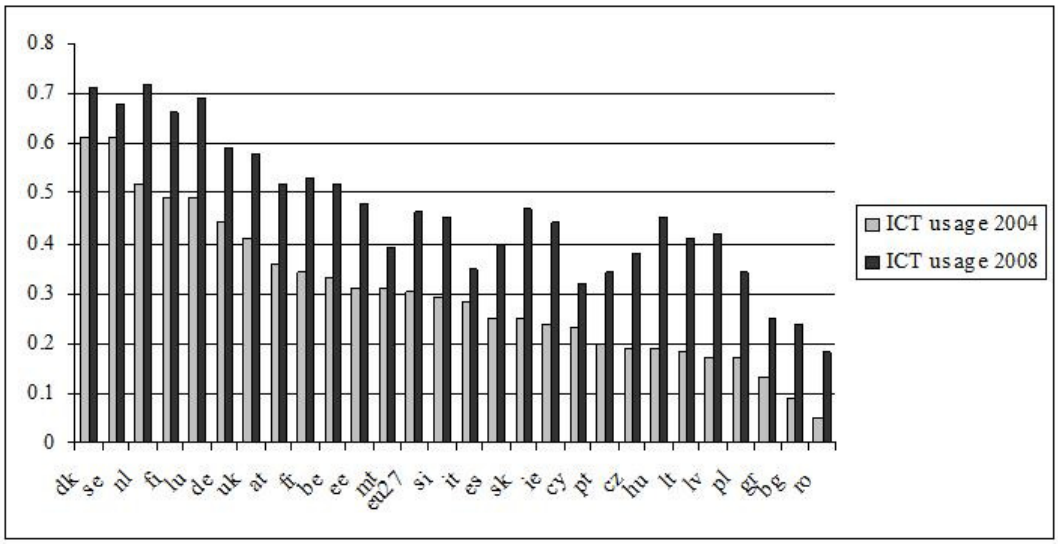

Figure 3: ICT empowerment across European countries: 2004 and 2008

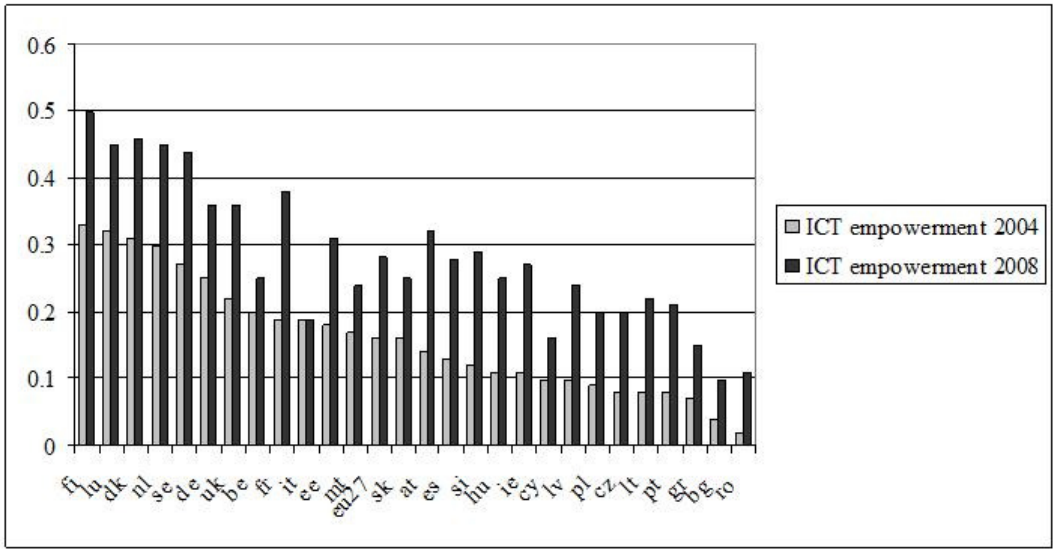

Table I: Infrastructure, Usage and Empowerment indexes of digitalization: sub-dimensions, indicators and data sources

ICT-Infrastructure	*ICT-Usage (Eurostat)*	*ICT-Empowerment (source: Eurostat)*
Network 1. Broadband penetration rate (Eurostat) 2. International Internet bandwidth per inhabitant (bit/s) (WDI) 3. Secure Internet servers (1 million people) (WDI) **Affordability** 1. Information and communication technology expenditure per capita (WDI) **Availability and quality** 1. Internet subscribers fixed broadband per 100 inhabitants (ITU) 2. Internet subscribers fixed per 100 inhabitants (ITU) 3. Level of Internet access for households (Eurostat) 4. Percentage of households using a broadband connection (Eurostat)	**Autonomy** 1. Percentage of individuals who accessed Internet at home **Intensity** 1. Percentage of individuals who accessed Internet every day or almost every day **Skills** 1. Percentage of individuals who have copied or moved a file or folder 2. Percentage of individuals who have used basic arithmetic formulae in a spreadsheet 3. Percentage of individuals who have connected and installed new devices	**Economy** 1. Percentage of individuals who used Internet for Internet banking 2. Percentage of individuals who ordered goods or services for private use over the Internet 3. Percentage of individuals who used Internet for using services related to travel and accommodation **Labor** 1. Percentage of individuals who used Internet for looking for a job or sending a job application 2. Percentage of persons employed using computers connected to the Internet in their normal routine **Education** 1. Percentage of individuals who used Internet for training and education **Health** 1. Percentage of individuals who used Internet for seeking health information on injury, disease or nutrition **Government** 1. Percentage of individuals who used Internet for interaction with public authorities **Culture, communication and recreation** 1. Percentage of individuals who used Internet for sending/receiving emails 2. Percentage of individuals who used Internet for playing/downloading games and music 3. Percentage of individuals who used Internet for reading/downloading newspapers/news magazines 4. Percentage of individuals who used Internet for listening to web radios/ for watching web television 5. Percentage of individuals who used Internet for downloading software 6. Percentage of individuals who used Internet for other communication uses

Note: Subdimensions are in bold. Indicators are numbered items. Data sources are in brackets.
Source: Adapted from Guerrieri and Bentivegna (2011)

Table II: Economic effects of digital empowerment: areas of impact and transmission mechanisms

Area of impact	Transmission mechanisms	Variables affected
Economic	- Change of consumption behaviours and final demand composition (in favour of service industries) - Development of new services Increased market competition/ - Cost savings - Potential labour saving effects	- Economic growth (especially service industries) - Total Factor Productivity - Employment growth (especially service industries)
Labour	- Better matching - Job flexibility (encouraging part-time)	- Labour productivity -Employment and participation rates (Total population and disadvantaged groups) -Employment growth
Educational	Increases in human capital Longlife learning Cost savings	- Labour productivity, employment growth - Employment rate of older and long-term unemployed
Health	- Cost savings - Potential labour saving effects	- TFP, labour productivity
Government	-Cost savings, efficiency gains	- TFP, labour productivity
Cultural, communicative and recreational	-Creation of new markets	-Economic growth -Employment growth (especially service industries)

Source: Adapted from Guerrieri and Bentivegna (2011)

Table III: The impact of various dimensions of digitalization on the rate of growth of labour productivity and per capita GDP 27 EU countries 2004-2008

	Labour productivity (yearly growth)			***Per capita GDP (yearly growth)***		
	Coef.		*z-value*	*Coef.*		*z-value*
Infrastructure (change)	0.016		0.39	-0.084		-1.64
Usage (change)	0.090	*	1.83	-0.111		-1.60
Empowerment (change)	-0.047		-0.95	0.202	***	2.84
Secondary education (change)	-0.002		-1.37	0.340	***	3.43
Long life learning (change)	-0.004	***	-3.00	-0.003		-1.49
Investment	0.053	***	5.21	0.103	***	8.73
Population (growth)				-1.871	***	-4.63
Constant	-0.147	***	-4.69	-0.272	***	-7.16
Number of observations			107			105

Notes. *z*-values are based on heteroscedasticity consistent standard errors (using White's method); *, **, *** denote respectively statistical significance at 10, 5 and 1%. Wald Chi-squared tests are always significant at 1%.

Table IV: The impact of various dimensions of digitalization on the rate of growth of total, manufacturing and services employment: 27 EU countries 2004-2008

	Total employment (yearly growth)		***Manufacturing Employment (yearly growth)***		***Services Employment (yearly growth)***	
	Coef.	*z-value*	*Coef.*	*z-value*	*Coef.*	*z-value*
Infrastructure (change)	0.016	0.57	-0.061	-0.91	0.084 **	2.09
Usage (change)	-0.014	-0.48	0.099	1.18	-0.009	-0.24
Empowerment (change)	0.046 *	1.62	0.176 **	2.39	0.052	1.50
Wages (growth)	-0.097 **	-1.91	-0.125	-1.19	0.054	0.90
Demand (growth)	0.260 ***	4.16	0.107	0.74	0.243 ***	3.27
Secondary education (change)	0.003 ***	2.81	0.001	0.47	0.003 ***	2.85
Long life learning (change)	0.002 ***	3.87	-0.001	-0.11	0.003 ***	3.21
Population (growth)	0.353	1.40	-0.946 ***	-3.16	0.516 **	2.04
Constant	0.003	1.26	-0.001 *	-1.84	0.006 **	1.98
N. observations		104		104		104

Notes. *z*-values are based on heteroscedasticity consistent standard errors (using White's method); *, **, *** denote respectively statistical significance at 10, 5 and 1%. Wald Chi-squared tests are always significant at 1%.

Table V: The impact of various dimensions of digitalization on the rate of growth of the employment rate of disadvantaged groups: 27 EU countries 2004-2008

	Female employment rate (yearly growth)		***Long term unemployment rate (yearly growth)***		***Employment rate of aged 55-64 (yearly growth)***	
	Coef.	*z-value*	*Coef.*	*z-value*	*Coef.*	*z-value*
Infrastructure (change)	0.067	0.71	-0.258	-0.86	0.029	0.46
Usage (change)	-0.064	-0.75	0.244	1.28	0.221 **	2.28
Empowerment (change)	0.292 ***	3.11	-0.626 **	-2.28	-0.234 **	-2.05
Wages (growth)	-0.322 **	-2.05	0.909 **	2.13	-0.047	-0.49
Demand (growth)	0.967 ***	4.54	-3.409 **	-6.04	0.410 ***	3.20
Secondary education	0.004	1.35	0.011	1.04	0.003	1.14
Long life learning (change)	0.011 ***	4.29	-0.048 **	-5.00	0.003 ***	2.65
Rate of growth of population	-1.315 ***	-2.55	5.138 **	3.05	-0.883 ***	-2.50
Constant	-0.021 ***	-2.57	-0.002	-0.09	0.011 *	1.81
Number of observations		107		105		107

Notes. *z*-values are based on heteroscedasticity consistent standard errors (using White's method); *, **, *** denote respectively statistical significance at 10, 5 and 1%. Wald Chi-squared tests are always significant at 1%.

Appendix: The impact of various dimensions of digitalization on labour productivity, per capita GDP and employment: robustness checks for endogeneity (Arellano-Bond GMM estimates)

	Labour productivity			***Per capita GDP***			***Total employment***			***Manufacturing employment***			***Service employment***		
	Coef.		z	Coef.		z	Coef.		z	Coef.		z	Coef.		z
Lagged dependent variable	0.494	***	4.05	0.711	***	8.38	0.208		0.86	0.469	**	2.10	-0.06		-0.31
Infrastructure	0.009		0.53	0.005		0.26	0.009		1.20	-0.000		-0.05	0.017	*	1.79
Usage	0.043	***	2.70	-0.044		-1.47	-0.005		-0.29	-0.005		-0.09	-0.000		-0.00
Empowerment	-0.001		-0.09	0.042	***	2.96	0.018	**	2.08	0.064	***	3.01	0.025	***	2.44
Investment	0.161	***	2.81	0.372	***	5.23									
Wages							-0.384	***	-3.98	0.022		0.11	-0.328	**	-2.32
Demand							0.452	***	2.67	-0.233		-0.91	0.574	***	3.01
Secondary education	-0.205		-1.43	0.394	**	1.92	0.165	*	1.83	-0.214		-1.50	0.281	***	2.90
Long life learning	0.021		0.58	0.058		1.52	0.013		1.22	-0.017		-0.36	0.015		1.27
Population				-0.63	*	-1.68	-0.208		-0.96	-0.425		-0.83	0.261		0.97
Constant	2.153	***	3.68	5.69	*	1.72	3.422	**	2.31	10.878	**	2.23	-1.100		-0.58
Number of observations			80			105			107			103			103

Notes: *z*-values are based on heteroscedasticity consistent standard error; *, **, *** denote respectively significant at 10, 5 and 1%. Wald Chi-squared tests are always significant at 1%. In the labour productivity and per capita GDP equations we allow for endogeneity of education and investment; in the employment equations we allow for the endogeneity of demand and wages, using the Arellano-Bond estimator. In the labour productivity equation ICT variables are lagged one year since contemporaneous values were not significant. Arellano-Bond tests for second order autocorrelation in the residuals reject autocorrelation.

[1] The title of the EU research project is "Analysis of e-Inclusion impact resulting from advanced R&D based on economic modeling in relation to innovation capacity, capital formation, productivity, and empowerment" (DG Information Society, Contract No: 30-CE-0220618/00-21. The main results of the project are contained in Guerrieri and Bentivegna (2011).

[2] Barth, McNaught and Rizzi (1993) argue that old-age workers, given that are less flexible, may either directly slowdown the process of innovation, or make harder to implement those organizational changes necessary to fully exploit ICT (see Skirbekk (2004), for a review of the literature and evidences on impact of age on productivity).

[3] An increasing number of firm-level studies have started to challenge the idea that ICT have an economic impact "per se", showing that this impact is dependent on parallel changes in the organizational structure of firms and in the level and type of skills and competencies (Brynjolfsson and Hitt 2000; Bresnahan and Brynjolfsson 2001; Crespi et al. 2007; Koellinger 2008).

[4] This seems to be confirmed by various policy oriented contributions which have either looked at the actual and expected macro-economic effects of digitalization (NTATREP 2006; OECD 2004; Fornefeld, Delaunay and Elixmann 2008) or have tried to assess the economic benefits brought about by digital technologies in specific socio-economic areas such as health, government and public services, education, energy (PriceWaterhouseCoopers 2009; Moyer and Hughes 2012).

[5] The empirical analysis contained in this article covers a slightly shorter period (2004-2008).

[6] Unfortunately data on Total Factor Productivity (from EUKLEMS database) were available only for 12 countries with only two years overlapping with the e-inclusion indexes (2004 and 2005), this did not allow us to directly test the impact of e-inclusion on TFP. However evidence of such effects may be indirectly taken from the estimation of countries rates of growth.

[7] The dynamic panel estimator is preferred to the fixed effect or random effect panel estimators due to the presence of autocorrelation in the error term.

[8] In order to test the possible complementary role of the various dimensions of digitalization taken into account in this study three additional interacting ICT variables have been computed, multiplying two by two the infrastructure, usage and empowerment indicators. None of these variables has emerged as statistical significant (estimates not reported). A wider set of interactions between the three ICT indicators and education variables has been taken into account and their

effect estimated. These econometric exercises have shown that the interaction between empowerment and secondary education has a positive impact on per capita GDP growth and the interaction between usage and long life learning has a positive impact on the employment rate of older people, no other significant interactions have been found (results are available on request).

[9] The negative impact of the growth of wages on the growth of total employment is found only when controlling for the growth of demand. This probably implies that the wage variable has a different effect on employment according to demand conditions. This is an interesting result which would require further theoretical and empirical investigation that however goes beyond the scope of our contribution.