GSR-17 Discussion paper

SOCIAL AND ECONOMIC IMPACT OF DIGITAL TRANSFORMATION ON THE ECONOMY

Work in progress, for discussion purposes
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CONTENTS

Executive Summary

Digitization refers to the transformations triggered by the massive adoption of digital technologies that generate, process, share and transfer information. Digital transformation is not a one-time event. It proceeds in waves driven by technological progress and diffusion of innovations. The first wave of digitization is associated with the introduction and adoption of what today are considered “mature” technologies, such as management information systems aimed at automating data processing and applied to monitoring and reporting of business performance, telecommunications technologies such as broadband (fixed and mobile) and voice telecommunications (fixed and mobile) which allow the remote access of information. The second wave of digitization entails the diffusion of the Internet and its corresponding platforms (search engines, marketplaces), which enable the networking of enterprises to consumers and enterprises among themselves for purchasing of supplies, and distribution of output. The third wave of digitization entails the adoption of a range of advanced technologies, such as big data/analytics, Internet of Things, robotics, sensors, and artificial intelligence, and is aimed at enhancing information processing and the quality of decision making, while further automating routine tasks within business enterprises and governments. These technologies are not typically adopted in a stand-alone fashion but are integrated with the mature technologies characteristic of the first and second waves.

Each digitization wave has a specific set of social and economic impacts. Computing, broadband and mobile telephony networks have been instrumental in relaxing industry scalability constraints, thereby allowing traditional sectors of the economy to grow more rapidly. The alleviation of the resource constraint has led to increased demand for labor in service industries, (e.g., financial services, education, health care, etc.) although it also had a positive effect in manufacturing. Finally, the first wave appears to have had an impact on the growth of household income, and the facilitation of social inclusion (access to information, government services, and entertainment content).

The second wave of digitization has led to the introduction of new services and applications such as Internet information searches, electronic commerce, distance education and a whole range of collaborative businesses that characterize the digital economy (Uber, airbnb, etc.). This “innovation effect” has yielded enhanced demand for labor in certain occupations linked to the development of digital services or the emergence of collaborative business models, coupled with the disappearance of repetitive low and middle-skilled jobs resulting from task automation.

The third wave of digitization has significant implications for productivity improvements. It also promises to have significant benefits on social welfare, more particularly on several Sustainable Development Goals, associated with the delivery of public services. The evidence so far with regards to the disruptive labor effects of the third wave are quite speculative, unless once believes that third wave disruption is merely an extrapolation of the second digitization wave effects. However, there is almost universal agreement that, similarly to the prior waves of innovation, automation will tend to favor those workers with more education and training. In this context, it is relevant to consider the policy remedies that could propel the benefits of automation and limit the negative outcomes:

- Implement labor market policies focused on workers being able to either retain their current jobs or move to the new areas of demand. These policies comprise job placement services, special labor market programs and wage subsidies to lessen the transition cost;
- Deploy policies focused on increasing geographic mobility, which would allow workers residing in areas affected by automation to move to high job creation cities.
- Accelerate the creation of clusters of industries and universities around high quality of life locations that stimulate high-skilled labor demand in under-developed areas.
- In particular, emerging countries need to actively promote the digitization of production and digital transformation. This requires emphasizing policies focused on accelerating the digitization of production of small and medium enterprises, by reducing the cost of technology acquisition, training of employees, and the provision of consultancy services to support companies in their process of digital transformation.
- Launch changes in educational and training systems to address the human capital gap (implement tracking systems aimed at sorting out top performers; introduce short term technology careers; structure two-tier university systems);
- If ICT deployment leads to job destruction in certain areas or sectors, governments should be ready to implement retraining programs and temporary safety net mitigation initiatives.

The policy challenge going forward is that the digital transformation resulting from all three waves of digitization is so all-encompassing that sector-specific strategies developed within institutional silos are not applicable any more. Governments need to build cross-institutional links fostering the collaboration among education, ICT, industrial promotion, science and technology to devise and jointly implement policies. In addition, the future public policy scope has to be significantly expanded beyond traditional domains such as taxation, competition, and digital literacy to include new areas such as privacy protection, cyber security, and the fostering of digital adoption such as trust and enhanced customer experience. As it is clear, the challenges for policy makers are significant, but so are the benefits for citizens and the need to mitigate any potential disruptions.

1. Framing the issue

The purpose of this paper is to provide an understanding of the social and economic impact of automation and digital transformation, and its potential benefits in developing technology applications with a fundamental positive contribution to our quality of life. At the same, as it is the case with all major technological innovations, automation and digitization may result in some social. In this context, the paper outlines policies aimed at maximizing benefits and controlling for any potential negative outcomes associated with these changes.

Digitization refers to the transformations triggered by the massive adoption of digital technologies that generate, process, share and transfer information. Unlike other innovations driven by a single innovation, digitization builds on the evolution of multiple technologies: telecommunications networks (mobile or fixed broadband networks), computer technologies (computers/laptops, wireless devices/tablets), software engineering (operating systems, machine learning and artificial intelligence) and the spillover effects resulting from their use (common platforms for application development, electronic delivery of government services, electronic commerce, social networks, and availability of online information in fora, blogs and portals). The gradual adoption of these technologies has led to a massive technological discontinuity, similar to the introduction of steam engines, electricity and railways, sweeping across economies, affecting our societies, and leading to spillover effects within the local, regional and global communities.

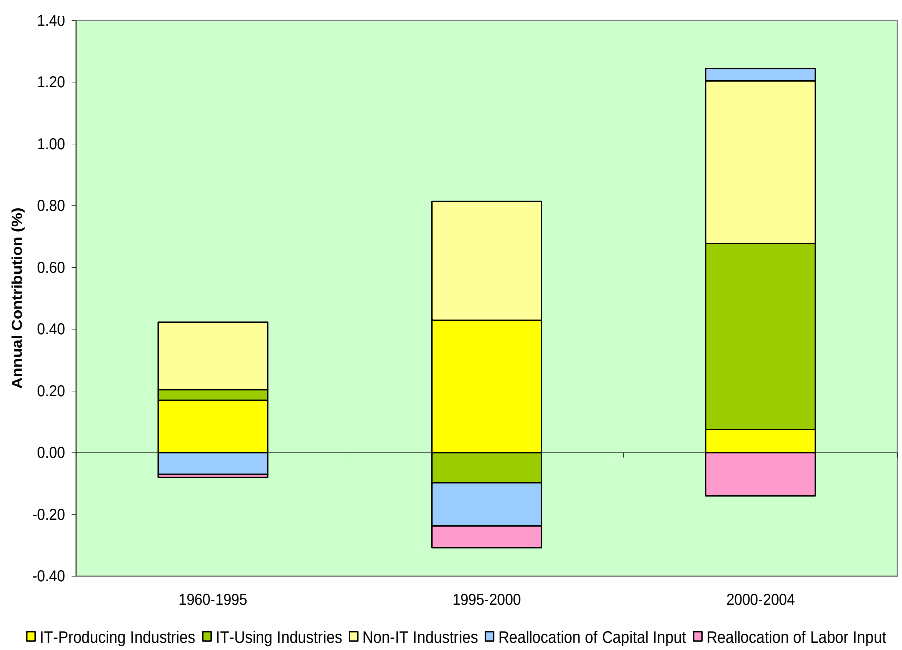
Digital transformation impacts society at several levels. On the production side of the economy, digital transformation enables the automation of business operations, yielding operational efficiencies, such as reduction of transaction costs, with an impact on productivity. Similarly, digital transformation provides new business opportunities, impacting employment and entrepreneurship. Regarding the delivery of public services, digital transformation enhances the provision of health and education, while improving the way citizens interact with their governments. Finally, digital transformation has an impact on human relationships and individual behavior, facilitating social inclusion and communication. It should be noted, however, that digital transformation could also result in potential negative effects, such as workforce disruption, the disappearance of companies, cybercrime and social anomie.

Regulators and policy makers need to consider that digital transformation is not a one-time event. It proceeds in waves driven by technological progress and diffusion of innovations. In understanding these processes, ICT regulators and policy makers can not only anticipate the changes to come as a result of each wave but also be capable of projecting the time it will require for some of these innovations to be fully adopted. Along those lines, digitization should be understood as two simultaneous processes: technology evolution through innovation as well as R&D, and technology adoption among enterprises, governments, and consumers. It is important to differentiate between both processes because technological progress (the first process) is well ahead of diffusion (the second process), meaning that there could be a significant lag between product availability and impact. As an example, the introduction of computing resulting from R&D conducted in the 1940s and 1950s did not yield a significant impact on business productivity until well in the 1990s. The reader might recall Robert Solow's famous statement published in 1987:

> *"One of the central beliefs is that there has been a Revolution in manufacturing, its name is Programmable Automation, (….) (We) are somewhat embarrassed by the fact that what everyone feels to have been a technological revolution, a drastic change in our productive lives, has been accompanied everywhere, including Japan, by a slowing-down of productivity growth, not by a step up. You can see the computer age everywhere but in the productivity statistics."*[1]

The lag between technology development, adoption and impact was clearly shown by Dale Jorgensen et al. (2005) in their study of ICT impact on multifactor productivity in the United States (see exhibit 1).

Exhibit 1. United States: Sources of Aggregate Total Factor Productivity Growth



Source: Jorgensen, D. et al. (2006) Productivity Growth in the New Millennium and its Industry Origins

[1] Solow, R. "We'd better watch out", *New York Times*, July 12, 1987, p. 36

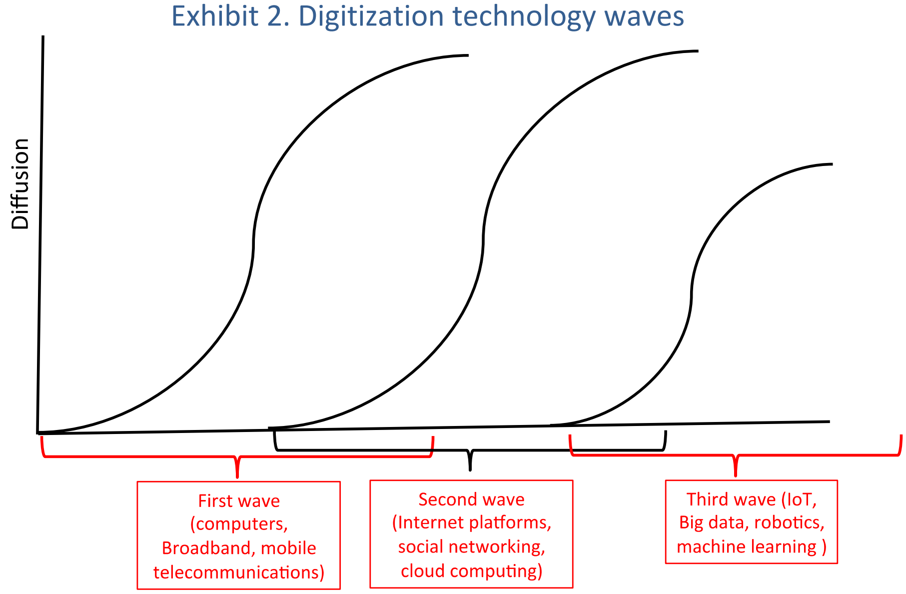
As exhibit 1 indicates, despite its early development and consistent adoption in the 1970s and 1980s, it is only in 1995 that ICT begins to have a sizable impact on productivity. Moreover, despite the downturn in the early 2000, the contribution of ICT to productivity continued increasing.

Along these lines, it is important to start this paper by conceptualizing the different digitization waves while determining how long each of these waves is lasting and understanding how much time current technological innovations, such as artificial intelligence and machine learning, will take to have a significant and measurable social and economic impact. This last point is critical because a clear determination of adoption lags and impact will help anticipating any potential workforce disruptions and devise the proper policy remedies to deal with them.

2 Definition of digitization technology waves

The same way earlier waves of technological change, such as the steam engine, railroads, telegraph and automobiles have transformed society, technological innovation linked to digitization proceeds along “waves” (see exhibit 2).

Exhibit 2. Digitization technology waves



Source: author

The first wave of digitization is associated with the introduction and adoption of what today are considered “mature” technologies, such as management information systems aimed at automating data processing and applied to monitoring and reporting of business performance, telecommunications technologies such as broadband (fixed and mobile) and voice telecommunications (fixed and mobile) which allow the remote access of information. Computers were introduced in business environments in the 1960s and reached 92.61% penetration among businesses in OECD countries only in 2014[2]. Mobile telephony was launched in 1985 and achieved 99% worldwide penetration by 2015. Personal computers, introduced in 1982, were adopted by 80.29% of OECD households in 2015[3]. Similarly, fixed broadband was introduced approximately in 1995 and has reached 80.07% adoption within the same universe, while mobile broadband networks (3G and above) reached 84% of the global population in 2016.

The second wave of digitization entails the diffusion of the Internet and its corresponding platforms (search engines, marketplaces), which enable the networking of enterprises to consumers and enterprises among themselves for purchasing of supplies, and distribution of output. In addition to adoption of the Internet, this wave led to the diffusion of cloud computing[4]. These technologies are supported by equipment, ranging from servers and routers to mainframes and switches. Despite its early development in the late 1960s through 1980s, the popular introduction of the Internet can be situated in 1995[5]. By 2015, 77.2% of the OECD population accesses the Internet in a regular fashion, while 45% of the emerging world population has reached the same level.

Diffusion cycles of digital technologies are becoming faster with each generation. For example, while Facebook, the dominant worldwide social networks, was launched in 2005, by 2015, 48.05% of the OECD population accesses the dominant social network in each country on a regular basis. In emerging countries Facebook penetration has reached even higher levels (Argentina: 62.19%, Malaysia: 59.35%, United Arab Emirates: 68.80%)[6].

The third wave of digitization, whose diffusion start point can be somewhat arbitrarily placed around 2010, entails the adoption of a range of technologies aimed at enhancing information processing and the quality of decision making, while further automating routine tasks within business enterprises and governments. They comprise:

[2] Source: UNCTAD (2016).
[3] Source: http://www.itu.int/en/ITU-D/Statistics/Documents/facts/ICTFactsFigures2016.pdf
[4] Cloud computing is defined as an architecture of computer systems whereby a network of remote servers connected through the Internet fulfils the fouction of hosting, managing, and processing data. This configuration allows for sharing of hosting infrastructure and accessing resources. Most common applications include webmail, data hosting and back up, and shared remote software platforms. This market is segmented across software as a service (SaaS), infrastructure as a service (IaaS), outsourced business processes (Business Process as a Service), and applications services (Platforms as a Service). Cloud computing most important benefits are cost reduction, reliability, and usage scalability. However, this technology is dependent on fast and reliable broadband access.
[5] Having started as a research project of the Advanced Research Projects Administration (ARPA) of the US Department of Defense, its management was transferred to the National Science Foundation in the mid-1980s and limited to academic locations. In 1995, NSFNET was shut down and only for-profit organizations were left running the commercial backbone. At this point, the diffusion process was driven exclusively by market forces (Greenstein and Prince, 2006).
[6] Source: Owloo.

- **Big data/analytics** is defined as the capability of processing extremely large data sets to identify patterns of relationships (correlation, causality) among data to be used in detecting market trends, consumer behavior and preferences. Most common applications range from epidemiological and climate change research (in the public domain), as well as marketing and business process design (within the private sector).

- **Internet of things** entails platforms that link multiple sensors and data devices in order to generate a complete vision of the behavior of an organization, a system, a business operation, or a phenomenon. The most common applications are precision agriculture (which controls fertilizers, monitors rain and determines the most appropriate harvest), smart cities (which allow the control of traffic flows or manage energy use in public places), and telemedicine (which monitor hospital patients health). The adoption of Internet of Things is directly linked to vertical applications, and while these platforms are different from machine to machine applications, they are based on common components. Machine to machine applications are generally conceived as point solutions that link similar devices, such as thermostats, connected via a cellular network, a flow sensor in a refinery, a vehicle location system for fleet management, or home appliances monitoring. On the other hand, an Internet of Things system is a platform that interconnects a variety of discrete devices (including Machine to Machine sensors) to provide a holistic vision of certain phenomena. In that sense, M2M devices are a component of an Internet of Things network.

- **Robotics** entails the application of digital technology to the performance of repetitive manual tasks, such as those required in car assembly, agricultural harvesting, and exploration in dangerous environments.

- **3D printing** is a technology that allows the creation of objects by means of successive printing of adhesive materials such as polymers. While applications of 3D printing are widespread, its use is fairly common in product design (medicinal prosthetics, architectural models, textile design) as well development of spare parts (in consumer electronics and industrial products)

- **Artificial intelligence/machine learning:** these two technologies are not equivalent, although they share some common concepts. Machine learning is an artificial intelligence application consisting in the development of programs that allow a computer to learn routines without being necessarily pre-programmed. In that sense, the machine learning program transforms itself once it starts processing information. The most common machine learning applications are self-driving cars, product recommendations, Internet platforms like Amazon and Netflix, fraud detection in credit card usage, and calculation of consumer credit profile.

These technologies are not typically adopted in a stand-alone fashion. In order to be incorporated within an industry 4.0 digitization context, they are integrated with the mature technologies characteristic of the first and second waves. Along those lines, industry 4.0 represents the assembly of mature and advanced technologies to respond to new requirements in the configuration of value chains in order to yield higher efficiencies and new capabilities in product development and delivery (which naturally leads to an increase in consumers' willingness to pay). As an example of changes in business operations:

- Collaborative development of products and services among different firms;
- Optimization of production chains in order to reduce transactions costs between functions;
- Reduction in production sizes and decrease in response time to allow for higher product personalization;
- Optimization of logistics chains to reduce supply intervals;
- End to end multidimensional traceability in order to increase monitoring and management of the production chain;
- Flexibilization and efficiency in the management of production means; and
- Transformation of distribution in order to optimize market reach (better signalling, better prices, improved segment coverage).

The interaction between matured and advanced technologies is oriented towards meeting the requirements discussed above (see exhibit 3).

Exhibit 3. Technologies and applications of Industry 4.0

	DIGITAL TECHNOLOGIES										
	Hybridization of physical and digital worlds			**Communications and data processing**			**Management applications**				
	Sensors/M2M/IoT	**3D Printing**	**Robotics**	**Cyber-security**	**Cloud computing**	**Broadband**	**Platforms**	**Big Data/analyticss**	**Artificial Intellgence/ machine learning**	**Applications (ERP, CRM)**	**Financial flows**
Collaborative development of products and services				✓	✓	✓	✓		✓		
Industrial chain (re) configuration				✓	✓	✓	✓			✓	✓
Reduction of production series and response time		✓	✓					✓			
Optimization of lpogistics chains			✓					✓	✓	✓	
End-to-end multidimensional traceability	✓			✓	✓			✓		✓	
Flexibility and efficiency of means of production			✓					✓		✓	
Distribution transformation	✓			✓		✓	✓	✓	✓		✓

Source: adapted from Indra (2015)

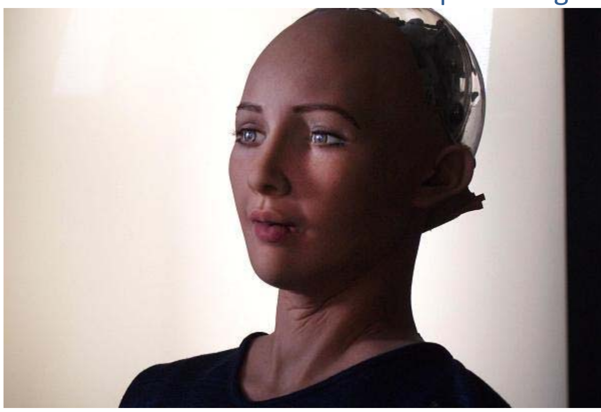
The third digitization wave entails further embedding of the more advanced technologies, such as artificial intelligence, machine learning, and deep learning in production. While some discrete applications are starting to be developed, we still lack widespread assimilation as it is in the case of the second wave. Part of this delay is related to the complexities and high investment required for developing these applications. Furthermore, development in some areas is related to ethical and/or privacy concerns, where industry seeks guidance from regulators and policy makers[7]

The assessment of third wave of digitization is constrained by the lack of statistics, particularly in the developing world. That being said, preliminary data indicates that adoption of third wave digitization technologies is advancing as a fast pace. For example, the installed base of machine-to-machine devices reached 9.58 per 100 populations among OECD countries in 2015[8]. This trend is not restricted to developed countries. In

[7] A common policy issue pertains to data sharing across applications and its privacy implications. Another one is whether an AI platform can have the potential to deliver biased recommendations, such as credit approval in loan applications or crime prevention.
[8] Source: GSMA Intelligence.

Latin America, for example, penetration in 2015 reached 3.10 per 100 populations. Similarly, robot density (a measure of the installed base per 10,000 employees) was 531 in South Korea, 398 in Singapore, 305 in Japan, 301 in Germany, and 176 in Germany. As expected, density is highest in the automotive industry, with a density of 1,276 in Japan, 1,218 in South Korea, 1,218 in the United States, and 1,218 in Germany[9].

Box 1: When deep learning meets robots




Sophia is Hanson Robotics' latest and most advanced robot. Sophia is a "social robot" using AI software developed at Hanson Robotics. She can process visual data to see people's faces, she can process conversational data and emotional data and use all them to converse with people. She has given numerous interviews to multiple media outlets, sang in a concert, and has been featured on the cover of a top fashion magazine. She has also appeared onstage as a panel member and presenter in high-level conferences, covering how robotics and AI will become a prevalent part of people's lives.

Source: Hanson Robotics, at www.hansonrobotics.com/robot/sophia/

To sum up, we have reviewed three waves of digitization and differentiated innovation versus adoption and social and economic impact cycles (see exhibit 4).

Exhibit 4. Technological Innovation, Adoption and Impact

Technological Innovation	Development	Adoption	Social and Economic Impact
Computers, broadband, mobile telecommunications	1950-1975	1960-2000	1990-2010
Internet platforms, cloud computing	1970-1990	1995-ongoing	2005-ongoing
Internet of Things, Robotics, Artificial intelligence, Machine Learning	1980-ongoing	2010-ongoing	2020-ongoing

Source: Author

[9] Statistics sourced from World Industrial Robotics 2016.

Having conceptualized and provided some basic statistics of the three digitization waves, it is pertinent to review the evidence regarding their social and economic impact. This will allow defining what role should be assumed by ICT policy makers and regulators in fostering innovation and adoption, while controlling for potential social disruptions.

3. Social and economic impact of the first wave of digitization

3.1 Impact on economic growth

At the highest level, computing, broadband and mobile telephony networks have been instrumental in relaxing scalability constraints, thereby allowing traditional sectors of the economy to grow more rapidly. It is common to observe that many traditional sectors of the economy are growth constrained by limited access to resources such as raw materials or distribution channels. In this context, digitization based on mature technologies has provided a way to allow businesses to scale further, addressing additional final demand and thereby creating increased need for factor inputs, namely labor. The initial push for alleviating the scalability constraint has been identified in several pieces of research:

- Improved productivity as a result of the introduction of more efficient business processes supported by ICTs, and marketing of excess inventories and supply chain optimization [10] (Atkinson et al., 2009)

- Revenue growth resulting from extended market coverage (Varian et al., 2002, Gillett et al., 2006, and Jonscher and Tyler, 1982)

- Impact on the composition and deployment of industrial value chains. First wave digital technologies can attract jobs from other regions as a result of the ability to process information and provide services remotely. The services most greatly impacted are outsourcing and the deployment of virtual customer care centers. Abramovsky et al. (2006) analyzed an extensive dataset of UK firms and found that broadband Internet use increases the probability of a firm offshoring business processes and services between 6% and 12%, thereby reducing its overall costs.

- Growth of some industries within the services sector (Crandall et al., 2007): for example, growth in software development and business process outsourcing.

In particular, with regards to revenue growth, Clarke (2008) studied the impact of broadband access on exports of manufacturing and service firms. The analysis was

[10] Efficient telecommunications make it possible to reach a broader market, facilitating business processes. They also result in reduced input costs as the capacity to search for lower prices increases.

performed for countries of medium and low levels of development in Eastern Europe and Central Asia. The study controlled for variables such as firm size, industrial sector, foreign ownership, firm performance, level of domestic competition, international trade organization affiliation, progress in privatization, and telecommunications infrastructure. The author found that in the manufacturing sector firms with Internet access enabled by broadband generated 6% more foreign sales than the rest.

This particular effect has been well researched in the microeconomics literature. The opportunity provided by broadband to increase market reach and seek out the highest possible selling price in open economies is essential in the development of a vibrant manufacturing sector. In the service sector, broadband enabled firms generate between 7.5 % and 10 % more sales. In this case, the impact is primarily driven by enhanced access to foreign markets. In both cases of manufacturing and service industries, broadband improves export performance by facilitating the communication with foreign buyers, improving information on overseas markets, consumers and standards, and by ultimately linking the enterprise to consumers, and by allowing bidding for contracts or participating in business-to-business platforms.

At an aggregate level, Katz and Callorda (2017) estimate that 1% increase in a digital ecosystem development index, which corresponds mainly to the first and second waves of digitization (including all telecommunications technologies and digital services such as e-commerce, e-government, e-health) yields 0.13% increase in per capita GDP growth, meaning that a ten-point increase in the index yields 0.26% increase in per capita GDP (which includes direct and secondary effects). The coefficient is higher for OECD countries than emerging economies[11].

In particular, ICTs have been found to have a positive impact on the development of new businesses. This results from the network effects of connectivity. When a large enough number of households are connected to broadband, the incentive to develop new businesses around information search, advertising and electronic commerce increases. For example, Crandall et al. (2007) estimated that the network effects of universal broadband access could have a multiplier of 1.17 on the investment in infrastructure. Similarly, as a result of 40% lower broadband penetration in the United Kingdom, Liebenau et al. (2009) estimated the multiplier to be somewhat lower (0.33) for the British economy.

3.2. Impact on job creation

Beyond job creation as a result of the construction and deployment of telecommunications networks, the first wave of digitization has already had significant

[11] An increase of 1% in the Digital Ecosystem Development Index yields an increase on 0.14% in per capita GDP for OECD countries, while the impact of a similar change in non-OECD countries will be 0.10%. In other words, the higher the economic development, the stronger the contribution of the digital ecosystem on economic growth.

employment contribution. Research has allowed extending the positive impact of the first wave of digitization from alleviation of the resource constraint mentioned above to increased demand for labor. According to Crandall et al. (2007), the job creation impact of broadband tends to be concentrated in service industries, (e.g., financial services, education, health care, etc.) although the authors also identified a positive effect in manufacturing as well. In another study, Shideler et al. (2007) found that, for the state of Kentucky in the United States, county employment was positively related to broadband adoption in multiple sectors, including manufacturing and certain services. This specific effect has also been analyzed by Katz et al. (2010) for rural economies of the United States. In this research, the author found that, within rural counties, broadband penetration contributed to job creation in financial services, wholesale trade and health sectors. This is the result of enterprise relocation enabled by broadband, which benefits primarily urban communities in the periphery of metropolitan areas (Katz et al. 2010).

At the aggregate world level, Katz and Callorda (2016) also show that between 2004 and 2015 an increase of 1 percent in the digitization of consumption index results in a 0.07% reduction in the unemployment rate. Furthermore, Goos et al. (2015) estimate that across locations in Europe the local high-tech job multiplier is around five. Some research estimates that those jobs are compensated at 30% rate higher than average (therefore, they are high-skilled).

That being said, research also found that certain industries undergoing digitization of their production, contrary to creating jobs, were prone to reduce their workforce. For example, Katz et al. (2010) found that the lodging and food services industry undergoing broadband adoption in the United States was found to reduce its number of jobs. This was the result of a particularly strong capital/labor substitution process taking place, whereby productivity gains from broadband adoption yielded reduced employment. Similarly, Thompson and Garbacz (2008) concluded that, for certain industries, "there may be a substitution effect between broadband and employment"[12].

3.3 Impact on social welfare

In recent years, the implementation of national household surveys that now include ICT modules has allowed to research the impact on social welfare of the first wave of digitization. For example, using information from Peruvian households between 2007 and 2009, De Los Rios (2010) found that, during this time period, Internet adopters experienced significant income growth relative to those households that did not have the service. Similarly, Katz and Callorda (2014) have estimated through analysis of household data in Ecuador that the introduction of broadband yielded an increase of 3.67% increase in average household monthly income (increasing to 5.01% among households equipped with a personal computer).

[12] This effect was also mentioned by Gillett *et al.* (2006).

While the causes for this increase can vary, broadband appears to have an impact on the growth of household income through four effects. First, broadband deployment requires infrastructure construction in order to provide the service (the "construction" effect referred to above), additional workers for the operator's new commercial offices, and technical personnel for the installation and maintenance of the new infrastructure. The new demand for labor in a market with an unemployment rate that is already below 5% generates a shift in the demand curve for workers, which leads to an increase in equilibrium wages. In other words, at full employment, additional demand for workers tends to result in an increase in compensation. Furthermore, the rise in wages through this channel may reflect a need for better compensation for those workers who, given the low unemployment rates, should receive better wages to meet or exceed their reservation wage.

A second explanation for the income increase is that, as seen in Katz (2012a), broadband has a positive effect on worker productivity. Classic labor economics literature shows that wages in competitive markets equal marginal productivity. As a result, higher labor productivity should yield higher wages. This is labeled the "productivity effect".

Third, research results also show that the effect of broadband deployment is greater for computer and Internet users. In this sense, the introduction of broadband at the county level allowed workers with digital literacy skills to signal their computer knowledge to potential employers and then use those skills in the workplace in return for a higher wage. We call this impact the "skill signaling effect".

Finally, the introduction of ICT can also help to reduce the time otherwise required for an effective job search, allowing underemployed workers to look for full-time work using broadband services. This increase in efficiency leads to a reduction in unemployment periods and generates an increase in the migration of underemployed workers to full-time positions, which, in turn, results in higher labor income. In other words, reduced transaction costs related to finding employment can ultimately result in higher income (with less search time required, the underemployed can find full-time work).

* * * * *

In summary, research on the social and economic impact of the first wave of digitization indicates significant contribution to business growth and cost optimization. On the other hand, job creation effects appear to differ by industry sector. The first wave of digitization may have simultaneously caused labor creation triggered by unlocking scalability in certain sectors while enhancing productivity in other labor-intensive industries, resulting in job destruction. In other words, while triggering job creation by alleviating scalability constraints in certain sectors, the productivity impact of broadband can cause capital-labor substitution and may result in a net reduction in employment in other industries. In any case, research on the first wave indicates that job creation far outpaces workforce reduction in certain labor-intensive sectors. Exhibit 5 summarizes the evidence regarding the social and economic effects of the first digitization wave.

Exhibit 5. Social and Economic Effects of the First Wave of Digitization

Area	Positive Contributions	Negative Effects
Economic growth	• Improved productivity as a result of the introduction of more efficient business processes supported by ICTs • Revenue growth resulting from extended market coverage • Impact on the composition and deployment of industrial value chains • Growth of some industries within the services sector (software development and business process outsourcing)	
Employment	• Job creation impact of broadband tends to be concentrated in service industries, (e.g., financial services, education, health care, etc.) although a positive effect was detected in manufacturing as well • In the United States, county employment was positively related to broadband adoption in multiple sectors, including manufacturing and certain services • For rural economies of the United States, broadband penetration contributed to job creation in financial services, wholesale trade and health sectors, as a result of enterprise relocation, benefitting primarily urban communities in the periphery of metropolitan areas • Between 2004 and 2015 and increase of 1 percent in the digitization of consumption index results in a 0.07% reduction in the employment rate • In Europe the local high-tech job multiplier is around five	• Certain industries undergoing digitization of their production, contrary to creating jobs, were prone to reduce their workforce as a result of result of a particularly strong capital/labor substitution (for example, lodging and food services industry)
Social inclusion	• Increase in average household income as a result of broadband access	• Reinforcement of social divide patterns as a result of technology have's and have not's

Source: Author

As indicated in exhibit 5, while the first wave can elicit some negative effects, they are vastly outpaced by the positive contributions. Moreover, the negative effects can be mitigated through well-proven targeted policy remedies described below.

4. Social and economic impact of the second wave of digitization

Moving on to the second wave of digitization, empirical evidence on social and economic impact can be grouped into three categories: 1) innovation triggered economic growth, 2) labor force impact, and 3) social welfare negative effects. Each category will be reviewed in turn.

4.1 Business innovation as a driver of economic growth

In the beginning of the second wave of digitization, economic growth was fueled by the introduction of new services and applications such as Internet information searches, electronic commerce, distance education and social networks (Atkinson et al., 2009). This initial move has achieved considerable impact. For example, in countries with high broadband penetration, by 2015 the percentage of total retail trade conducted through electronic commerce had already exceeded 10% (South Korea: 15.09%, Denmark: 12.63%, United Kingdom: 13.41%).

Beyond this initial spur, empirical evidence supports the existence of a second "innovation" effect triggered by the combined adoption of platforms, broadband, and cloud computing. This results in the development of new products and services, such as the whole range of collaborative businesses that characterize the digital economy (Uber, airbnb, etc.). In addition, the development of Internet platforms has resulted in the emergence of a large market for creating local Internet content and applications in native languages. In addition to creating jobs in the production, distribution and management of a local content digital industry, its development has multiple benefits, including helping to strengthen national cultural identities, reducing foreign trade imbalances, and promoting demand for local ICT infrastructure services (e.g., domestic ISPs and cloud services to support domestic content). The development of local digital content entails enormous opportunities not only to develop a vibrant domestic content and applications industry but also to meet the needs of population that would only adopt broadband if they were to find a product that is culturally relevant to its needs. For example, research conducted by Katz and Callorda (2011) for the Colombian Digital Plan Vive Digital indicated that 1 percentage point increase of local e-Government applications yields an increase of 0.55 percentage points in broadband penetration.

Similarly, on-line B2B and B2C platforms have allowed domestic businesses to address international markets, which in turn, yield an increase in employment. As an example, as of 2015, the videogame industry in Latin America comprised 418 companies employing approximately 7,000 developers, while developers of applications in the same region relying on Facebook platform amounted to approximately 20,000 (Katz, 2015). In the case of Latin America, *Mercado Libre*, the most important e-Commerce platform has triggered the creation of approximately 120,000 registered users offering their goods through the network[13]. This amount vastly exceeds the direct jobs created by the platform (2,635). Additional new jobs created by the "new" digital economy could include support services for these businesses, which include advertising, platform maintenance and management, and the like.

[13] Mercado Libre (2015). *Business Overview*.

On the other hand, the increased use of digital technologies associated with the second digitization wave has raised the potential negative economic effect of an Internet disruption, as a result of natural emergency, cybercrime, technological failure, or politically motivated blackout. World economies are increasingly reliant on the Internet, while, as explained above, the Internet is vital for economic development. In this context, it is reasonable to consider what the economic impact might be of a disruption of the Internet as a result of either natural or man-made causes. These appear to be fairly common as documented by Howard, Agarwal, and Hussain (2011). The authors identified 606 government-imposed shutdowns of the Internet between 1995 and the first part of 2011, for a total of 99 countries. In 2010 alone, the number of man-made shutdowns reached 111. Between July 2015 and June 2016, West (2016) counted 81 government-imposed disruptions, of which 36 affected the national broadband network and 22 impacted subnational mobile networks. Beyond government-initiated downtime, the Internet is constantly affected by localized downtimes. According to the disruption tracking platform Pingdon, at any hour period worldwide, the Internet is affected by approximately 16,000 outages. Man-made and technology disruptions have an economic impact. The economic impact per day varies by the type of disruption, ranging, according to West (2016), from US$ 3,816,000 for a national platform (such as Twitter or Google) to US$ 14,968,000 for the national Internet[14].

4.2 Labor force impact

The other stream of social and economic impact research of the second wave of digitization has focused on the restructuring of labor markets in certain sectors of the economy. Along these lines, the extensive evidence can be categorized along three clusters:

- Disappearance of jobs resulting from task automation
- Job creation resulting from enhanced demand for labor in certain occupations linked to the development of digital services or the emergence of collaborative business models
- Labor force polarization resulting from "hollowing out" of middle-skill jobs

4.2.1 Elimination of jobs

The same way that technology fostered capital labor substitution in agriculture and manufacturing, the primary assumption of this body of research, as reported by Brynjolfsson and McAfee (2014), is that new digital technologies have an adverse effect on low and middle-skilled workers. This is supported, according to the authors, by stagnant median wages and the falling labor share of income.

[14] This impact only looks at GDP, and excludes lost tax revenues, impact on worker productivity, barriers to business expansion, and loss in investor or consumer confidence.

However, this body of research is not completely endorsed. For an example, in an opposing view, Gordon (2012) argues that automation linked to the second wave of digitization is not significantly affecting labor markets in the aggregate, and that sluggish productivity growth in the United States indicates slow technological progress. In support of this statement, some sectors such as health care and personal services continue to create jobs at a fast pace. Furthermore, despite what one could assume in terms of the disappearance of some repetitive occupations, the fact is that there are still 3,000,000 cashiers in the United States, although a large percentage is likely to be replaced by automated registers over a period of time driven by the adoption of innovation timeline (Frey and Osborne, 2013).

In response to this finding, both Brynjolfsson and McAfee (2014) and Summers (2015) argue that productivity statistics do not accurately capture fundamental changes in labor markets. First, the negative effects of automation are primarily concentrated at the low-skill level of occupations (Sachs and Lawrence, 2012). Second, the job creation contribution of the second digitization wave cannot completely cancel out the disappearance of jobs.

4.2.2 Creation of jobs

The consensus of research regarding job creation as a result of the second wave of digitization is that, while new employment has emerged, the effect has not been sufficient to counterbalance the disappearance of jobs discussed above. For example, Berger and Frey (2016a) reported that the emergence of new technology- related industries throughout the 2000s —including online auctions, video and audio streaming, and web design—had negligible effects on aggregate employment patterns, employing less than 0.5 percent of the US workforce. In a similar vein, Spence and Hlatshwayo (2012) report that between 1990 and 2008, technologically progressive sectors of the US economy, accounting for more than 34 million jobs in 1990, grew by a negligible 0.6 million jobs, while technologically stagnant sectors, experiencing slow productivity growth accounted for 98 percent of total job creation.

A more nuanced view of this effect has been presented by Lin (2011). According to this researcher, job creation resulting from digitization was strong as a result of the first digitization wave (reported in the section above) but has decreased as a result of the second wave. For example, during the 1980s, some 8.2 percent of US workers shifted into jobs that appeared for the first time during that decade, while by the end of the 1990s that share had almost halved to 4.4 percent. Given the recent occurrence of this trend, evidence of this trend in emerging countries is still not available.

Research has also been able to identify the clusters of employment growth resulting from the second digitization wave. As digital technologies have diffused across a wider range of occupations and industries, the demand for workers with analytical, interactive, and problem-solving skills has surged (Autor et al, 2003). In this context, Acemoglu and Autor

(2011) estimate that the supply of skilled human capital is not keeping up with demand triggered by technological change; this, in turn, has driven an increase in wages of high-skilled occupations. Coincidentally, Spitz-Oener (2008) reports that computer use in jobs is associated with an increase in wages by some 8-15 percent.

Simultaneously, the surge in low-skill service jobs is driven by increase in demand from higher income occupations combined with the fact that manual non-routine tasks that are prevalent in service occupations are not substitutable by computers (Autor and Dorn, 2013). Similarly, Moretti (2010) showed that the indirect contribution of new technology jobs is still significant as they create additional demand for local services. For example, one additional job in the tradable high-technology sector generates about 4.9 new jobs locally in the non-tradable sector, as skilled workers with higher incomes create additional demand for local services.

4.2.3 Labor force polarization

Labor polarization is defined as the disappearance of medium-skilled jobs combined with the growth of employment at the high-end and more routine service end. Based on research by Goos et al., (2007; 2009; 2014), labor markets throughout the OECD economies have experienced a reduction of routine jobs with significant expansions of employment at both ends of the skill spectrum. Coincidentally, Akerman et al. (2015) report that digital technologies and automation are the primary drivers of job polarization in most developed countries. Part of this effect can be linked to limited digital skills in those sectors of the population that have little access to education beyond secondary schooling.

* * * * *

In summary, the difficulty in assessing the combined negative and positive effects of the second digital wave of digitization on labor markets is due to three factors. First, as pointed in the first wave of digitization, the job creation/job destruction effects vary by industry and occupations. So far, research indicates that adverse effects on labor markets are concentrated on low and middle-skilled jobs, which are more prone to being replaced by technology. Second, the speed at which capital – labor substitution is proceeding is conditioned by the pace at which firms implement the necessary organizational and business process changes to assimilate the new technologies. Katz (2015) research in Latin America indicates, for example, that despite the high adoption of digital technologies among all industries, their contribution to productivity is almost negligible. This finding is consistent with Basu and Fernald (2007) who point out that productivity growth follows investment in digital technologies with lags of between five and 15 years. This means that steep changes in job destruction take some time to materialize, particularly in emerging economies. Third, while hypothetically, some jobs could be easily replaced by automation, the fact is that we still have limited knowledge of the "non repetitive", intuition-based tasks that are part of these occupations.

That being said, researchers agree on three conclusions:

- Automation effects will have a significant change on the occupational profile of labor markets, particularly in sectors that are labor intensive with an emphasis in repetitive tasks
- The main impact will concentrate at the low-skilled levels
- These effects will accelerate over time fueled by the accumulation of intangible capital of firms (organizational changes, reengineering of business processes due to digital transformation) and the increasing potential of digital technologies linked to the third digitization wave

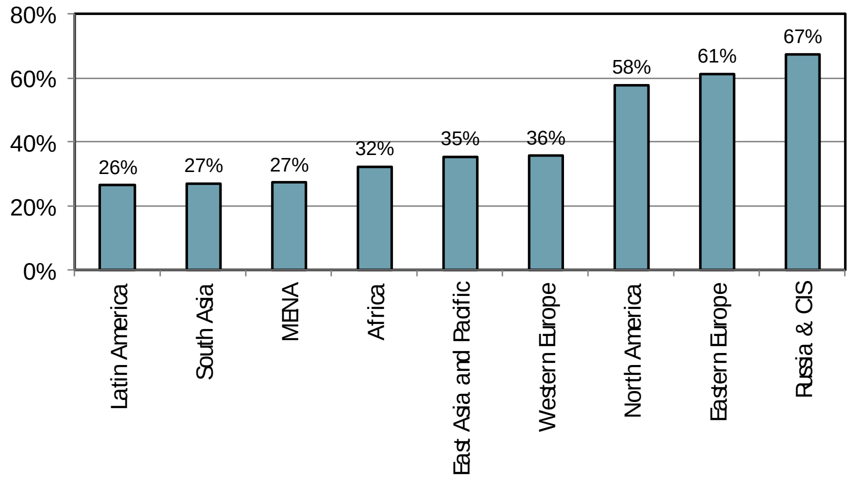
4.3. Welfare impact

The second wave of digitization has also been found to trigger a number of negative effects. The first risk is the degradation of human relationships resulting from intense digital consumption. Americans spend an average of five and a half hours a day with digital media, more than half of that time on mobile devices, according to the research firm eMarketer. Moreover, users check their phones 221 times a day—an average of every 4.3 minutes—according to a UK study. This number actually may be too low, since people tend to underestimate their own mobile usage. Research by Turkle (2015) argues that the digital revolution, by its intensity, is degrading the quality of human relationships. Turkle finds the roots of the problem in the failure of young people absorbed in their devices to develop fully independent selves. She argues that digital devices disrupt the ability of children to separate from their parents, and raise other obstacles to adulthood. Because they aren't learning how to be alone, Turkle contends, young people are losing their ability to empathize. Along these lines, social media offer respite from the awkwardness of unmediated human relationships.

The second risk, particularly among adolescents, is the decline in conducting other knowledge gathering activities such as reading. In a research by this author (Katz, 2012), high school students in the United States spend on average 554.80 minutes (or 9.25 hrs.) a day using technology devices during the week. Of these, 279 minutes are spent in front of a PC and 191 in front of a cellphone. Given the increasing capability of cellphones, it is expected that future studies would yield a much higher time allocation to smartphones at the expense of the PC. Conversely, the study found that teenagers read for leisure an average of 5.6 books per year. Along these lines, girls tend to read more than boys (6.6 vs. 3.9). The higher levels of video game playing amongst boys could partly explain this trend. Furthermore, when it comes to human interaction, most adolescents prefer texting to calling on their cellphones.

A third risk that has been studied particularly in developing countries is cultural uprooting. An analysis conducted by this author of the most popular Internet sites accessed by region indicates that in MENA countries, only 27 of 100 most popular sites, measured by number of visitors and time spent on the site are produced locally, while the remaining are either produced overseas or developed overseas and translated to local language (see exhibit 6).

Exhibit 6. Percentage of Local Internet Content by Region (2013)



Source: Katz (2013) based on Alexa data

The data in exhibit 5 indicates two important patterns. First, developed regions appear to have a higher percentage of the most popular Internet sites to be local. Second, regions with linguistic specificities (such as Russia) appear to have a higher percentage of local content. Conversely, developing regions with use of one of the world languages (Latin America for Spanish, South Asia for English, MENA and Africa for French and English) tend to have a lower percentage of local Internet content. The implications of these data are that as result of limited local content production, the Internet could act as vehicle for cultural uprooting. This situation raises the importance for ICT policy makers to promote the development of local Internet content and applications.

A related risk of 'opportunity cost' has to do with the fact that a portion of the population does not gain access to the benefits implied by digitization due to concerns related to data privacy, trust, and cybercrime. ICT regulators and policy makers need to devise the right initiatives to address these adoption barriers.

4.4 Compilation of social and economic impact of the second digitization wave

As demonstrated in the research reviewed in this section, the second wave of digitization can be linked to a number of positive contributions and negative effects. Exhibit 7 summarizes the evidence regarding the social and economic effects of the first digitization wave.

Exhibit 7. Social and Economic Effects of the Second Wave of Digitization

Area	Positive Contributions	Negative Effects
Economic growth	• Development of new products and services, such as the whole range of collaborative businesses that characterize the digital economy • Emergence of a large market for creating local Internet content and applications in native languages, which strengthens national cultural identities, reduces foreign trade imbalances, and promotes demand for local ICT infrastructure services (e.g., domestic ISPs and cloud services to support domestic content) • On-line B2B and B2C platforms allow domestic businesses to address international markets	• Negative economic impact related to Internet blackout as a result of technological failure, cybercrime, or political shutdown
Employment	• Create jobs in the production, distribution and management of a local content digital industry, its development has multiple benefits • Creation of indirect employment as a result of multi-sided Internet platforms (social networks, search engines, etc.) • Additional new jobs created by the "new" economy could include support services for these businesses, which include advertising, platform maintenance and management, and the like.	• While job creation resulting from digitization was strong as a result of the first digitization wave, it has decreased as a result of the second wave • Adverse effect on low and middle-skilled workers • Negative effects of automation are primarily concentrated at the low-skill level of occupations • These effects will accelerate over time fueled by the accumulation of intangible capital of firms (organizational changes, reengineering of business processes) and the increasing potential of digital technologies linked to the third digitization wave
Social welfare	• The development of local digital content entails enormous opportunities to meet the needs of population that would only adopt broadband if they were to find a product that is culturally relevant to its needs	• Degradation of human relationships resulting from intense digital consumption (failure of young people absorbed in their devices to develop fully independent selves, digital devices disrupt the ability of children to separate from their parents, and raise other obstacles to adulthood. Because they aren't learning how to be alone) • Decline in children and adolescents conducting knowledge-gathering activities such as reading. • Developing regions with use of one of the world languages (Latin America for Spanish, South Asia for English, MENA and Africa for French and English) tend to have a lower percentage of local Internet content. As result of limited local content production, the Internet could act as vehicle for cultural uprooting.

Source: Author

As is self-evident in the data on positive and negative effects, while the second wave of digitization is still driving significant number of social and economic benefits, the number of negative effects appears to be increasing: job creation resulting from innovation does not seem to compensate for job losses at the medium and low-skilled level, the economic risk linked to disruption associated to the increased reliance on the Internet are rising, and there are some potential negative social effects related to human relationships, learning capability, and cultural uprooting.

The policy implications are clear. First, it is imperative to maximize the application of levers that accelerate innovation. This could have an impact not only in the creation for additional labor demand, but also regarding the supply of local Internet content and applications. Second, workforce retraining would appear to be a natural requirement to mitigate the disruptions associated with low-skilled jobs. This policy intervention will be addressed in detail below. Third, there is an urgent need to approach education in an integrated, holistic manner where the value of technology is properly integrated with more traditional approaches to teaching.

5 Social and economic impact of the third wave of digitization

As mentioned above, the third wave of digitization is still in its inception. Along these lines, research on social and economic impact is substantiated by either anecdotal evidence or technology forecasting that assessing past effects.

5.1. Impact on economic growth

The expanding scope of the third wave of digitization has significant implications for productivity improvements. The advances in robotics, big data analysis and machine learning have already yielded applications that, when adopted on a mass scale, should have a significant impact on operating costs (see exhibit 8).

Exhibit 8. Examples of economic impact of advances in third wave digitization technologies

Application	Technology	Impact
Medical Diagnosis conducted by IBM's Watson	• Big data (cancer: 600,000 medical reports and 2 million pages of medical papers • Machine learning	• Match patient symptoms and genetics to deliver tailored treatment • Reduction in health care costs
Google Translate	• Machine Learning	• Improve accuracy in translation services • Reduction in delivery time of translated content
Smart Action call automation	• Speech recognition • Natural Language processing	• Reduce call center costs by 60-80 percent
Workfusion software	• Machine learning	• Splits job streams between routine ones that can be automated and those that cannot • Platform learns from humans as to how they execute tasks and routinizes / codifies them
Rethink Robotic (Baxter) Workday software	• Robotics • Sensors • Big data • Artificial Intelligence • Big data	• Robot can be instantly reprogrammed to perform different tasks ranging from line loading and machine tending to packaging • Identify most promising job candidates by scanning CVs • Accelerate recruiting time by reducing paper data analysis

Source: compiled by the author

As these applications are still moving from the lab to adoption, it is not feasible yet to quantify their impact at a macro-economic level. Moreover, turning back to the distinction between technological innovation, diffusion and economic impact, it is fairly difficult to forecast the speed at which they will undergo adoption. For example, it is likely that some of these platforms will be adopted only by some large companies in industries more likely to be affected by high operating costs. Thus, beyond firms such as Amazon, Wal-Mart (with high fulfillment costs), and the big telecommunications operators (affected by high call center costs), it is unlikely that adoption will proceed at a rapid pace. Moreover, the adoption of these platforms will require a massive change in operating processes and organization structure, as well as employee training (accumulation of intangible capital), which will have an impact on timing to adoption. Finally, many of these platforms raise fundamental issues regarding employee resistance, lack of management awareness and even ethical considerations. For example, the CV scanning platform mentioned above might push managers to abdicate judgment in recruiting talent or push the boundaries with regards workers' privacy[15]. All these factors might delay for some time the actual economic impact to be yielded by the third wave of digitization.

Assuming that mass adoption of the third digitization wave will occur within a decade or two, it is fair to conclude that the economic impact will be significant. First, if operating

[15] Greenwald, T. "How AI is transforming the workplace". The Wall Street Journal. April, 9, 2017.

costs diminish substantially, at least part of this reduction will be transferred to consumers, which they will also benefit by increase efficiency. Second, the third wave of digitization could reverse the offshoring trend of multinational corporations and dramatically alter the global production chains. For example, it is projected that the operating cost of a welding robot in an automobile assembly line will be lower than that of a welder in an emerging country factory. At that point, the incentive towards globalization of the automobile value chain lessens and the geographic division of labor could undergo a significant change. The third impact pertains to labor force disruption, which is addressed in the next section.

5.2. Impact on labor force

The factors regarding time of adoption notwithstanding, the third wave of digitization promises to have an impact on employment. That said, research is clustered around two bodies: one that forecasts a dramatic disappearance of jobs as a result of automation, and a second one that establishes that negative disruption effects are overstated.

The primary assumption supporting the first body of research is that automation of repetitive tasks, linked to robotics, and combined with enhanced power of technology in areas such as artificial intelligence and speech recognition, is linked to the disappearance of jobs. For example, Frey and Osborne (2013) estimate that nearly half of jobs in the United States are susceptible to automation over the forthcoming decades, while jobs requiring creativity and complex social interactions are at low risk of automation. According to this research, three key bottlenecks that ultimately set the current boundaries for the application of machine learning and AI to occupations: (i) creative intelligence; (ii) social intelligence; and (iii) perception and manipulation. Coincidentally, McKinsey (2015) estimates that 45 percent of tasks undertaken by US workers are automatable with existing technology. In the same vein, Bruegel (2014) estimates that 45 percent of EU jobs are at risk of automation, ranging from 47 percent in Sweden to 62 percent in Romania.

The primary premise of the second body of research is that not all jobs can be replaced by automation and that second-order job creation derived from either new innovation and/or increased productivity and spending can actually cancel out any disruption effects. It should be noted that some research acknowledges that innovation-driven job creation will never compensate for automation-driven job losses, but that new jobs will be triggered by an increase in purchasing power of consumers (Atkinson and Wu, 2017). Along those lines, the concern of these researchers is that if productivity does not increase, living standards will not improve and, consequently, second order effects will not materialize.

5.3. Impact on social welfare

The third wave of digitization promises to have significant benefits on social welfare, more particularly on several Sustainable Development Goals, such Good health and Well Being (SDG 3), Affordable and Clean Energy (SDG 7), Decent Work and Economic Growth (SDG 8), and Sustainable Cities (SDG 11). Applications, particularly those related to health, and e-government services, have a potential for providing the population for information regarding environmental sustainability. On the other hand, the same applications should contribute to a reduction in traffic of vehicles, particularly in urban and suburban environments. Similarly, e-Government applications reduce travel time needed to conduct transactions in public administrations. In fact, introduction of some of these applications is fairly routine around the world (see exhibit 9).

Exhibit 9. Examples of welfare impact of advances in third wave digitization technologies

Application	Technology	Impact
Horizon Scanning Center (United Kingdom)	• Big data	• Platform forecasting the impact of climate change on food and water availability, among other factors
Prediction of vacant residential property (United States	• Big data	• Help predict and prevent vacant residential property
ATISMART	• Big data • CAS mathematical core	• Traffic flow simulation platform based on the use of smart traffic lights, network sensors, and signals
Foot and mouth disease syndrome prevention (South Korea)	• Big data	• Analysis of data streams coming from animal disease overseas, customs/immigration records, breeding farm surveys, livestock migration, and workers in the livestock industry
Fraud detection in Social benefits payment (United States)	Machine Learning (Unsupervised Learning performing anomaly detection using unlabeled data)	• Fraud reduction in Medicare payments
Public transportation management	• Machine Learning	• Provide just-in-time access to public transportation • Expected to be faster, cheaper and more accessible to the public
Criminal Justice System (United States)	• Machine Learning	• Improve crime reporting, policing, bail, sentencing, and parole decisions (Data Driven Justice, Police Data Initiative) • Aid for decision-making in the criminal justice system

Source: compiled by the author

Diffusion of third wave digitization technologies in the public sector with impact on citizen welfare is proceeding at a fast pace. A recent survey in nine countries completed by Accenture indicated that 70% of interviewed agencies are considering the implementation of an advanced technology, while 25% are moving beyond pilot into full implementation[16].

[16] Accenture. *Emerging Technologies in Public Service*. February 2, 2017.

6. Policy implications

So far, the evidence points out that the first wave of digitization has yielded significant social and economic benefits, coupled with very limited disruptions in labor markets restricted to labor intensive sectors. Secondly, the second wave of digitization has, so far resulted in increased business efficiencies, coupled with job destruction in low-skilled categories (although it is likely that this trend will accelerate once firms accelerate the accumulation of intangible capital and they become more adept at substituting capital for labor). Thirdly, the evidence so far with regards to the disruptive effects of the third wave are quite speculative, unless once believes that third wave disruption is merely an extrapolation of the second digitization wave effects. That being said, it is relevant to consider the policy remedies that could propel the benefits of automation and limit the negative outcomes.

6.1. Promoting innovation and addressing workforce disruption in developed countries

Despite the lack of consensus around the ultimate effects of digitization, there is almost universal agreement that, similarly to the prior waves of innovation, automation will tend to favor those workers with more education and training. Those with limited education (which implies no digital skills) tend to either shift to lower paid occupations or drop out of the workforce entirely. In this context, it would seem obvious, as Sachs (2016) says that,

> *"the most important policy response is to ensure that students stay in school long enough to achieve the skills needed for the new jobs".*

The problem is, however, that training alone might not be a sufficient remedy. In fact, the average number of years in school for populations around the world has been consistently increasing in the last ten years [17](see exhibit 6).

Exhibit 6. Education years expectancy (2006-2015)

	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015
OECD	15.38	15.47	15.54	15.64	15.83	15.94	15.98	16.32	16.37	16.36
North America	16.05	16.22	16.34	16.44	16.58	16.69	16.62	16.54	16.54	16.54
Western Europe	16.05	16.08	16.18	16.27	16.45	16.53	16.59	17.13	17.20	17.21
Latin America	13.26	13.32	13.61	13.69	13.81	13.92	13.96	14.40	14.42	14.42
Asia Pacific	11.17	11.50	11.78	11.90	12.16	12.52	12.74	12.92	12.98	12.98
Eastern Europe	13.79	13.94	14.02	14.06	14.39	14.61	14.74	15.42	15.47	15.47
Africa	10.95	11.16	11.36	11.56	11.68	11.77	12.01	12.19	12.19	12.19

Source: UNESCO; analysis by the author

[17] While the number of school years is increasing, this might not be resulting in more courses focused on digital skills.

As data in exhibit 6 indicates, the average number of education years has been consistently increasing particularly for industrialized countries. However, the OECD countries trend is worrisome insofar that the increase in schooling suggested by Sachs has not been enough to keep up with the shift in occupations triggered by automation. In other words, the first and second digitization waves have reduced the need for low skilled workforce and, despite increasing demand for more educated workers, there were not enough jobs to absorb the supply of more educated population. Two factors appear to be at work that need to be dealt with proactively: capital-labor substitution for low skilled workers, coupled with not enough demand for the highly educated. The relevant question is then, can an increase in the number of school years or non-formal digital training be enough to cancel the trend already observed in developed countries? For this question to happen, the shift towards a supply of high skilled labor (more education) needs to be matched by increasing demand: more education needs to be matched with more job opportunities for the high skilled. This requires an acceleration of the rate of innovation. If this does not occur, a portion of the highly educated will find themselves without job opportunities. This trend is already occurring in advanced economies, which has prompted a debate around what can governments do to lessen the disruption effect.

At the highest level, two policy options are at play. From a proactive standpoint, it is argued that with the loss of international comparative advantage, job destruction/disruption is going to be so significant that governments need to anticipate the wave and proactively intervene (see Pisano and Wheelwright, 2012). Alternatively, from a 'laissez faire" perspective, given the uncertainty in anticipating the occupational shifts, and, recognizing the importance of digitization in enhancing productivity, governments need to focus on reducing the cost of capital and regulation to enable companies to acquire new technologies and let the private sector address the "creative destruction" challenge (Crafts and Toniolo, 2010; van Ark, 2014; Nicoletti and Scarpetta, 2005).

The proactive camp endorses labor market policies focusing on workers being able to either retain their current jobs or move to the new areas of demand. These policies comprise job placement services, special labor market programs and wage subsidies to lessen the transition cost. In particular, the German government has been quite active in promoting apprenticeship programs aimed at training young workers on the new digital skills. On the subsidy side, tuition-free higher education, a temporary cut in payroll taxes are some of the policy initiatives. Many OECD countries (in particular, France and Belgium) have reduced the amount of taxation among low income workers as a way of lessening the negative income effect of low-skilled workers. More radical policy initiatives to address job disruption effects comprise the introduction of a basic income guarantee for low skill workers. Others raised the option of taxing robots to compensate for the jobs being taken over by robots as a way to ensure the viability of the social security systems[18].

A different set of proactive policies aimed at addressing workforce disruption focus more on the demand side of skilled jobs, aiming at fostering the growth of poles of innovation that would need more workers. This approach is supported by two types of evidence. First, under the first and second wave of digitization conditions, job creation tends to be focused on cities that concentrate new industries, while employment declines in locations with industries more susceptible to automation (Berger and Frey, 2016; Fey, 2015; Duranton and Puga, 2001). Second, high technology secondary job multipliers appear to be around five (Goos et al., 2015). Under these premises, policies focused on increasing geographic mobility would allow workers residing in areas affected by automation to move to high job creation cities. For example, these policies should focus on reducing high relocation costs such as housing. On the negative side, these policies could risk stimulating the "hollowing out" of certain areas and accelerating the divergence between innovation-prone poles and backward regions. This is where proactive policies aimed at creating clusters of industries and universities around high quality of life locations will stimulate high-skilled labor demand in under-developed areas. The cross-sectorial/cross-institutional nature of these initiatives imply the importance of implementing them through collaborative approaches built among government entities and the ICT regulator. These initiatives are quite popular across developed, and even emerging, countries.

Moving to the policies focused on creating conditions for development of industries in need of skilled labor, they tend to focus on lowering the barriers to enterprise development (time needed to launch a new business, access to capital) or reducing tax burdens. They tend to be prevalent in advanced countries, although in certain geographies they are implemented with the more proactive interventions, discussed above.

6.2. Promoting Innovation and addressing workforce disruption in emerging economies

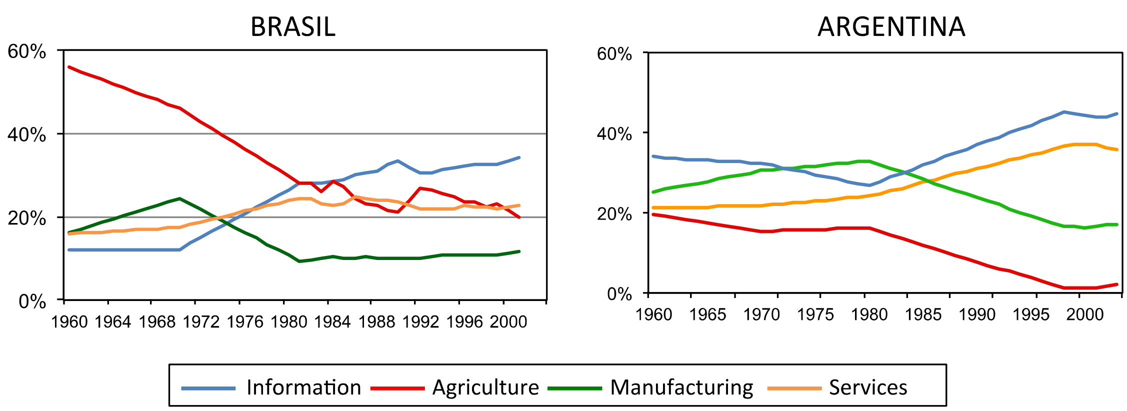
As expected, the policies discussed above to prevent workforce disruption have been more prevalent in the advanced economies, since they have been more affected by the combination of automation and international trade. To what extent will these trends, particularly automation, affect emerging economies? And, if so, when will this happen? The policy premise underlying these questions is that, if emerging countries are likely to soon follow the labor disruption trend of developed economies, the urgency of putting in place policy remedies becomes apparent. Moreover, if emerging countries face the imperative to foster the digitization of industries in order to increase their

[18] See the draft Report to the European Parliament by MEP Mady Delvaux which was in the end rejected by the legislators: http://www.europarl.europa.eu/sides/getDoc.do?pubRef=-//EP//NONSGML%2BCOMPARL%2BPE-582.443%2B01%2BDOC%2BPDF%2BV0//EN

competitiveness, they will sooner or later have to deal with the implied labor disruption effects.

Berger and Frey (2016) argue that the labor force shift trend is already affecting emerging economies through an effect that has been labeled premature deindustrialization (Rodrick, 2015). According to the authors, it would appear that, even at lower wage levels that characterized emerging economies, automation of production chains has become cost-effective and that capital labor substitution is occurring not only in agriculture but also in manufacturing. Thus, the automation of manufacturing jobs triggered by the first and second waves of digitization has resulted in a reduction in manufacturing jobs, which have shifted to occupations that manage information (not necessarily in an automated fashion), such as government bureaucracies. Exhibit 7 displays the composition of employment for two emerging economies after 1960, isolating four occupational categories: information (comprising professional, technical and related workers, administrative, executive and managerial, and clerical works), agriculture (farmers, fishermen, hunters), industry (craftsmen, production process workers), and service sector (workers in transport and communication, sales workers, service, sport and recreation workers)[19].

Exhibit 7. Employment shifts and Premature Deindustrialization



Source: ILO Laborstat; analysis by the author

In addition to showing the widely acknowledged shift away from agricultural employment as a result of a wide range of innovations that resulted in productivity growth, exhibit 7 shows a secular decline in manufacturing employment, coupled with an increase in service and information employment. The decline in manufacturing employment could be attributed to automation. However, research by this author would indicate a lag in assimilating digital technologies in production processes (Katz, 2017). An alternative explanation of the reduction of manufacturing employment is that, being exposed to international trade, emerging economies become non-competitive and, therefore, undergo a «premature» deindustrialization trend (Rodrik, 2015).

[19] A first version of this approach was utilized by Katz (1985).

As to the increase in the share of «information» occupations, this would be the result of the expansion of state expenditures triggered by new needs poor public, regulatory and protective roles, combined with the capacity of the State to absorb a high-skilled workforce that cannot be employed within the private sector.

What are the policy prescriptions suited for this situation? In the first place, in order to tackle the international competitiveness challenge, emerging countries do not have a choice but to actively promote the digitization of production and digital transformation. This requires moving along the industrial digitization path, emphasizing policies focused on accelerating the digitization of production of small and medium enterprises. This entails the need of policies aimed at reducing the cost of technology acquisition, training of employees, and the provision of consultancy services to companies that would want to initiate a process of digital transformation. For example, the European Commission is implementing the Smart Use of ICT for SMEs, a program focused on promoting digital transformation among small and medium companies through innovation promotion vouchers, guidebooks for regional authorities, and innovative financing solutions.

Secondly, emerging economies should address human capital gaps in driving the second and third waves of digitization. These gaps are not related to the overall supply of skilled labor. In fact, as shown above, educational systems might be training more resources than what the private sector can absorb. The gaps are related to technical and engineering skills. This includes launching changes in educational and training systems introduced to address the gap (introduce tracking systems aimed at sorting out top performers, launching short term diplomas, structuring two level university systems, etc.).

Additionally, governments in emerging countries need to stand ready to help reduce the costs of disruptions and adjustments. If ICT deployment leads to job destruction in certain areas or sectors, governments should be ready to implement retraining programs and temporary safety net mitigation initiatives. The experience of deployment of the technology in emerging regions such as Chile and Saudi Arabia has highlighted the fact that once digitization increases, job creation is directly a function of human capital availability. Studies in digital economy development tend to underscore the fact that once the infrastructure gap has been addressed, human capital becomes the stumbling block. To rapidly tackle this barrier, governments are implementing short training programs focused on creating the necessary digital skills to innovate utilizing the technology in the development of new businesses.

7. Conclusion

This paper has raised the question that in order to assess the social and economic of digitization, it is necessary to differentiate three “waves” of digitization and understand where societies stand in terms of the technological innovation and adoption cycles.

Research evidence has clearly stated the productivity, economic growth, job creation, and welfare resulting from the first wave of digitization associated with the diffusion of computers, broadband and mobile telephony.

The second wave of digitization, linked to the diffusion of the Internet, its corresponding platforms and cloud computing has resulted in an extensive "innovation" effect resulting in the emergence of digital industries, which have absorbed high-skilled labor. However, automation has also resulted in the disappearance of jobs in certain low and medium-skilled occupations. On the other hand, the increase in high-skilled employment has triggered an increase in demand for low-skilled workers at the local level. Trends linked to the second wave of digitization are still difficult to measure in a consistent manner because of the lag existing between technology adoption and its social and economic impact. That being said, researchers agree on the fact that automation effects will have a significant change on the occupational profile of labor markets, affecting primarily low-skilled workers. These effects will accelerate over time fueled by the accumulation of intangible capital of firms (organizational changes, reengineering of business processes) and the increasing potential of digital technologies linked to the third digitization wave.

Research on the third wave of digitization, linked to innovations such as robotics, 3D printing, machine learning, and big data among others, is still at its infancy. There is research that posits that automation of repetitive tasks, linked to robotics, and combined with enhanced power of technology in areas such as artificial intelligence and speech recognition, is linked to the disappearance of jobs. On the other hand, other researchers consider that not all jobs can be replaced by automation and that second-order job creation derived from either new innovation and/or increased productivity and spending can actually cancel out any disruption effects. Yet, these researchers concede that if productivity does not increase, living standards will not improve and, consequently, second order effects will not materialize.

In this context, considering the advantages and risks entailed in the three waves of digitization, governments need to devise the right policy instruments that could maximize its benefits, while limiting the disruption risks. In particular, this paper has highlighted policies aimed at promoting innovation in advanced technologies while mitigating workforce disruption in developed economies:

- Increase public expenditures in education to increase the skills (including digital skills) acquired through formal training;
- Implement labor policies focused on workers being able to retain their current jobs or move to new areas of demand (job placement services, special labor market programs, apprenticeship programs);
- Put in place subsidies to lessen job disruption of low-skilled workers (tuition-free education, temporary cut in payroll taxes, basic income guarantees);
- Implement policies aimed at increasing geographic mobility (reduction of relocation costs, subsidized housing; and

- Promote demand for skilled workers by accelerating the rate of innovation in areas likely to be affected by job disruption effects.

The evidence of labor disruption effects in emerging economies is still not conclusive. Yet, the evidence points at a "premature deindustrialization" as a result of an erosion of manufacturing competitiveness (trend which excludes China and other Asian economies) and a growth of "information processing workers", which are being absorbed by expanding state governments. In this context, emerging countries do not have a choice but to actively promote the digitization of production and digital transformation. This requires putting in place policies, which combine the expansion of innovative capacity, "learning capacity" and human capital generation:

- Implement policies aimed at reducing the cost of technology acquisition, training of employees, and the provision of consultancy services to companies that would want to initiate a process of digital transformation;
- Launch changes in educational and training systems introduced to address the gap (implement tracking systems aimed at sorting out top performers, introduce short term diplomas, structure two level university systems); and
- If ICT deployment leads to job destruction in certain areas or sectors, governments should be ready to implement retraining programs and temporary safety net mitigation initiatives.

The policy challenge going forward is presented by the fact that the digital transformation resulting from all three waves of digitization is so all-encompassing that sector-specific strategies developed within institutional silos are not applicable any more. Governments need to build cross-institutional links fostering the collaboration among education, ICT, industrial promotion, science and technology to devise and jointly implement policies. In addition, the future public policy scope has to be significantly expanded beyond traditional domains such as taxation, competition, and digital literacy to include new areas such as privacy protection, cyber security, and the fostering of digital adoption such as trust and enhanced customer experience. As it is clear, the challenges for policy makers are significant, but so are the benefits for citizens and the need to mitigate any potential disruptions.

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