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# Growth and Transformative Effects of ICT Adoption

## A Survey

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## Abstract

This paper provides a compressive synthesis of the most recent and widely cited literature on the economic effects of information and communications technology adoption at the country, firm, and individual levels. The study surveys and analyzes the available literature on the topics of economic growth and transformation, and highlights the main conclusions drawn by scholars, areas of ongoing debate, and remaining research questions that need to be addressed in future work. Over 85 percent of the reviewed papers are of quantitative nature, and approximately 32% of those show causal effects. The majority of the studies find a positive relationship between the adoption of information and communications technology and country economic growth, firm level growth, household/individual welfare, or labor conditions, with most showing statistically significant results. The paper shows that, for policy making purposes, the effects of information and communications technology adoption should be thoroughly evaluated at all levels to ensure that the benefits outweigh any potential negative consequences.


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# Growth and Transformative Effects of ICT Adoption: A Survey[1]

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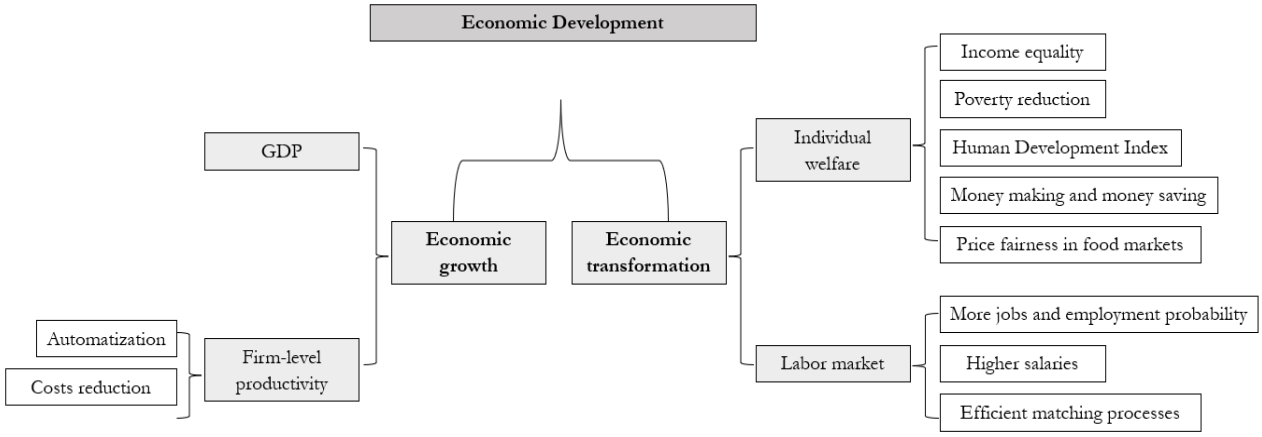
## 1. Introduction

Information and communications technologies (ICT) -including the internet, mobile phones, and other tools to collect, store, analyze, and share information digitally- are essential enablers of economic growth and economic transformation. This work reviews 112 studies that examine the transformative economic impacts of digitization at the country, firm, and household levels, acknowledging that economic growth on its own cannot guarantee development, reduction of poverty, and shared prosperity, but economic growth together with transformative effects on factors such as employment conditions (e.g., more and better jobs) can foster development (see Figure 1). Our review covers a variety of technologies, but we focus primarily on the most popular ones, such as mobile handsets, mobile services, and internet services such as websites, email exchange, digital platforms, and cloud computing tools.

*Figure 1: Effects of ICT captured in this review*




*Source: authors' own elaboration.*

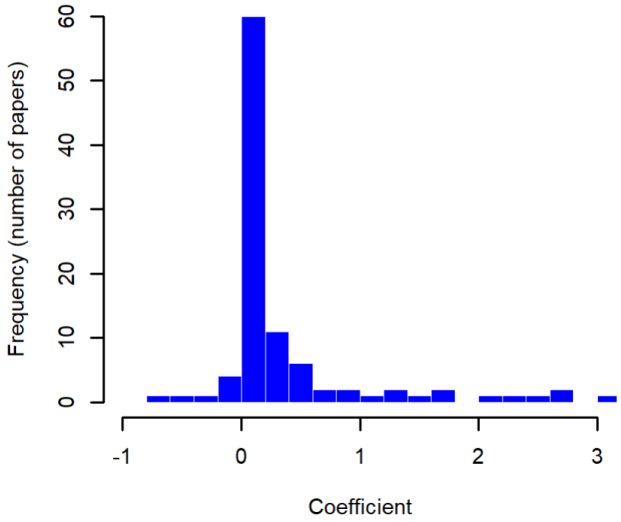
While there is a vast literature exploring the predictors of ICT adoption (see, for example, Kongaut and Bohlin, 2016), our review is rather focused on the economic effects of its use. Therefore, this paper is organized around the main channels of impact and the economic agents involved. Each level (i.e., country, firm, and household/individual) is presented in a section that summarizes the most recent studies. We take care to identify heterogeneity by contrasting the literature findings according to the level of development, time of adoption, and type of technology, among others. First, we study the effects of ICT adoption on countries' economic growth. Then, we turn our attention to the microeconomic effects on firms' productivity levels. Equipped with that knowledge, we proceed to address the relationship between ICT adoption and household/individual welfare (e.g., effects on poverty, income, wealth equity, human capital formation, among others). However, we also acknowledge that although economic growth can increase income and boost individuals' quality of life, it is not enough to ensure shared prosperity. According to the World Bank's Jobs and Economic Transformation agenda, to ensure prosperity for all, growth should be able to create more inclusive jobs. In light of this, our review is complemented by an analysis of the literature on the effects of

digitization on individuals' jobs. We conclude with a discussion of the main messages from the literature and future research paths.

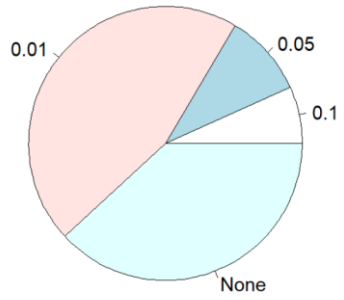
Over 85% of the studies included in this survey are of quantitative nature, and approximately 32% show causal effects, while the rest indicate correlations. The majority (about 90%) of the reviewed papers find a positive relationship between ICT adoption and country economic growth, firm level growth, household/individual welfare, or labor conditions, with most showing statistically significant results (See Figure 2).

*Figure 2: Distribution of the empirical findings of the reviewed papers.*

*a) Coefficients of the relationship between ICT adoption and growth (country or firm levels) or welfare*




*b) Statistical significance of the coefficients found in the reviewed literature*

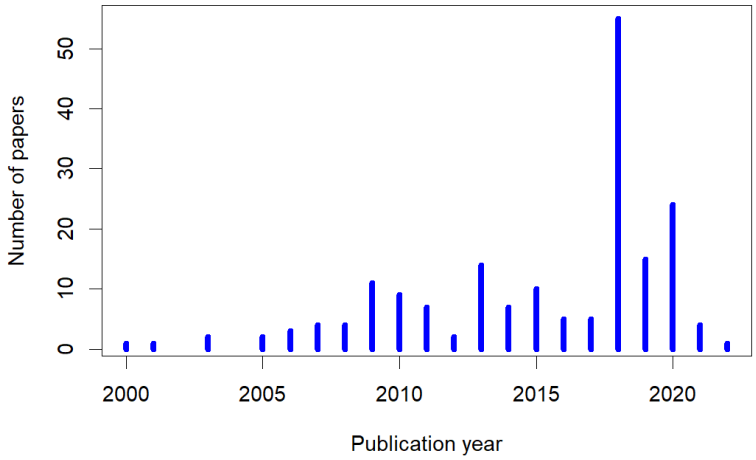



*Source: authors' elaboration. Note: The histogram does not consider outliers, which correspond to results of about 15 papers. The pie chart shows the p-values of the reported coefficients (e.g., a p-value of 10% corresponds to a confidence level of 90%).*

This literature survey[4] benefits from previous reviews on ICT adoption and related topics. However, to our best knowledge, this study represents the most recent comprehensive review of the literature focusing on the multiple agents and channels impacted by the adoption of ICT after the 2000s (see Figure 3). In principle, our selection did not have a geographical restriction; however, on average, the sample size of the reviewed works is 65 countries, and 69% of the studies focus on developing economies. Moreover, most of our papers focus on the 1980-2015 and 2000-2017 periods.

[4] This review is based on a systematic search of the main databases of papers and books on the subject, as well as in the main journals and reports. The search was not limited to economic journals as it also includes journals on technology and information communications, computer science, as well as reports from the World Bank and other international organizations. The search for relevant papers was primarily conducted in English, but we also reviewed a few studies in French using a backward snowballing (examining the bibliographies of the selected papers) approach. The prioritization of relevant papers followed two criteria. First, we gave priority to the papers with the most citations in Google Scholar. Second, although we do not have a strict timeframe for our search, we prioritized papers published in the past 10 years.

*Figure 3: Distribution of reviewed studies by year of publication*




*Source: authors' elaboration.*

## Literature review

Previous reviews that contributed to this paper include Dedrick et al. (2003), which analyzes 50 empirical studies on the economic growth effects of Digital Technology (DT[5]) adoption; Cardona et al. (2013), who summarize the empirical literature on the effects of ICT adoption on productivity; Biagi (2013) who reviews the literature on the relationship between ICT and productivity; Bertschek et al. (2015) who synthesize the quantitative economic impacts of telecommunications networks and broadband internet deployment documented in 24 papers published before 2016; Goldfarb and Tucker (2019) who engage with the available literature on the economic transformation carried by digitization and its cost reducing effects (search, reproduction, transportation, tracking, and verification), and the most recent work by Hjort and Tian (2021) who provide an overview of the literature on growth effects of the internet in developing countries. We feed from these most recent surveys but we recognize that a vast number of literature surveys were published at the end of the millennium driven by the fast technological development between the 1980s and 2000s and the growing number of ICT studies in these decades (for example, Brynjolfsson and Yan, 1996 and Brynjolfsson and Hitt, 2000).

The productivity paradox (a claim that there is no positive and significant connection between Information Technology (IT) investment and labor productivity and economic growth) is refuted in an analysis of over 50 empirical articles showing significant and positive results (Dedrick et al., 2003). Thus, proving that greater investment in IT is correlated with productivity growth at the country and firm levels. However, such refutation comes from a study of articles from the late 1990s and early 2000s. Similarly, through a study of over 100 papers, Cardona et al. (2013) also conclude that the productivity effect of ICT is positive and significant although there exist methodological differences

[5] ICT include the whole range of technologies used for collecting, processing, storing, and transmitting information, including digital technologies— plus, they also include telephones, as well as PCs, mobile devices, etc. Digital technologies, on the other hand, refer specifically to technologies that use digital signals for processing, storing, and transmitting information.

in the empirical studies. The review by Cardona et al. (2013) adds that there are also differences in magnitudes of the effects, like for example, they register different results among the papers measuring the effects of ICT on aggregate productivity between the United States and Europe, although they did not find country-differences at the firm-level. The literature survey by Biagi (2013) cites that for the U.S. economy "the share attributable to ICT goes from 43% for the period 1971-1995 to 59% for the period 1995-2000, with an almost doubling of the contribution from capital deepening" and identifies ICT adoption as a catalyzer of productivity in the period 1996-2006, which could explain the productivity gap between the United States and the E.U. in the same period. Among the first attempts to divide the literature findings by development levels is that of Stanley et al. (2018) who through an analysis of 59 econometric studies find ambiguous effects of internet adoption, with insignificant overall effects for OECD countries and significantly positive effects for developing countries. Our literature review adds to these surveys a contrast of the effects among development levels, industry, and type of technology.

Bertschek et al. (2015) was among the first to categorize the literature by type of technology by differentiating between wireline and wireless items as well as broadband availability and adoption. The main insights of their survey confirm the positive growth effects of ICT adoption found in previous literature reviews and adds that ICT could also help create new jobs although with labor outcomes favoring skilled workers. Finally, Hjort and Tian (2021) add a review of empirical papers showing heterogenous internet effects on labor outcomes (e.g., wages) across demographic groups, mainly favorable for women and high skilled workers, and papers on firm-worker matching which they claim has been mainly present in rich countries. Our literature review builds on these surveys and adds papers suggesting that the effects on labor are seen from different perspectives such as the creation of employment opportunities, changes in the labor structure, and demand for labor. The studies reviewed suggest that the creation of jobs from ICT adoption is an effect mainly present in developing countries while labor displacement (higher demand for people with ICT training) is observed in the developed world (Eichhorst et al., 2016). However, there is no evidence of substitution effects in developing countries. Despite the findings, there is evidence that ICT have a positive impact on labor through increased productivity. This is supported by the work of Cusolito et al. (2020), which shows that overall, ICT enhance labor and, in some cases, even lead to higher wages for both skilled and unskilled workers.

## 2. Economic growth effects at the country level

Various studies emphasize the link between ICT adoption and economic growth using data from multiple countries, periods of time, estimation techniques, and technologies (Choi and Yi, 2009; Niebel, 2018; Stanley et al., 2018). ICT have transformed production in many sectors of the economy; however, growth effects have been hard to identify in the macroeconomic data (Maurseth, 2018). This phenomenon has been popularized as the Solow-paradox after Robert Solow noted that "You can see the computer everywhere but in the productivity statistics" (Solow, 1987). A similar phenomenon is noted by more recent studies like Brynjolfsson et al. (2019) who claim that despite the big developments with AI, measured productivity has declined in the last decade. To analyze this

phenomenon and study the real role of ICT in economic growth, we disaggregate the effects by technology, degree of development, and timing of adoption.

When addressing the impact of ICT adoption on economic growth, there appears to be a distinction in the literature between effects in developed versus developing countries. Dedrick et al. (2003), based on a review of 50 empirical studies, conclude that computer adoption has positive effects in the United States but mixed effects among developing countries. A possible explanation of this evidence could be that IT investment represents a significant share of the U.S. capital stock, which is not the case in the developing world. Niebel (2018) measures the impact of ICT on economic growth on a sample of 59 countries between 1995 and 2010. The results show a positive relationship between ICT and GDP growth. Despite that, the author does not find statistically significant differences in the impacts among developing, emerging, and developed countries. These results, however, might suffer from sample bias since data on ICT capital was mostly available in countries with large GDPs. An analysis including a larger group of countries (especially providing better coverage of smaller economies) would be needed to address this bias. Similarly, Stanley et al. (2018) analyze 58 empirical studies, and find positive and significant impacts of mobile and landline communication technologies on economic growth. Yet, the effects of mobile technologies are twice as large as those of landline. This could explain the technological leapfrogging in developing countries (particularly, in Sub-Saharan Africa) that have passed over landline infrastructure and jumped directly to mobile telecommunications (UNCTAD, 2018). Likewise, using different proxies of ICT infrastructures on economic growth in 28 countries of the European Union between 2000 and 2017, Toader et al. (2018) find that a 1 percent increase in the use of digital infrastructure would increase GDP per capita by between 0.08 percent, if the infrastructure is measured by fixed broadband subscriptions, and 0.4 percent, if it is measured by mobile phone subscriptions. On the other hand, Stanley et al. (2018), find little evidence supporting the positive impact of the internet and fixed broadband on economic growth. These results could be explained by the findings of Andrews et al. (2016) that suggest a recent slowdown in global productivity growth explained by productivity divergence between global frontier firms ("top 5% of firms in terms of labor productivity or multi-factor productivity") and laggard firms. Therefore, the authors suggest analyzing the effects of technology on productivity and growth at different levels (global, country) and types of firms (global frontier and laggard firms).

Given the complexities and various nuances that lie at the nexus between ICT and the developing world, there are discrepancies in the literature about the intensity of the effects of the internet on economic growth. Bertschek et al. (2015) provide a review of empirical studies from the last decade on the effects of fixed broadband internet (e.g., networks and services) and economic growth, employment, and productivity. Overall, telecommunications and fixed broadband deployment have a significant positive impact on economic growth and productivity. However, the general conclusion seems to point at a disparity between the effects found in data before and after 2000. For instance, Choi and Yi (2009), use data reported for 207 countries between 1991 to 2000 from the World Bank's World Development Indicators (WDI) to conclude that a 1 percentage point increase in the percentage of people with access to the internet results in an increase in the growth rate between 0.049 and 0.059 percentage points. However, using the same dataset but for a longer period, 1990-2015, Maurseth (2018) finds significant negative effects of the share of internet users on

economic growth. These results show negative effects in 2001-2015, whereas the positive effects found in Choi and Yi (2009) correspond to 1991-2000. Maurseth (2018) suggests that the greatest benefits of ICT adoption could lie a decade or more in the past. Similarly, Edquist et al. (2018) find that a 10 percent increase in mobile broadband (MBB) network adoption (measured as the percentage of total connections) causes, on average, a 0.8 percent increase in GDP but with a decreasing impact over time (disappearing 6 years after introduction), and it is smaller in magnitude in OECD countries.

More recently, studies have tried to address the question of whether there are additional economic impacts with the adoption of newer mobile technologies. Bahia et. al (2019) investigate the impact of the rollout of mobile broadband technologies on GDP growth from 2000 to 2017 across more than 160 countries. The period under analysis covers the deployment of 2G technology until the roll-out of 4G. The authors find that, in general, a 10 percent increase in the adoption of (any) mobile technology is associated with an increase in GDP between 0.5 and 1.2 percent. This impact is 15 percent higher when connections are upgraded from 2G to 3G, and 25 percent higher when transitioning from 2G to 4G. The study also notes that the impacts are larger in countries with high education levels, suggesting a relationship between human capital and the potential gains of ICT adoption. Concerns about endogeneity are addressed using structural equations models, dynamic panel data, and instrumental variables. Haftu et al. (2019) also find that the expansion of mobile phone subscribers in 40 Sub-Saharan African countries had a significant positive causal effect on increases in the region's per capita GDP reported between 2006 and 2015. Explicitly, a 10 percent increase in mobile phone penetration in the region increases by 1.2 percent the GDP per capita. Contrary to these results, the authors find that internet penetration has not contributed to GDP per capita growth during 2006-2015. The authors claim that this could be due to the low internet penetration in the region, high technology illiteracy, or limited technological infrastructure, among others.

The literature on causal effects is sparser but, to a large extent, it points at positive causal effects of ICT adoption on growth. Castaldo et al. (2018), use General Method of Moments—Instrumental Variable (GMM-IV) to find a positive and statistically significant causal effect between fixed broadband and economic growth in 23 OECD countries between 1996 and 2010, even after controlling for countries' initial endowments (measured as fixed capital formation). Similarly, based on panel co-integration and Granger causality tests, Arvin and Pradhan (2014) claim a causal relationship between broadband adoption and GDP growth using data for 19 countries—developed and developing—between 1998 and 2011. Furthermore, the study finds a bidirectional relationship between GDP growth and broadband penetration only in developed countries. In contrast, in developing countries, the authors find that economic growth has a causal effect on broadband penetration. Gruber et al. (2014) use simultaneous equations models to conclude that fixed broadband adoption has had a significant positive causal effect on GDP growth in 27 countries in the European Union from 2005 to 2011. The authors argue that the effect is larger in high adoption countries. More recently, Calderon and Cantu (2020) examine the impact of digital infrastructure on the development of Sub-Saharan Africa, by comparing data from 177 countries between 1990 and 2019. The authors use a principal component analysis (PCA) and general method of moments with instrumental variables (GMM-IV) system estimator to find a positive and significant causal impact of digital infrastructure

on economic growth, income inequality, and poverty across countries and over time.[6] Moreover, according to Pradhan et al. (2019), the growth effects from ICT adoption can be fostered if combined with other factors such as innovation and diffusion.

More recently, ICT adoption together with good telecommunications infrastructure have proven to be crucial at mitigating the economic losses during pandemic times (Katz et al., 2020). According to Ting et al. (2020), during the COVID-19 outbreak, ICT were being used for monitoring the spread of the virus, performing forecasting models of the new cases, educating individuals about the pandemic, engaging in public communication, and the creation of detection and diagnosis tools (e.g., those that use artificial intelligence (AI) tools). Previously, using data reported from 178 countries between 2000 to 2017, Katz et al. (2020) demonstrate that countries with better broadband connectivity minimized the economic losses caused by the 2003 SARS pandemic. They find that the economic effect of increasing connectivity by 1 percent is negligible for a country with a broadband level above 20 percent, but it is linked to a 13 percent offset in countries with a 10 percent broadband penetration. Another important role lies in the health care system through, for example, virtual clinics and medical "chat bots". Budd et al. (2020) identify the role of ICT in epidemiological surveillance (through machine learning, digital surveys, and data collection and visualization), identification (via sensors for symptoms checking, Wi-Fi-based diagnostic devices, and machine learning), tracing (through smartphone apps and mobile phones' GPS tracks), public communication (via social media, "chat bots", and online search engines), and clinical care (e.g., telemedicine).

In conclusion, the findings presented in this section suggest that the adoption of ICT has a positive and significant impact on growth, although the extent and timing of the impact can vary depending on the level of development. A more comprehensive understanding of the benefits of ICT may be achieved by considering the adoption of emerging technologies, as Brynjolfsson et al. (2019) suggest that the greatest potential benefits from AI and IoT might still be yet to come and may be realized through complementary innovations.

## 3. Firm-level growth effects

ICT can boost firm efficiency, increase productivity, reduce costs (e.g., automatization of administrative processes through online submissions), and enhance innovation and globalization (OECD, 2008). Firm productivity gains from ICT are significant enough to be compared to the productivity gains from electricity adoption. According to Welsum (2007), electric power generation, distribution, and use in the UK represented a 3.3 percent productivity boost by 1937, whereas the productivity boost from broadband is estimated at around 0.4-2.7 percent by 2015 and 0.8-5.7 percent by 2028.

[6] According to the authors, parameter identification is achieved by making several assumptions about the distribution of the error term such as that the error term is serially uncorrelated, and that the explanatory variables are uncorrelated with unobserved country-specific effects.

*Table 1: Main empirical findings from studies on ICT adoption and economic growth*

| Growth | Main conclusions | Sample | Time coverage |
|---|---|---|---|
| Dedrick et al. (2003) | Positive effect of ICT adoption on growth in the USA but a mixed effects among developing countries. | Global | 1986-2002 |
| Draca et al. (2007) | The positive impact of ICT on USA growth was evident after ICT represented a significant share of the capital. | USA, Europe | 1986-2006 |
| Niebel (2018) | Positive relationship between ICT and GDP growth from data of 59 countries from 1995 to 2010 | Global | 1995-2010 |
| Stanley et al. (2018) | Positive impacts of adoption of mobile technologies and landline on economic growth. | Global | 1987-2017 |
| Toader et al. (2018) | An increase of 1 percent in fixed broadband and mobile phone subscriptions increases GDP per capita by 0.08 percent and 0.4 percent, respectively. | EU | 2000-2017 |
| Bertschek et al. (2015) | Telecommunications and broadband deployment have a significant positive impact on economic growth and productivity. | Global | 1992-2015 |
| Choi and Yi (2009) | Positive effects of Internet adoption and economic growth based on data of 207 countries from 1991 to 2000. | Global | 1991-2000 |
| Maurseth (2018) | The greatest benefits of ICT adoption could lie a decade or more in the past. | Global | 1990-2000 |
| Castaldo et al. (2018) | Positive correlation between fixed broadband and economic growth in 23 OECD countries between 1996 and 2010. | OECD | 1996-2010 |
| Arvin and Pradhan (2014) | Causal positive relationship between broadband adoption and GDP growth using data of 19 countries between 1998 and 2011. | G-20 | 1998-2011 |
| Gruber et al. (2014) | Broadband adoption has had a significant positive effect on GDP growth in 27 countries part of the European Union between 2005 and 2011. | 27 EU member countries | 2005-2011 |
| Edquist et al. (2018) | A 10 percent increase in MBB adoption causes a 0.8 percent increase in GDP. | Global | 2002-2014 |
| Bahia et. al (2019) | A 10 percent increase in the adoption of (any) mobile technology increases GDP between 0.5 and 1.2 percent. | Global | 2000-2017 |
| Haftu et al. (2019) | The expansion of mobile phone subscribers in SSA had a significant positive effect on the region's per capita income between 2006 and 2015. | 40 SSA countries | 2006-2015 |
| Pradhan et al. (2019) | Co-development of innovation, diffusion, and ICT penetration fosters economic growth in the long run, in Europe | Europe | 1961-2016 |

| | | | |
|---|---|---|---|
| Calderon and Cantu (2020) | Positive impact of digital infrastructure on the development of SSA, by comparing data from 177 countries between 1990 and 2019. | Global | 1990-2019 |

The relationship between ICT adoption and firm productivity has been widely studied in the literature, mainly suggesting positive effects. Cardona et al. (2013) summarize the empirical literature on ICT adoption and productivity by classifying the literature between methodology used, aggregation level, and type of ICT. The authors conclude that most of the studies find positive and statistically significant effects of ICT adoption on productivity. They also note the methodological differences apparent in the empirical literature, as well as the impact of estimating effects at different levels of aggregation (such as country-level versus firm-level). Additionally, Cardona et al. (2013) find stronger productivity effects of ICT at the macroeconomic levels (country and continents) than at the firm-level. Welsum (2007) adds that measured total factor productivity (TFP) should rise in sectors using ICT, but it is possible that this occurs more rapidly in already highly productive and technological sectors. At the same time, Basu et al. (2003) suggest that the adoption of ICT may be associated with a decrease in total factor productivity (TFP), which could be attributed to the learning curve involved in the adoption of these technologies and the accompanying organizational changes. Similarly, Schweikl and Obermaier (2019) review 86 empirical studies at the firm level and claim that this productivity paradox could be explained by adjustment delays, measurement issues, mismanagement, and unrealistic expectations on the ICT productivity effects.

The productivity effects of ICT are even more challenging to generalize at the sector level, especially between manufacturing and service firms. Bertschek et al. (2013) find that there is no causal effect of fixed broadband internet adoption and productivity using data from a sample of German manufacturing and services firms between 2001 and 2003. The identification strategy relies on an instrumental variable approach considering that, by that time, only 60 percent of the firms had adopted broadband internet. However, the authors find that broadband internet adoption has a causal effect on innovation activities. Aboal and Tacsir (2015) complement the previous findings by exploring the role of ICT adoption (especially, the internet) in the performance of manufacturing and services firms in Uruguay. The authors find that investment in ICT has a significant and positive correlation with the productivity of both manufacturing and services firms. DeStefano et al. (2018) study the heterogenous effects of ICT adoption (especially, broadband internet) on firm performance in the UK from 1999 to 2005. The authors use a comprehensive dataset on the physical units of ICT used within a firm, known as the Ci Technology Database (CiTDB) and conclude that ICT adoption has a causal effect[7] on firm size (measured by sales or employees) but not on productivity. In contrast, more recent studies, such as Cusolito et al. (2020), estimate the effects of ICT adoption (like the creation of a website and email address) on the productivity of manufacturing firms in 82 developing countries from 2002 to 2019 and find significant positive effects on firms' revenue-based total factor

[7] To correct for endogeneity concerns, the authors use an instrumental variable two-stage least squares (2SLS) approach, in which they exploit the variation in the determinants of ICT.

productivity and factor demand. The authors add that the median productivity effects of email and website are potentially larger than those from exporting and augmenting managerial skills.

Verhoogen (2020) summarizes recent empirical literature that discusses the determinants of upgrading (such as innovation, technology adoption, and increases in productivity) in developing countries, focusing primarily on studies of large manufacturing firms. The author argues that one of the channels of upgrading is selling to consumers from developed countries, and that ICT adoption is linked to the internationalization of firms, especially, to exporting activities. For instance, Tseng and Johnsen (2011) find a positive relationship between usage of the internet and a firm's internationalization process in the UK manufacturing small and medium enterprises (SMEs), while Hagsten and Kotnik (2017) show similar results for a set of European SMEs. Similarly, Atiyas and Dutz (2021) study the case of informal micro-sized firms in Senegal and find that the use of a smartphone is positively correlated with exporting activities. Jagun et al. (2008) add that mobile phones have reduced information failures and costs for Nigerian micro-enterprises. However, the authors note that there is conflicting evidence regarding the effect of these technologies on reducing income inequality among firms. They argue that the businesses with the most resources were early adopters of these technologies and benefited from mobile orders, while the least resourceful businesses may be losing orders due to either late adoption or a learning curve.

The literature also relates ICT productivity effects to firm ownership, size, and digitization level. Chew et al. (2010) use regression analysis and a sample of female entrepreneurs from Mumbai to show that business growth in female-owned micro-enterprises is positively affected by ICT access. Tseng and Johnsen (2011) claim that internet adoption is more important in the internationalization process of high-tech firms rather than low-tech firms (classified based on the share of expenses devoted to R&D). To this, Gal et al. (2019) add that productivity gains from ICT in the EU do not depend on firm size but rather on productivity level and type of technology. They find that gains are higher in high productivity firms, increasing the productivity gap between frontier and laggard firms. For instance, the authors find that, on average, a 10 percentage-point increase in adoption of cloud computing services increases a firm's productivity level by 3.5 percent, but that these productivity gains are more than doubled for high productivity firms. This difference could be explained by the dependence on ICT specialists which is higher in less productive firms (Berlingieri et al., 2018). In terms of type of technology, Gal et al. (2019) find that cloud computing has bigger productivity effects on smaller firms, while Enterprise Resource Planning (a type of IT applications, designed to automate business processes) is more beneficial for bigger firms.

In general, the literature points to multiple channels of impact on productivity, and when considering ICT as a determinant, there is a consensus that their impact is amplified when accompanied by other factors such as employees' skills. Colombo et al. (2013) study how the adoption of broadband internet has affected the productivity of 799 Italian SMEs using data from 1998 to 2004. The authors find that the impact of internet adoption on productivity is negligible, but that broadband application fosters productivity if combined with complementary strategic and organizational changes such as adjustment of internal routines to maximize the potential of ICT, cultural adaptation to the use of technologies, and good organizational skills.

More recent scholarly works focus on investment in intangibles (e.g., digital platforms). Online platforms have the potential to increase market efficiency, enhance business opportunities, and boost productivity. Moreover, digital platforms are correcting market failures by addressing information asymmetries. For example, Vergara Cobos (2020) finds that e-hailing technologies in the taxicab market in New York City had a positive causal effect on product demand benefiting both incumbents and new entrants, while at the same time, placing them as complements. In this sense, OECD (2021) finds a positive association between online platform diffusion and incumbents' productivity growth. This effect could be explained through different channels like encouraging incumbents to innovate (e.g., the case of the Uber technology being applied in yellow taxicabs), upgrading market logistics, reducing information asymmetries, and ultimately, making markets more efficient. Moreover, digital platforms could present positive profit effects through new pricing mechanisms as noted by Li et al. (2019) who find that the online travel platform Booking.com has increased its clients' revenue by 7 percent, on average, through its pricing strategy which matches firms with consumers willing to pay more.

*Table 2: Main empirical findings from studies on ICT adoption and firm-level growth*

| Productivity | Main conclusions | Sample | Time coverage |
|---|---|---|---|
| Cardona et al. (2013) | Summarizes the empirical literature on ICT adoption and productivity. | Global | 1957-2012 |
| Bertschek et al. (2013) | No causal effect of broadband Internet adoption and productivity, by using data from German manufacturing and services firms from 2001 to 2003. | Germany | 2001-2003 |
| Aboal and Tacsir (2015) | ICT has a significant and positive effect on the productivity of both manufacturing and services firms. | Uruguay | 2004-2006 and 2007-2009 |
| DeStefano et al. (2018) | ICT adoption causally affects firm size (measured by sales or employees) but not productivity. | UK | 2000 |
| Cusolito et al. (2020) | Significant effects of DT adoption on firms' revenue and productivity. | Global | 1980-2000 |
| Goldfarb and Tucker (2019) | Lower search costs driven by digitalization reduce both price and price dispersion, increase the variety of products, and facilitate matching processes. | Global | 1961-2019 |
| Verhoogen (2020) | DT adoption is linked to the internationalization of firms, especially, to exporting activities. | Global | 1957-2021 |
| Tseng and Johnsen (2011) | Positive relationship between usage of the Internet and a firm's internationalization process of the UK manufacturing small and medium enterprises. | UK | NA |
| Colombo et al. (2013) | The impact of Internet adoption on productivity is negligible, but broadband application engender productivity if combined with organizational changes. | Italy | 1998-2004 |
| Díaz-Chao et. al (2015) | Wages affects more productivity than ICT use in small firms in Spain. | Spain | 2009 |
| Hagsten and Kotnik (2017) | Positive relationship between ICT capacity of small and medium-size European firms and engagement in exporting activities. | Europe | 2010 |

## 4. Economic transformation of individuals' welfare

The role of ICT adoption in promoting economic development has been studied from a wide range of perspectives including the effects on market outcomes, poverty, income inequality, and human capital formation. In this section, we engage with studies particularly associated with the effects of ICT adoption on income and wealth equity, as well as its effects on social and human capital formation and correction of market failures that could ultimately affect consumer welfare. Moreover, ICT can also foster opportunities to promote human development through the creation and communication of new knowledge, impacts on agricultural production, and increased connection with the rest of the world (Heeks 2010; Prado et al., 2011). As devices that increasingly rely on mobile broadband technologies, such as smartphones, have become more widespread there has been a significant change in consumers' access to information (Rennhoff and Routon, 2016). For instance, according to Aker and Mbiti (2010), services such as text-messages are helping development in SSA by increasing access to information on a wide range of topics like communication about fair prices, HIV/AIDS medicine provision and reminders, and crime reporting.

Carabregu et al. (2019) study the re-distributional effects of mobile phone and network penetration by looking at the correlation between mobile broadband and income inequality in Western Balkan countries (Albania, Bosnia, Serbia, among others). The analysis uses as dependent variable income inequality, and cell phone diffusion as one of the predictors, and finds that a 1 percent increase in mobile penetration decreases the Gini index between -0.049 and -0.055 points. In addition, Iqbal et al. (2019) study the correlation between ICT adoption and the Human Development Index (HDI) in South Asian countries during 1990 and 2016. The authors find a positive and significant effect of mobile phone usage on human development. Namely, the findings suggest that a 1 percent increase in mobile phone penetration leads to a 0.12 percent increase in the HDI while internet penetration is not identified as a significant predictor.

Some studies point to the money-making effects of ICT adoption while others place them as a financial burden for the poorest, potentially increasing inequality. For example, Heeks (2010) analyzes various works that look at the relationship between ICT and poverty. The author highlights studies that find a positive association between ICT adoption and money-saving and money-making effects among the poorest (Abraham 2007; Levy et al. 2010). However, such findings are not clear when looking at different technologies. For instance, Scott et al. (2005) conducted a study on the economic impacts of mobile phone usage in India, Mozambique, and Tanzania and found that poor users of mobile services allocate a larger portion of their income towards mobile phones compared to higher income groups, indicating that mobile telephony represents a financial burden for the poorest. Additionally, they found that mobile phones are primarily seen as a means to save money rather than a source of income. Similarly, Malásquez et al. (2021) note that in countries such as Mauritania and Senegal lower welfare quintiles spend a higher share of their income on mobile services than the top quintiles. Furthermore, other studies associate mobile phones with an increase in inequality and poverty. For example, Mpogele et al. (2008) conduct a survey in rural areas of Tanzania to examine how people perceive the relationship between mobile phones and poverty; the results revealed that although people do not see direct financial benefits from mobile phone usage, there are indirect

economic benefits such as when sellers use mobile phones to inform buyers about product availability. Furthermore, researchers such as Liu et al. (2019) explore the cost-saving potential of using digital platforms, specifically e-hailing apps in the New York City taxicab market. The authors suggest that the implementation of search and match technology accompanied by GPS tracking could result in yearly savings of over $11 million per year just by reducing unnecessary detours from rides departing from La Guardia airport.

Competition reforms are a cost-efficient way to reduce prices, alleviate poverty and improve the living conditions of the poor (Purfield et al., 2016). For instance, Goldfarb and Tucker (2019) discuss the changes in costs associated with digitization. The authors claim that lower search costs driven by digitization reduce both prices and price dispersion, increase the variety of products, and facilitate the matching processes, especially in service markets (the costs included are related to search, replication, transportation, tracking, and verification). Recent studies rely on simulation methods to show that increasing competition in the mobile telecommunications sector in African countries could help alleviate poverty and, in some cases, consumption inequality (Rodríguez-Castelán et al., 2020; Malásquez et al., 2021). Moreover, emerging literature shows that the reduction of communication and search costs provided by mobile phone adoption increases consumer welfare as well as producer welfare. For instance, Jensen (2007) shows how the adoption of mobile phones by fishermen and wholesalers reduced price dispersion and increased profit in the South Indian fisheries sector. Aker (2010) finds a positive effect of mobile phone adoption on the reduction of price dispersion in the grain market in Niger. More precisely, mobile phone adoption explains a 10 to 16 percent reduction in grain price dispersion between 2001 and 2006, through a reduction in search costs (i.e., mobile phones reduce price dispersion). Similarly, Aker and Mbiti (2010) highlight the magnitude of the effects in rural areas, for example, in Ghana, farmers in the countryside are now using mobile phone services (e.g., text messages) to learn about the prices of corn and tomato in Accra.

Mobile broadband has also allowed the dissemination of technologies such as mobile banking that have the ability to promote inclusive development (Baabdullah et al., 2019) through a decreasing effect of poverty and income inequality (Asongu and Nwachukwu, 2018). By using data from 93 developing countries for 2011, Asongu and Nwachukwu (2018) find that mobile banking has a significant and positive correlation with the Human Development Index (HDI) with the magnitude of the association varying among different country income groups (low, middle, upper). Mbiti and Weil (2016) analyze the Kenyan mobile banking M-Pesa and conclude that the success of M-Pesa has decreased the prices of money-transfer competitors, increased transactions among individuals, served as a saving mechanism, and increased the probability of being banked.

Finally, to foster significant welfare and development gains, ICT adoption should be accompanied by increased digital literacy. Gebremichael and Jackson (2006) discuss the concept of "information poverty" and claim that to foster development and to not fall behind the developed world, SSA countries and other developing nations should bridge the digital divide and alleviate information poverty. To do so, governments should focus on targeting the determinants of ICT adoption such as the education level of the household head (Mwanthi, 2009).

*Table 3: Main empirical findings from studies on ICT adoption and household/individual welfare*

| Welfare | Main conclusions | Sample | Time coverage |
|---|---|---|---|
| Prado et al. (2011) | ICT create opportunities to foster human development through several channels such as the creation and communication of new knowledge. | Brazil | 2010 |
| Heeks (2010) | Survey: ICT are showing a progressive contribution to development | Global | 1990-2010 |
| Chew et al. (2010) | Business growth in female-owned micro-enterprises is positively affected by ICT access. | India (Mumbai) | 2009 |
| Scott et al. (2005) | Poor users of mobile phones in India, Mozambique, and Tanzania spend higher shares of income on mobile phones than the top income quintiles. | India, Mozambique, Tanzania | 2004 |
| Jagun et al. (2008) | In Nigeria, there are mixed signs about the role that DT have played on inequality reduction. | Nigeria | NA |
| Mpogele et al. (2008) | People in Tanzania do not perceive financial benefits from the usage of mobile phones. | Tanzania | NA |
| Gebremichael and Jackson (2006) | To foster development SSA countries and other developing nations should bridge the digital divide, and thus, alleviate information poverty | Global-developing | 1991-2005 |
| Mwanthi, 2009 | The governments should focus on targeting the determinants of ICT adoption such as the education level of the household head. | Kenya | 2008 |
| Jensen (2007) | The adoption of mobile phones by fishermen and wholesalers reduced price dispersion and increased social welfare in the south Indian fisheries sector. | India (Kerala) | 1996-2001 |
| Aker (2010) | Positive effect of mobile phone adoption on the reduction of price dispersion in the grain market in Niger. | Niger | 2001-2006 |
| Aker (2011) | Although mobile phones have been recognized by the literature as means of poverty reduction, there is a risk that the poorest may fall behind. | Global | 1985-2011 |
| Aker and Mbiti (2010) | Gains in development (through fair prices, job opportunities, etc.) from the increased usage of mobile telephony in SSA. | SSA | 2006-2009 |
| Baabdullah et al., 2019 | Mobile broadbands have allowed for the creation of mobile banking, one of the most promising technologies of recent years. | Saudi Arabia | 2017 |
| Asongu and Nwachukwu, 2018 | Mobile banking promotes inclusive development through a decreasing effect of poverty and income inequality. | Global | 2011 |
| Carabregu et al. (2019) | Positive correlation between MBB and the reduction of income inequality in the Western Balkan countries. | 5 Balkan countries | NA |
| Iqbal et al. (2019) | Positive effect of mobile phone usage and human development. | 5 South Asian countries | 1990-2016 |

## 5. Economic transformation of labor market conditions

ICT adoption presents important effects on firms' labor structure, demand for labor, wages, and other labor outcomes (Iacovone and Pereira-López, 2018), creating new labor opportunities worldwide (OECD, 2008). Thus far, the literature shows that the skills in demand are changing towards ICT-skills; however, at the same time, ICT adoption also brings wider benefits for the overall labor force. For instance, although ICT adoption by Mexican manufacturing firms has increased the demand for more high-skilled workers between 2008 and 2013, the wages increased for both skilled and unskilled workers (Iacovone and Pereira-López, 2018). Cusolito et al. (2020) look at manufacturing businesses in 82 developing countries from 2002-2019 and find that ICT adoption (particularly, email and website creation) is labor enhancing with a significant and positive correlation between ICT adoption and labor demand. This level of correlation is higher than the one from the variable managerial experience, and lower than the one from exporting activities. Such association could be explained by the productivity gains from digitization which affect product demand (e.g., through lower prices), lead to firms having more revenue, and requiring more labor. ICT can also affect the labor market by facilitating the matching process, like in Niger where people are calling acquaintances in flourishing labor markets to learn about job opportunities without having to incur transportation costs (Aker and Mbiti, 2010).

ICT' labor effects might differ between developed and developing nations. Michaels et al. (2014) find that labor demand in the United States has shifted towards demand for college graduates and people with ICT skills since late 1980s and Akerman (2015) claims that adoption of broadband internet in Norway has also resulted in wage increases for high-skill workers. Czernich et al. (2011) find significant and positive correlations between internet adoption and wages in rich countries. Atalay et al. (2018) use newspaper ads that have been published between 1960 and 2000 in three main U.S. journals with wide readership nationally to measure the correlation between job tasks and ICT adoption. The authors find that ICT adoption has boosted analytic activities while decreasing manual tasks. Such an effect could potentially damage the employment prospects of unskilled low-income workers. This effect is also discussed by Eichhorst et al. (2016), who focus on the role of adoption in the transformation of occupations in Germany and other developed countries. The authors, however, note that the latest changes in the job market (e.g., new employment opportunities from internet-based marketplaces and self-employment opportunities) have been fostered not only by ICT adoption but also by globalization.

There is also an open debate identified across the literature on the effects of the internet regarding job creation and job matching. Although Czernich (2014) initially finds a negative relationship between Digital Subscriber Line (DSL) availability and unemployment in German municipalities, the results only hold under a linear model specification and therefore, the author concludes that the availability of broadband internet has no effect on unemployment. However, such results do not imply that the internet does not affect the overall labor market (e.g., through speeding the matching process and increasing employment, especially of offsite jobs). More recently, Hjort and Poulsen (2019) study the causal relationship between fast internet and employment rates using individual and firm-level data from 12 African countries, and compare individuals and firms located

near and far from terrestrial network of internet cables. They find that the probability that an individual (in one of the 12 selected countries) is employed increases between 6.9 and 13.2 percent when fast internet becomes accessible. Importantly, such probability is significant for skilled occupations, while unskilled jobs are unaffected by access to fast internet.

In parallel, another branch of research examines the effects of ICT adoption in rural areas, focusing mainly on those that have just received mobile coverage, and finds positive effects on the labor market. For instance, Klonner and Nolen (2008) study the effect of mobile network coverage in the rural labor market outcomes in South Africa. To identify the causal effect of network coverage on market outcomes the authors use terrain characteristics as instrumental variables. The authors find that employment increases by 15 percentage points when a region receives mobile coverage, and that this is even reflected in poverty reduction. Atasoy (2013) studies the effects of broadband internet adoption from 1999 to 2007 across counties in the United States. The author finds that broadband adoption is correlated with a 1.8 percentage points increase in the employment rate, but the impact is higher in rural counties. Similarly, Lu and Song (2020) rely on survey data from college students in China to study the effects of ICT on college students' labor market outcomes and find that students who have received education on ICT-related subjects are more likely to obtain a job and a higher salary than their peers who did not receive such training.

Another stream of emerging studies focuses on the labor enhancing effects of the growth of new businesses based on online-platforms and AI. The common agreement is that digital platforms are transforming markets, making them more efficient, increasing product demand and ultimately, creating new jobs. For instance, in the taxicab market, the "Uber technology" has been linked to increased number of rides and the creation of over 30,000 jobs just from one startup (Vergara-Cobos, 2020). Our survey of the literature suggests that future research should focus on developing new online business models and work routines in response to the COVID-19 pandemic. Among other works, for example, Leonardi (2020) claims that the new work-model that COVID-19 enabled (in other words, the "work-from-home" model) has changed the work routine of companies; consequently, such a work model will continue to drive institutional innovation for decades to come.

*Table 4: Main empirical findings from studies on ICT adoption and labor market outcomes*

| Labor market | Main conclusions | Sample | Time coverage |
|---|---|---|---|
| Iacovone and Pereira-López (2018) | ICT adoption in the manufacturing sector has increased the demand for more high-skilled workers. | Mexico | 2008-2013 |
| Czernich (2014) | The availability of broadband Internet does not reduce unemployment. | Germany | 2006 |
| Hjort and Poulsen (2019) | The probability that an individual is employed increases between 6.9 and 13.2 percent when fast Internet becomes accessible. | 12 African countries | 2006-2014 |
| Klonner and Nolen (2008) | Employment increases by 15 percentage points when a region receives mobile coverage and that mobile coverage is linked to poverty reduction. | South Africa | 1995-2001 |

| | | | |
|---|---|---|---|
| Atasoy (2013) | Broadband adoption is correlated with a 1.8 p.p. increase in the employment rate. Such an effect is higher in rural areas. | USA | 1999-2007 |
| Atalay et al. (2018) | ICT adoption has boosted analytic tasks while decreasing manual tasks. | USA | 1960-2000 |
| Eichhorst et al. (2016) | DT-based employment has been fostered not only by DT adoption but by globalization. | Global-developed | 1995-2016 |
| Lu and Song (2020) | Students who have received education on ICT are more likely to obtain a job and a higher salary. | China | 2010-2016 |

## 6. Conclusions, limitations, and future work

This literature review presents a comprehensive overview of the central findings drawn from 112 studies that examined the impact of information and communications technology (ICT) adoption on economic growth at the country and firm levels, as well as its influence on economic transformation through its impact on the well-being of individuals and the labor market.

In terms of macroeconomic effects of ICT adoption, we identify three main types of empirical conclusions that can help inform future empirical research and interventions. First, we observe evidence of an overall positive effect of digitization on economic growth in both developed (e.g., Jalava and Pohjola, 2008; Koutroumpis, 2009; Toader et al., 2018) and developing countries (e.g., Bahrini and Qaffas, 2019; Haftu et al., 2019; Calderon and Cantu, 2020). Second, we identify an ongoing debate across the literature with some studies claiming that developed economies have gained the most from digitization (Dedrick et al. 2003), while others stating the opposite (Dimelis and Papaioannou, 2009; Majeed and Ayub, 2018). Third, we see a trend of a few works that do not find a significant relationship between digitization and development (e.g., Niebel, 2018). It is important to note that our search mainly examined studies on mobile technologies from which we see an agreement on the positive economic effects of their use. However, as shown by other scholars, the magnitude of the effects varies across time, technology rollout, and geographical scope (e.g., Edquist et al. 2018 and Bahia et. al, 2019). For example, similar to mobile technologies, the Internet of Things (IoT), AI tools, and internet services have also been identified as inducers of economic growth (Graetz and Michaels, 2018). Although the resonating message is that the adoption of ICT has contributed to economic growth, the timing of the effects is questioned with some results indicating that the peak of such effects occurred years ago (Maurseth. 2018).

While productivity growth has decelerated in the last decade in developed and (some) developing countries (Syverson, 2017; Brynjolfsson et al., 2020), there is vast evidence of the positive effects of recent AI tools and IoT on firm-level productivity (Brynjolfsson and McAfee, 2014; Raj and Seamans, 2018). Accordingly, our review shows that there are emerging studies pointing out at positive effects of ICT adoption on labor productivity (Graetz and Michaels, 2018; Lakshmi and Corbet, 2020). Despite that, we also recognize that there are ongoing claims that ICT are unable to, at least alone in scope, boost the stagnated productivity levels with recent breakthroughs like, for example, those of AI. As in the case of the effects on macroeconomic growth, however, we pinpoint conflicting findings on the magnitude of the productivity effects of ICT adoption depending on the firm size (Colombo et al., 2013; Díaz-Chao et al., 2015; Hagsten and Kotnik, 2017; DeStefano et al., 2018), industry (e.g., manufacturing versus services firms in Bertschek et al., 2013; Aboal and Tacsir, 2015), and

technological levels in the production process (Tseng and Johnsen, 2011). Moreover, internet services are among the most analyzed items, mainly through the channels of firms' increasing online presence, internationalization, and reduction of production costs (Hagsten and Kotnik, 2017; Goldfarb and Tucker, 2019). At least on macro-scale and among development levels, we did not find conclusive evidence to differentiate productivity effects in developed countries from those in developing ones (Tseng and Johnsen, 2011; Díaz-Chao et. al, 2015; Verhoogen, 2020).

In the poorest regions of the world, technologies such as the internet itself and the growing number of mobile services are highly priced, which poses the risk that the poorest might be doomed to fall behind welfare gains (Aker, 2011; Scott et al., 2005; Jagun et al. 2008; and Mpogele et al., 2008). However, there is also an important literature evidencing positive welfare effects of ICT adoption. This literature points at different ways of achieving welfare gains, including the correction of market failures through the use of technology (see decreasing price dispersion by Aker, 2010); consumption and its effects on poverty (Bahia et al., 2020); and money saving and money-making opportunities (e.g., e-banking - Aker, 2011; Asongu and Nwachukwu, 2018). Moreover, mobile technologies allow for the development of new services that have also been linked to welfare improvements and inclusive development.

Growth that creates poverty reduction and shared prosperity should be able to create more inclusive jobs. Economic transformation involves changing the nature of people's jobs, what they do, and how they do it. The literature on this topic mainly focuses on the creation of jobs. An example is Hjort and Poulsen (2019) who empirically demonstrate that the probability of getting employed increases between 3.1 and 13.2 percent after the introduction of fast internet in Sub-Saharan Africa. Needless to say, ICT and, more specifically, mobile technologies, have also allowed for the development of digital platforms (e.g., e-hailing applications) that have restructured inefficient markets (e.g., increased the search and match rate and decreased the detouring rate in the taxicab market), increased product demand, and ultimately, created new jobs (Liu et al., 2019; Vergara-Cobos, 2020). However, these effects may vary by level of development (Klonner and Nolen, 2008; Atasoy, 2013; Czernich, 2014; Hjort and Poulsen, 2019).

Despite these indications, our survey points to the fact that ICT adoption and economic development are not just about the creation of new jobs, but of better and more productive jobs, that can provide, among other things, competitive salaries, good working conditions, and social protection for all in an increasingly technology-dependent society. On that note, one of the existing hurdles of ICT adoption in this regard is that it could foster better jobs just for those with ICT skills. In this sense, there is evidence of the effects of ICT adoption on specialization of the labor force (Eichhorst et al., 2016; Atalay et al., 2018; Iacovone and Pereira-López, 2018) and the increase of opportunities for those with ICT training (Lu and Song, 2020).

## Future research

The evidence gathered throughout this paper via a thorough analytical review of empirical works suggests positive economic effects of ICT adoption but with differences in magnitudes depending on various factors such as a country's degree of development, a firm's size, or a household's income decile. In this sense, we suggest that the need for comprehensive work that analyzes the economic effects of ICT adoption considering different cofounding factors will remain as more top-notch

technologies are swiftly launched and democratized such as the many AI-powered tools accessed by millions on a daily basis worldwide. Another noteworthy point is that the decline in productivity growth worldwide could be explained by the productivity gap between frontier and laggard firms. Therefore, future research exploring the relationship between ICT adoption and development should consider collecting data from both groups of firms and analyze them separately. This will help determine if the decrease in productivity growth is due to ICT having no impact or if it is connected to a widening productivity gap between leading firms and lagging firms that have been slow to adopt and effectively use ICT.

All in all, our review suggests that current literature is hampered by the difficulty of establishing average effects at a more granular level. Therefore, empirical evidence at an individual level can also help us understand poverty and equality matters, as well as potential gains from transformation of the labor market. Hence, it is imperative that future work is able to enhance our understanding of ICT adoption by examining various disaggregating factors such as industry type (e.g., service versus manufacturing), firm type (e.g., laggard firms versus frontier firms), geographical context (e.g., across regions and/or in rural versus urban contexts), level of development, among others. Additionally, studying the effects of ICT adoption from the perspective of different demographic groups (i.e., gender, age, education) could provide valuable insights into how technology affects economic growth differently within each group. Pursuing further research in these areas might result in a more nuanced and sophisticated understanding of the relationship between ICT adoption and economic growth. This in turn could provide policy makers and other stakeholders with more effective means for designing interventions and maximizing the economic benefits that ICT can offer to developing countries that are becoming increasingly connected to the internet and its opportunities for economic growth.

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## Appendix 1: ICT policies and regulations

*Table 5: Additional papers reviewed on ICT policies and regulations*

| Policies and regulations | Main conclusions | Sample | Time coverage |
|---|---|---|---|
| Mansell, (2011) | Market valuation is considered by many as the most efficient mean of telecommunications distribution | Global | 1959-2011 |
| Bichler et al. (2014) | Simple "compact" bids increases the auction's efficiency and revenue. | Europe | 2012-2013 |
| Grunwald (2001) | Auctions could be helpful in distributing licenses amongst those who monetarily value them the most. | Global | 1951-1999 |
| Kwon and Kim (2012) | Governments should supply additional spectrum to incumbents without the need to participate in new actions | Republic of Korea, UK | 2001-2011 |
| Kumar and Bhardwaj (2015) | In India, most telecom companies are facing high costs and stagnant revenues, which is expected to affect quality. | India | 2002-2015 |
| Meddour et al. (2011) | Sharing strategies among MNOs could be of particular benefit for developing countries since they foster affordability and accessibility. | Global | 2010 |
| Ritala et al. (2015) | Cooperation between firms fosters efficiency, access, and the creation of new knowledge and opportunities. | Finland | 2012 |
| Arakpogun et al. (2020) | High levels of IS increase cooperative strategies, resolution of technical incompatibilities, and engagement of standards settings among MNOs. | SSA | 2020 |
| Kibilda and DaSilva (2013) | Identifies cost efficiency gains by simulating a wireless network sharing regime | Poland | NA |
| Amadasun et al. (2020) | IS and co-location of sites in the mobile telecommunications market of Nigeria will reduce operational costs for MNOs | Nigeria | 2007-2016 |
| Hazlett and Munoz (2009) | The largest social welfare gains occurred in countries with liberal use of radio spectrum. | Latin America | 1999-2003 |
| Salemink et al. (2017) | Survey: policies directed towards DT adoption are rapidly outdated by market developments. | Global-advanced | 1992-2015 |
| Paunov and Planes-Satorra (2019) | Highlight the need to constantly revise ICT and innovation policies in order to ensure that they remain effective at addressing new challenges. | OECD | 1990-2019 |
| Amankwah-Amoah (2019) | Weak regulatory frameworks and limited banking and credit systems lead to the creation and popularization of mobile banking services | SSA | 1934-2019 |
| Corrales and Westhoff (2006) | Market-oriented policies are associated with a higher probability to adopt DT | Global | 1990-2003 |
| Diaz-Chao et al. (2015) | Policies directed only towards increasing ICT use, without considering other determinants, could be unsuccessful. | Spain | 2009 |
| Seim and Viard (2011) | Deregulatory policies in the telecom sector have lead to higher variety of products and lower prices. | USA | 1996-1998 |

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|---|---|---|---|
| Sorbe et al. (2019) | Policies directed towards increasing the availability of high-speed Internet could support firm productivity and encourage DT adoption. | Europe | 2010-2016 |
| Maicas et al. (2009) | Policies directed towards reducing switching costs could improve competition in telecom markets. | Spain | 2001-2004 |
| Lee et al. (2005) | Number portability not only lowers switching costs but increases competition among providers. | Republic of Korea | 2004 |
| Eichhorst et al. (2016) | The new forms of employment based on DT face a challenge to policymakers, especially in topics related to pensions and taxation. | OECD | 1991-2015 |
| **ICT and pandemic mitigation** | | | |
| Katz et al. (2020) | Countries with better broadband connectivity minimized more the economic losses caused by the 2003 SARS pandemic | Global | 2000-2017 |
| Ting et al. (2020) & Budd et al. (2020) | DT are being used for monitoring, forecasting, tracing, educating, and communicating. | Global | 2004-2020 |
| Papadopoulos et al. (2020) | Support of IT-operations and IT-strategies around all the levels of the production process is needed during pandemic times. | Global | 1978-2020 |
| Leonardi (2020) | The "work from home" model have changed the work routine of companies and will build new business models for decades to come. | Global | 2012-2019 |