The impact of ICT investments on economic growth – Literature review[1]

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Abstract

This paper presents a survey about the effects of information and communication technologies on productivity and economic growth.

The literature suggests that information and communication technologies investment has been an important source of economic and productivity growth at the aggregate, industry and firm level.

Keywords: Information and Communication Technologies, Economic Growth, Productivity

JEL Classification: O33, O43, L86, L96

1. Introduction

Since Solow's 'Productivity Paradox' remark (1987), where the economist stated that computers could be found everywhere except in productivity statistics, that researchers have been trying to establish a link between information and communication technology (ICT) and economic growth. Furthermore, the exponential growth of technology in recent decades has also stimulated a lot of research on this topic.

ICT are used to create, transmit, share, store or exchange information through a combination of complementary technologies such as the Internet, computers, live broadcasting technologies (television, radio and webcasting), recorded broadcasting technologies (audio and video players, podcasting and storage devices) and telephony (fixed or mobile, satellite, *etc.*).

In general, literature shows that information and communication technologies, through multiple transmission channels, have been a key driver of innovation, technological change, and socio-economic development in recent decades (OECD, 2017; Toader *et al.*, 2018). Developments in the ICT sector also have led to significant changes in production methods and employment patterns.

ICTs allow communication to be more efficient, reduce transaction costs, make market transactions more efficient and, in addition, improve the organizational efficiency and marginal productivity of skilled labour. These effects must be visible in the productivity of companies producing ICT, but also in companies using ICT (Stanley *et al.*, 2018).

This paper aims to summarize the main conclusions that the literature presents on this topic.

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2. Impact of ICT investments

Among the rapidly growing number of studies regarding this subject, it is possible to divide the research approach of the surveyed literatures based on the scope of the study, method and data used. On the one hand, several papers make use of country level data and utilize growth accounting methodology or cointegration techniques to analyse the extent of ICTs contribution to economic growth (macro-level studies). On the other hand, some empirical work also focuses on firm level data to investigate the effects of ICT investments on firm characteristics and productivity.

We present the literature review on the impact of ICT investments considering these different approaches.

2.1. Macro-level Studies

2.1.1. Causality analysis with country level data

Researchers have been focused on examining the causal relationship between ICT investments and economic growth. Veeramacheneni *et al.* (2008) applied ECM (extracellular matrix) to India and ten Latin American economies and found a bi-directional causality between ICT investments and economic development in two thirds of the countries considered, as well as that ICT-led growth in eight out of ten cases considered. While a similar study conducted in Eastern Europe found only a unidirectional causality running from IT investments to economic growth (Dvorjnik and Sabolić, 2007), contrary to the results found in China at national level where the unidirectional causality runs the in the opposite direction (Shiu and Lam, 2008). Shiu and Lam (2008), apply the dynamic panel data model to 22 provinces over the period between 1978 and 2004 and found causality from telecommunications development to real Gross Domestic Product (GDP) in provinces in the affluent eastern region.

2.1.2. Growth accounting analysis: industry and country level data

Throughout the rapidly growing number of studies relating to this subject, some utilize growth accounting methods using country level data. The majority of the results from this method estimate contributions of ICT capital to growth between 0.1 and 1.0 percentage points.

According to Oliner and Sichel (2000), between 1996-1999, ICT accounted for 1.5 pp of the 2.6% growth rate per year in labour productivity in the US business sector. The author states that the increase in productivity in the USA resulted mainly from the substantial increase in productivity of the ICTs sector since productivity growth in the rest of the economy remained slow.

In addition, O'Mahony and Vecchi (2005), based on an econometric analysis and using aggregate industry data for the United States and the United Kingdom to assess the impact of ICT on production growth in the US and UK industries, showed a positive return on ICT capital on production growth.

Likewise, using annual data from 192 countries over the period 1990–2007, Gruber and Koutroumpis (2011) found that investment in telecommunications infrastructure contributed 0.20 percentage points to economic growth in high-income countries in 1990-2007. This impact is smaller for countries with a low mobile penetration, usually low income countries.

Spiezia (2012), based on an econometric approach to estimate the contribution of three types of investments in ICT (computer, software and communication) in 26 industries (the entire business sector) in 18 OECD countries in the period 1995-2007, showed that the average contribution of ICTs varied between 0.4 (Australia) and 1.0 (Japan) percentage points, depending on the country. According to the results in most countries, except Finland and Japan, investments in computer equipment were responsible for more than 50% of the total ICT

contribution. In Finland, investments in communication equipment exceeded those in computing, and in Japan, investments in software were the most dynamic component of investments in ICT.

Additionally, there is evidence to suggest that the effect of ICT on growth enlarges over time (Cardona *et al.*, 2013; Tambe and Hitt, 2012). Within this strand of study researchers also use industry level data to show that productivity accelerated after the mid-1990s and that the gains from IT are relatively greater for IT intensive industries than others (Stiroh, 2002). Using industry level data from the United States (US), Stiroh (2002) compares productivity in industries from the period of 1993-99 to the period of 1973-93 and the results give evidence of productivity acceleration of 2.4 percentage points in ICT dominated industries in the 1990s.

In this context, investments in ICT have long been emphasized as a crucial element for technological change and growth (Schumpeter, 1942; Brynjolfsson and McAfee, 2014). In fact, one of the main drivers of growth in the US after 1995 was due to investments in ICT (Jorgenson *et al.*, 2008) with the US having an average productivity growth of 2.8% between 1996 and 2000. Hence, ICT based firms are viewed as essential to economic development.

Similarly, macro level research employing industry level data from Europe and the US are used to compare the heterogeneous relationship between ICT and economic growth of the two economies based on growth accounting. Studies have shown econometrically significant contributions of ICT capital to economic growth after the 1990s. Inklaar *et al.* (2005) revealed that ICT contributions of the US were much greater than the EU's during the period of 1979-2000. For the period of 1979 and 1995, only 2.5% of aggregate value added four economies of the EU (France, Germany, the Netherlands and the UK) was due to ICT capital, whereas in the US it was 3.4%. Likewise, the gap doubled in percentage points for the period of 1995 to 2000. Furthermore, during these two periods, the ICT share in value added in ICT-using industries made up more than 7.5% of value-added in the US whereas in the EU4 it was below 6%. The same authors also showed that there was substantial sectorial and cross-country heterogeneity with respect to contribution of ICT to labour productivity in developed economies. Similar results are confirmed for EU economies through the work of O'Mahony and Timmer (2009).

2.1.3. Leapfrogging hypothesis analysis: country level data

In addition to this, ICT has the potential to support and accelerate the development in emerging economies. Steinmueller (2008) demonstrates that investments made by developing nations into the ICT sector could allow these nations to promote the strategy of 'leapfrogging', that is, through the growth of the ICT sector nations could bypass the process of human capital accumulation and fixed investments and close the gap in productivity and output that separate developing and developed economies. The validity of this hypothesis depends on the ability and effort of the workforce in emerging economies to absorb the ICT capabilities (Henry *et al.*, 2009). In contrast to these findings, Niebel (2018) questions the 'leapfrogging' hypothesis by indicating that developing and emerging countries are not gaining more from investment in ICT than developed economies. The economist proposes an augmented Cobb-Douglas production function model to test the impact of ICT of developing, emerging and developed economies. The results reveal the same estimate of 0.048 for emerging and developed categories, implying that a 1% in ICT capital leads to 0.048% increase in output. Nonetheless, even though the estimate for developing nations resulted in a higher 0.077 it could not be proven with statistical significance that the estimates for the three subgroups are different. Likewise, when comparing developing and developed nations, data from 1985 to 1993 shows that developing countries were lagging behind developed countries in reaping ICT-led growth effects (Dewan and Kraemer, 2000).

The importance of ICTs should be even more emphasised since they are key enablers of innovation and speed up the process of knowledge creation within the economy. This is since ICTs

allow firms to reduce transaction costs and increase productivity due to ICT-related spillovers or network effects. For these reasons, in most OECD economies information industries account for the largest share of Business Expenditure on Research and Development (BERD), accounting for around 25% of total BERD. In addition, BERDs in the ICT sector represent about 0.8% to 1.9% of GDP. (OECD, 2017) Furthermore, academic work has shown that there needs to be an effective and well-structured innovation system such that the economy can acquire and use its knowledge base (Moncada-Peternò-Castello *et al.*, 2010).

2.2. Micro-level Studies

At the same time, micro level empirical studies investigate the relationship between ICT investments, productivity and examine the growth of firms conditional on the effects of firm size, age, sector, *etc*.

According to Van Reenen *et al.* (2010), the most firm-level studies reveal a positive and significant association of ICT with productivity.

Moreover, an Italian study using firm level data found that ICT investments have a positive effect on both productivity and technical efficiency on manufacturing firms. The study uses firm revenues as the dependent variable and utilizes a translog model. The empirical result suggests that higher ICT investments reduce firm inefficiency and the distance of the firm from its production frontier. From the different varieties of the model, the estimates varied between 0.014 and 0.101. Results also confirmed that firms that employ more educated workers increase their productivity more than others. This result could also emphasize that it is not only necessary to invest in ICT capital but also essential for the workforce to have the skills and adequacy to benefit from it. (Castiglione and Infante, 2014)

In addition to this, it is possible to focus on the effects firms have through digitalization and computerization. Over the course of time, computers have come to be known as general-purpose technology due to their ability to perform a wide range of tasks. Besides, the primary contribution of ICT technologies is to make new production methods possible, and firms gain the most from this process when combining it with complementary investments such as new work systems, organizational redesign and business process reengineering (Brynjolfsson and Hitt, 2003).

2.2.1. Influence of firm characteristics

Using micro-level data from S&P's Compustat database, Brynjolfsson and Hitt (2003) show that, in the short term, the contributions of computers are approximately equal to their costs. Therefore, computers contribute to the growth of production, but not to the growth of productivity in the short term. Nonetheless, over a longer period, digitalization assists in the growth of firm's multifactor productivity. This finding supports the conjecture that investments in ICT positively affect firms' productivity when firms complement this investment with other long term production process changes. For instance, in parallel to investments in ICT, firms could be required to make organizational changes which take more time to complete so that investments are fully maximized. Organizational changes could include decentralization of the decision-making process, job training and redesigning the business process, *etc.* (Brynjolfsson and Hitt, 2003).

Furthermore, it is important to note that the period analysed by the authors was between 1987 and 1994. During the 1980s, the world economy did not enjoy extraordinary growth as was witnessed during the late 1990s which exhibited a surge in productivity and output. Therefore, it could be a possibility that this growth was fuelled by the tremendous investments made in computerization and digitization in the early 1990s.

Likewise, researchers, in order to better understand the effect of ICT, are also interested in studying the determinants of ICT adoption throughout firms (see Hall and Khan, 2003).

The firm size is one of the most prevalent determinants in the literature. Several authors consider that large companies are more likely to adopt new technologies because they have more benefits in this adoption and because the availability of funds is greater and, therefore, they have greater capacity to respond to possible risks arising from the adoption of the new technology. (Bayo-Moriones and Lera-López, 2007; Hall and Khan, 2003). However, a study in Spain with 337 firms found significant evidence that larger firms tend to invest less in the digitization process (Bayo-Moriones and Lera-López, 2007). The researchers make use of a tobit regression model for the purpose of the study. Moreover, the authors find strong evidence supporting that firms employing high skilled workers and having exposure to international markets tend to adopt and invest in more ICT processes. Therefore, firms that are part of multinational organizations are more likely to adopt computerization. On the other hand, firms operating in the agricultural sector are less likely to adopt ICT processes.

Haller and Siedschlag (2011), in their study on the determinants of ICT diffusion at the company level, found that the speed of ICT diffusion is influenced by firm size, age, skill intensity, exposure to foreign markets and proximity to early adopters of ICT in the same industry and region. In addition, they conclude that small companies use ICT more intensively than medium-sized companies, although larger companies are more likely to adopt these technologies before small ones.

Khalifa (2016) concludes that firm size, strategic choices and affiliation to a multi-unit firm are determining variables in the adoption of Communication Technologies, but, on the other hand, age, competition and sector activity are not determinants.

3. Conclusion

This article presents a summary of the literature on the impact of ICT investments, dividing the analysis into studies at the macro level and studies at the micro level.

Overall, research shows that cross-country heterogeneity exists among economies for contributions towards ICT. Among firms, the effect of computerization can vary according to several factors, such as the size, age, sector and time horizon (short *vs.* long term) of the benefit to firms. Nonetheless, based on the gathered comprehensive literature survey, the majority of the authors agree that investments into ICT and digitalization of firms generate a positive impact on productivity leading to increases in output growth.

Since the impacts of the ICT revolution are palpable in all economies, it seems appropriate for governments to focus their policies on digitalization to foster and guide these changes so that all sectors can reap its benefits. Based on the empirical evidence obtained, numerous policy advice has been suggested by researchers. According to Jorgenson and Vu (2016), a comprehensive ICT framework should include appropriate adjustments so that policies are designed to manage and support new types of business practices in order to maximize public welfare and to be internationally competitive. Likewise, policymakers should not be alone in developing ICT policies engaging with all the relevant stakeholders, particularly taking into account the educational market, to maximize public welfare. Besides, due to the rapid technological growth in recent years it is important that policies are frequently updated to incorporate new technological developments such as 5G and Artificial Intelligence, *etc.* Lastly, it is crucial that relevant infrastructures are properly maintained so that the digital system is resilient to cyber-attacks which could otherwise yield negative consequences for firms (Vu *et al.*, 2020).

4. References

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