THE ADOPTION OF DIGITAL TECHNOLOGIES IN DEVELOPING COUNTRIES: INSIGHTS FROM FIRM- LEVEL SURVEYS IN The adoption of digital technologies in developing countries: Insights from firm-...

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THE ADOPTION OF DIGITAL TECHNOLOGIES IN DEVELOPING COUNTRIES: INSIGHTS FROM FIRM-LEVEL SURVEYS IN ARGENTINA AND BRAZIL

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The adoption of digital technologies in developing countries: Insights from firm-level surveys in Argentina and Brazil

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Abstract

This study draws on two pieces of research: one carried out in Argentina (Albrieu et al., 2019) and the other in Brazil (IEL, 2018; Ferraz, Kupfer, Torracca & Britto, 2019). Both included a survey of around 300 manufacturing firms in the former and 710 in the latter. Three key findings emerge from these studies: i) Industry 4.0 has not yet arrived in Brazil and Argentina. Most manufacturing firms use older digital technology generations; ii) Very few enterprises are introducing measures to change this situation, although Brazilian companies seem to be relatively more dynamic when considering both G3 and G4 technologies; iii) Three different groups can be identified in terms of competence and readiness level; firms that are "forging ahead", that is, firms closest to the technological frontier, firms with lower levels of digitalization and readiness, i.e. firms that are "lagging behind" and firms with lower levels of technology adoption than those that are 'forging ahead' but that are implementing concrete measures to bridge their technology gap, namely firms that are "catching up". This classification of firms—and the associated risks and opportunities—is crucial for designing policies to address the widespread technology gap in both Argentina and Brazil. Two major results on skill demand can be gleaned from the Argentinean study: i) Technological gaps are associated with both low demand and scarcity of skills in new technologies. ii) Enhancing both socio-emotional and cognitive skills and other complex skills related to the use of new technologies is a necessary condition for the Fourth Industrial Revolution to establish a foothold.

Keywords

Industry 4.0, technology, skills, automation

1. Introduction

This study analyses the current and future process of adoption of digital technologies in Argentina and Brazil. The Argentine case study also presents findings on the implications of digital technologies on skills and labour demand. This exercise is based on two independent surveys of manufacturing firms that have recently (2017 and 2018) been carried out in both countries.

The diffusion of digital technologies in the economy, particularly in manufacturing, has attracted the attention of companies, research institutes and governments around the world. References to Industry 4.0 as the "ultimate target" have become almost commonplace. This does not, however, apply to countries with industrial structures that are diversified in terms of the range of existing activities and heterogeneous in terms of their capabilities and economic performance. Moreover, it is neither useful for the debate nor to derive any implications for productive and technological development policies.

The economic structure of developing countries has two specific features that make the analysis of technological change more complex: first, their diversity in terms of different economic activities, and secondly, their heterogeneity in terms of different levels of competence among the firms within each industry. The scope of investigation of developing countries' modernization trends must be broader, thus, on the one hand, allowing for the possibility of different stages (or generations) of digital technologies to be present, and to investigate future trends, on the other. That is, the focus should not only be placed on global technological trends but also on identifying the digital technologies currently being used and which ones will be used in the near future as well as how to characterize "advanced" and "limited" digital companies.

This paper explores these particular issues. It draws on two recent comparable research studies. One was carried out in Argentina (Albrieu et al., 2019) and the other in Brazil (IEL, 2018; Ferraz, Kupfer, Torracca & Britto, 2019). The Argentine study surveyed 307 firms from 6 industries; the Brazilian sample consisted of 711 firms from all industries.

The respondents held executive positions in the selected firms and had full knowledge of the activities of the firm's most successful production unit (in the case of a multi-plant firm). Information about the current use of digital technologies (and implications for skills in the Argentine case) and future perspectives express the views of informed respondents. Their perceptions of the future are not predictions, but simply reflect their own expectations. This exercise is built around the assumption that company executives can provide the most in-depth information about the company's current and future situation. Even if not strictly representative of all Argentine or Brazilian industries, this analysis provides an overview of the present and expected stage of digitalization in the two countries.

The following section presents the conceptual framework of our analysis: the nature of digital technologies and their implications for skills and industrial development. Section 3 describes the methodology used in both surveys and the resulting database. The findings of our analysis are presented in Section 4. We first offer a general and descriptive overview for the cases of Argentina and Brazil. We then devote a separate subsection to both Brazil and Argentina to analyse the most relevant findings gleaned from these surveys in more depth. The following subsection explores the implications of digital technologies in Argentina on the labour force's skills. The final section addresses the question of whether digital technologies provide windows of opportunity for development and the consequent policy implications for both countries and for developing countries in general.

2. Conceptual framework

2.1. The nature of digital technologies

Advances in information and communication technologies (ICTs) are fundamentally changing the way we produce, consume, trade and, of course, the way we work. Reflecting on these changes, the concept of "Industry 4.0" was introduced in Germany, in 2011 to describe a process that entails the integration and control of production by sensors and equipment connected to each other in digital networks and the fusion of the real world with the virtual one, creating so-called cyber physical systems that are extensively supported by the use of artificial intelligence. This approach incorporates a vast array of innovations in industrial processes, design, operations and production-related systems, affecting the value generation at different organizational levels and throughout value chains. If effectively used, 4.0-related technologies could cause disruptions in business models, competitive drivers and market structures.

Industry 4.0 implies the convergence and integration of different and complementary digital technologies. In this context, the concept of technological convergence, originally proposed by Rosenberg (1963), can be expanded and linked to the concept of generic technologies (Gambardella & Torrisi, 1998) or general purpose technologies (GPTs) (Cantner & Vannuccini, 2012). Recalling Freeman's theory, when the supply of digital technologies expands exponentially, costs increasingly fall and such technologies can be extensively applied. Such attributes are associated with a high potential for change. According to Andreoni (2017), digital technologies share different technology properties: i) they have a "transversal" impact, which can be measured by the extent to which they are deployed in multiple sectoral supply chains; ii) their degree of "embeddedness", i.e. the extent to which they play a critical role within integrated technology systems; iii) their "quality enhancing potential", i.e. the extent to which they facilitate an increase in quality products and their functionalities; iv) their "productivity enhancing potential", i.e. the extent to which they affect the productivity of production processes; v) their "strategic" character in terms of facing major social and economic challenges in the future. It is, however, assumed that the pace of diffusion of such technologies differs across industrial sectors.

From a firm's perspective, digital technologies may represent a qualitative leap in the firm's development: they transform the firm's existing technological base and have an impact on different organizational areas of the company and its external connections. Business strategies must be adapted accordingly, requiring qualitative changes in investments and human resources. The adoption of digital technologies requires digital skill-biased investments.

Industry 4.0 is a concept that blends a "soft" side—big data, artificial intelligence—with a "hard" side—sensors, high performance computing, robots, etc.—as well as with a "connective" side, namely communication networks. Industry 4.0 is strongly dependent on the availability of relevant information in real time connecting all stages of the value chain. Development towards Industry 4.0 by combining the introduction of new solutions with the intensification of the diffusion of solutions already being implemented has been possible due to the reduction in the costs of core technologies. This, for example, is the case of sensors. The same development is evident in the processing and storage of large databases. Even so, the investment required to digitize a manufacturing plant is not insignificant, that is, although the trend towards Industry 4.0 is clear, the process of digitalization of industrial companies in developed and developing countries is still at an early stage.

According to the OECD (2017), digital technologies are associated with innovations on three fronts: 1) innovations in the production sphere or "advanced manufacturing"; 2) innovations in information processing, with intensive use of big data, cloud computing and connection of objects; and 3) innovations in the use and integration of information, with extensive use of artificial intelligence and the integration of smart systems. Industry 4.0 is associated with firms' ability to effectively catch up on these three fronts to generate the application of specific solutions, reflecting their strategic priorities according to competitive pressure and environmental stimuli. Given the vast array of digital solutions available, there are numerous possibilities of combining these technologies to solve specific problems industrial production pose.

Not all digital technologies are from the 4.0 generation. Some have been in use in industrial production (management systems, microelectronic-based automation, robotization, mobile communication, sensors and CLPs, etc.) for quite some time. As technological progress is made, new generations of digital technologies evolve, thereby reinforcing existing trajectories towards integration, interconnection and intelligence. With the fall in costs, the adoption of new solutions by industrial firms can occur at a fast pace if firms have competitive stimuli, the necessary financial resources and capability base. The adoption of new technologies tends to be modulated by a solution-driven perspective, that is, firms engage (or not) in the adoption of different solutions if these can effectively solve challenges that previously were insurmountable.

According to Kagermann, Wahlster & Helbig (2013), digital manufacturing can be conceived as an evolutionary process with three characteristics. Firstly, the adoption of digital technologies is a context-based process; manufacturing and engineering solutions are specific to firms, value chains, locations and markets. Secondly, benefits from digital manufacturing are accrued in the long term, requiring experimental and cumulative learning processes involving technologies, systems and processes. Thirdly, success depends on a firm's capacity to extract and appropriate the value of new solutions.

The integration, interconnection and intelligence dimensions of future digital technologies must be highlighted. Digitalization combined with artificial intelligence and communication technologies at firm level lead to real time approximation (represented by information flows) of activities carried out in different departments of the firm, in various industrial plants the firm operates and by its suppliers, service providers and customers. Administrative costs and stocks of parts, components and finished products can thus be reduced, thus increasing the efficiency of production processes, lowering transaction costs and optimizing logistics. The time to market (from R&D to marketing) is also reduced. Lower costs are not the only gain from real time approximation of different business functions. Digital technologies also translate into gains for firms in terms of flexibility in planning processes, design of products and attending to client demands. Digital solutions—with the increasing influence of artificial intelligence—also have the capacity to simulate productive and market environments, allowing for the testing of alternatives to identify the most feasible combinations for success. Analogously, simulation and augmented reality programmes can be used to develop new products.

In summary, Industry 4.0 is a game-changer, opening up a multitude of opportunities for firms to revamp or evolve towards business models characterized by product customization, short lead times, efficiency and flexibility in the use of assets. To reiterate a point already made, firms' business models and their value chains are evolving towards integrated, interconnected and smart models. These Industry 4.0-related digital technologies then have the potential to strengthen firms' competitiveness and market positions.

2.2. Digital technologies: implications for skills

How will 4.0 technologies affect labour markets? What is the related set of relevant skills for the future? These questions are difficult to answer. On the one hand, uncertainty prevails because of the incipient nature, speed of change and multiplicity of applications of 4.0 industries. It is difficult to foresee how advanced digital technologies will impact economic and employment patterns in the medium and long run. On the other hand, history shows that economic divergence emerged during periods of technological turmoil; certain countries, clusters of firms or individual firms are better able to absorb new technologies while others lag behind. Thus, if history serves as a guide, the impact of technology on the future of work is likely to diverge across economic spaces.

Even so, the discussion on the future of work can be organized by focussing on the specific issue of skills, with introductory comments on the issue of jobs.

As has been the case during former technological revolutions, —the presumption is that Industry 4.0 will make a large share of the workforce obsolete (Mokyr, Vickers & Ziebarth 2015). Some analysts warn that "technological unemployment", a concern Keynes had also raised in the 1930s, could well become a reality in the near future. Most importantly, as traded goods will increasingly be of a digital nature, producing more units once the good has been developed will require minimum additional costs. The possibility of simultaneously producing perfect copies of a given good at a near-zero marginal cost has substantial consequences for the labour market, jeopardizing traditional standardized production processes that are labour-intensive and routine (Rifkin,2015). More optimistic views refer to evidence that the recent impacts of automation on employment have mostly occurred within the workplace. The labour force would thus be dedicating fewer hours to automated tasks and more hours to complex tasks and interpersonal relations. In that case, the primary impact would be felt in the combination of tasks performed within jobs, and not so much in the combination or the number of jobs in the economy (Pounder & Liu, 2018). The first question that arises here is: what would the extent of job losses be due to digital automation?

Technological change does not usually remain neutral with reference to skills demand (Acemoglu, 2002). It tends to favour workers who have skills that complement the new technology. It is still difficult to identify which specific skills are required for 4.0 technologies, but they will typically tend to be biased towards three broad groups: general cognitive skills, specialized knowledge associated with new technologies (or IT skills), and socio-emotional (or soft) skills. At the same time, new technologies have the potential to mitigate income gaps and inequalities in several disadvantaged labour market sectors. For instance, women and youth might benefit from digital innovations that will enable them to bridge the wage gap by leapfrogging due to the use of technology, for example (World Bank Group, 2016).

A report prepared by Deloitte Access Economics (2017) predicts that soft skill-intensive occupations will account for two-thirds of all jobs by 2030 compared to half of all jobs in 2000, and that the number of jobs in those occupations is likely to increase by 2.5 times the employment rate in other occupations. Consequently, the future of labour will fundamentally depend on intellectual capital associated with the ability to process and integrate information of many different types and to perform complex tasks and communicating these to others. From this perspective, opportunities will arise in activities that strictly rely on intellectual capacities, such as curiosity, imagination, creativity and social and emotional intelligence. Over 30 per cent of all new high-paying jobs would be linked to "essentially human" social attributes (Levy & Murnane, 2013). The workforce's increased diversity is likely to encourage demand for more creative labour, particularly in emerging "hybrid" jobs that integrate technical and project management skills, mobilizing competencies associated with various domains of knowledge.

While the need for technological skills remains strong, the need for people with communication, interpretation and synthetic thinking skills is on the rise. These new social skills, in turn, lead to changes, namely from an educational model focused on STEM (science, technology, engineering and math) to one that is focused on STEAM areas, which in addition include general culture and arts education (as indicated by the inclusion of the letter A in the acronym). Appropriate skills to meet the challenges posed by the advent of digital technologies imply a restructuring and modernization of school curricula, especially in the fields of logic, creative thinking, problem solving, project work and teamwork. They require changes in education in all fields and at all levels, including formal and non-formal learning mechanisms. Such profound changes imply a need for innovative education models. The need to overcome traditional "cocoons" of scientific disciplines that characterize most of today's education systems is a major challenge for all societies.

Another relevant issue is the notion of "professionalization" which, in a traditionally industrial society, plays a key role in normalizing the competencies required to resolve problems in the realm of manufacturing. Historically, a career was defined by a relatively stable and predictable set of capabilities, aligned with an organization's and industry's needs. In the new emerging scenario, however, personal success will largely depend on accelerating the permanent process of learning throughout an individual's career. Instead of relying on employers to shape the nature and progression of their careers, employees may have to take the lead, cultivating a mindset that allows them to “move” among different jobs, always mindful of emerging high-value skills and of the associated training requirements. Simultaneously, changes in the realm of the employment relationship are also observable in terms of basic conditioning factors, which tend to encompass a well-defined framework of “occupations” associated with routine tasks performed in the work environment or “professions” linked to formal qualifications and stable jobs that outline a “professional career”, and are now shifting towards flexible employment relationships, which can depart from traditional professions and focus on specific skills, resulting in individualized career “paths”.

In summary, Industry 4.0 may create new relationships between computers and people, where technological change is not exclusively linked to labour-saving effects but is increasingly associated with integrated, interconnected and intelligent systems in which people will play a key role (Daugherty & Wilson, 2018). As technologies become standardized and skills begin to adapt, the complementarities between machines and people may become more relevant than the substitution of one for another. In this context, interactions between people and machines become increasingly important: from human input to define the action of machines and to train and maintain them to the ability of machines to augment human capabilities.

2.3. Digital technologies: implications for developing countries

The incorporation of digital technologies by entrepreneurs in developing countries entails specific challenges such as: a) the availability of solutions for different firms and sectors, including investments in equipment integrating such technologies; b) the adaptation of manufacturing processes; c) the adaptation of processes and of relationships between companies along the productive chain; d) the development of new skills and competences.

In addition, it implies transformations in business management practices, primarily with reference to two aspects. The first relates to the strategy to implement those technologies, which entails cooperation between different organizational components, such as IT and production. The second aspect is associated with the exploitation of these technologies’ full potential, which requires the adaptation of business models to the digital environment, internally and in their external relationships with suppliers and customers. More importantly, because digital technologies are constantly changing, a forward-looking attitude towards new opportunities is essential. Few companies are prepared to embrace all of these changes at once. In practice, companies tend to adopt new technologies gradually based on their trajectories, capacities and strategies. Hence, the diffusion of digital technologies associated with Industry 4.0 will not reach all sectors in the same way or at the same time.

In developing countries, which are characterized by strong heterogeneity both within and between sectors, it is also reasonable to assume that different realities will coexist with regard to the adoption of such technologies. On the one hand are companies that produce traditional goods and services through conventional production processes, without the use of digital technologies. These companies will need to adopt strategies that will allow them to gradually introduce new processes that are adapted to the Industry 4.0 paradigm. On the other hand are companies that are capable of developing new "digital" products, depending on the degree of technology they add to their products. Digitalization is an essential part of their business strategy. In the garment industry, for example, in addition to the production revolution, new materials may add technological components to the industry's goods. That is, the mere digitalization of production may not suffice to ensure an industry's long-term competitiveness.

The combinations of digital technologies are diverse, as are their impacts on companies, which vary depending on the technologies adopted, the degree of production integration and the business strategies being pursued. The extent and speed of adopting digital technologies depends on inherent features of the relevant sector, as well as on the increasing competitive pressures generated by other companies in the country and abroad. These forces affect the ability of firms to engage in a digital technology-based strategy. It is at the strategy level where decisions are made in relation to timing, breadth and depth of digitalization. Nevertheless, as the process of change is economically relevant for regions and countries, the role of public policies becomes crucial for facilitating diffusion processes as well as promoting providers of digital solutions for industry.

The process of adoption of digital technologies in Argentina and Brazil provides a valuable reference point for developing countries as the two countries' industrial sectors are characterized by two features that may find resonance in other national contexts: diversity and heterogeneity. Diversity in terms of industries, lines of products, location, size and ownership structure of firms in a country's industrial matrix implies that firms of every type are found in Argentina and Brazil, which can be useful for referencing structural challenges in the adoption of digital technologies elsewhere. In addition to differences in the breadth and depth of digital technologies in the majority of developing countries, diversity is a structural feature of both Brazil and Argentina. Heterogeneity, or the co-existence of marked differences in capabilities and performance within and between industries (and even at firm level) is yet another structural feature of the two countries. These structural features are most likely found in the majority of developing countries, albeit to a different extent and with a different scope. The analysis of digitalization processes in the Argentine and Brazilian industrial sector can provide interesting insights for strategic policymaking for the sector and for public policies in other developing countries.

When drawing lessons from the experiences of Argentina and Brazil, their specific features must be taken into account. Their industries' structural configuration indicates: (i) an increasing relevance of natural resource-based industries, (ii) a steady decline of the share of high-technology content industries and, (iii) a gradual loss of competitiveness in traditional, labour-intensive activities.

Taking the pros and cons of this structural configuration into consideration, the question that arises for all developing nations is whether the adoption of advanced digital technologies will improve their manufacturing sector's competitiveness and positively contribute to economic and social development.

The diffusion and adoption of digital technologies in developing countries is clearly associated with catching-up processes. According to the basic catch-up hypothesis, lagging behind may open opportunities for potentially rapid advances, as the growth rate of productivity can be accelerated. It is fair to assume that the pace of a catching-up process depends on several conditions such as the diffusion of knowledge, the mobility of resources and the rate of investment, which defines the level of adequate "social capability" to absorb advanced technologies. These factors play a key role in explaining why, according to Abramovitz (1986), some countries move forward (catch up) and join the more advanced countries (that are forging ahead) while others fall behind and fail to substantially raise their productivity levels.

While potential advantages may be linked to backwardness, as argued by Gerschenkron (1962), international points of reference are currently quite unpredictable. Even competitive robust firms in developed countries are currently initiating a push towards digitalization. While many studies on catching-up follow a basic assumption that the technical orbit is predictable, thus facilitating advances of laggards (XU, Xiong, Li & Li, 2018), the level of predictability is currently quite low.

Some scholars have also studied the process of catching up in latecomer countries from a competency building perspective (Kumaraswamy, Mudambi, Saranga & Tripathy, 2012; Malerba & Nelson, 2011; Zhao, Huang & Guo, 2015). Lee & Lim (2001) associate catching up with three alternative routes: 1) path-following, 2) path skipping and 3) path creation. Path-following occurs when a latecomer firm follows the same path as that taken by forerunners, moving along a similar path in a shorter period. We speak of path skipping when a latecomer firm leapfrogs one or more stages. Path-creation takes place when a latecomer firm explores its own path of development. These approaches to catching up differ by industry and according to the previous competences accumulated by local firms.

At firm level, the concepts initially proposed by Abramovitz (1986)—forging ahead, catching up and lagging behind—can be very useful in translating the above discussion into the integration of digital technologies. When investigating firms' level of digitalization in developing countries, it is essential to focus on evidence of: (i) firms at a more advanced stage (forging ahead) in the adoption of digital technologies; (ii) technologically backward firms (lagging behind), and (iii) firms capable of moving forward (catching up) in the integration of digital technologies. The relevant question (and related policy) thus becomes: if the adoption of advanced digital technologies imply competitive advantages, would firms that are forging ahead sweep aside those that are lagging behind? Alternatively, if the access to and adoption of digital solutions become pervasive, would firms that are lagging behind be able to catch up, thus opening windows of opportunities for "latecomers"? Would the increase in demand for products and services in diverse and heterogeneous countries like Brazil and Argentina be high enough to allow for the survival of "weaker" firms? Who would benefit from technical change and sustainable growth in the long run? These are relevant guiding questions for the present comparative research.

3. Methodology

3.1. Traditional approaches: focus on the adoption of specific solutions

Abundant research of what emerging technologies are and their potential use and direct impacts already exists. Significant efforts have been made to collect and disseminate data on the diffusion of specific technologies at country level, especially in developed countries. Further sectoral and firm level studies are, however, necessary to discuss the relevant implications for corporate planning and policy assessments as well as evaluations in the context of developing countries.

Some crucial questions must be emphasized in this regard: which digital technologies are being used in the present and which ones will be used in the near future? How are "advanced" and "limited" digital companies characterized? What are the capabilities and skills implications? What are the challenges, risks and opportunities involved?

Several international consulting firms (Accenture, 2017; Deloitte, 2018a, 2018b; Deloitte Access Economics, 2017; McKinsey Global Institute, 2018; PWC, 2016, 2018) have carried out surveys to assess the level of diffusion and the impacts of digital technologies associated with the Industry 4.0 paradigm. Many of these analyses refer to assessments of the diffusion of specific technical solutions and perceived impacts in terms of potential benefits. Often, attempts are made to evaluate the enterprise's readiness to incorporate these technologies in different organizational settings.

Such surveys are quite useful as they provide evidence on an emerging and relevant process of change. Nevertheless, they also have a few shortcomings: (i) the list of possible technological solutions is immense; consider, for example, the variety of available robots; (ii) technological solutions are specific to industrial activities and each activity entails specific processes or business activities; (iii) focussing only on the most advanced solutions disregards the fact that digital solutions have been around for a long time and some previous generations of technology are not necessarily obsolete from a performance perspective. Due to these issues, we sought an alternative path to question firms on the adoption of digital technologies.

To answer the proposed research questions, we took a novel approach by focussing on two aspects: (i) determining the firms' level of digitalization, and (ii) the relevant skill profile of the labour force in light of digitalization (only for the Argentine case).

3.2. An alternative approach: how business functions are realized

The focus of our analysis is on how digital technologies impact the way business functions. The reasons for this approach are threefold. First, digital technologies are available and have been used by industrial firms across all sectors for at least 30 years. Consequently, any analysis should include the possibility that companies are using digital technologies of different generations. Secondly, regardless of the generation of technology being used at firm level, digital technologies are being used in all business- functions such as client and supplier relations, product development or production management. Thirdly, as digital technologies are being used in every industrial activity, the proposed questions on adoption must be specified in a way to allow for any firm to respond them, regardless of their level of knowledge about these technologies.

The concept of "technology generation" requires a time-related dynamic approach to questions. That is, it does not suffice to identify which generation of technology a firm is actually using, but rather a technology foresight approach must be taken given the rapid process of change. The definition of different "levels" or "stages" in terms of "technological generations" seeks to capture the evolutionary logic of the integration of digital technologies in diverse and heterogeneous industrial environments.

This analytical framework does not only require us to determine the firms' stage of development but also (and even more importantly) which measures are being taken to adopt digital technologies. Qualitative leaps to newer technological generations are achieved through entrepreneurial efforts, since this requires planning and targeted actions to acquire the necessary technologies, as well as the proper resources in terms of physical infrastructure, knowledge and skills.

3.3. Linking generations of digital technologies to business functions and the Argentine and Brazilian surveys

To address the wide range of digital technology uses in different business functions and the possible coexistence of different technology generations within a company, a common methodology that required two specifications was applied to the Argentine and Brazilian case studies.

The first specification is related to the concept of digital technology generations. Both surveys followed a framework involving four generations of digital technology:

- **First generation - rigid production**: the use of digital technologies for a specific purpose in a specific function (CAD in product development).
- **Second generation - lean production**: the use of digital technologies that partially associate two or more business functions (CAD-CAM linking up product development and production processes).
- **Third generation - integrated production**: digital technologies are integrated and interconnected in all business functions (web-based sales support system).
- **Fourth generation - integrated, connected and smart production**: the use of digital technologies with information feedback within the operation to support decision-making processes (business management with big data and artificial intelligence support).

Secondly, as significant differences in strategy, competence and performance exist within firms and its different business functions—the essence of developing countries'—it is also expected that this may be the case in relation to the use of digital technologies. Hence, to empirically investigate firms' heterogeneities, the focus in both surveys was on five business functions: supplier relations, product development, production management, customer relations and business management.

Table 1 provides a roadmap of four digital technology generations, each corresponding to the five business functions of the analytical framework underlying the surveys[1].

Table 1: Digital technology generations according to business functions (*)

Generation	Supplier relationship	Product development	Production management	Client relationship	Business management
G1	Manual transmission of orders (e.g. fax)	Stand-alone computer-aided design - CAD	Stand-alone automation	Spread sheet registry of contacts	Information systems by area/department
G2	Electronic transmission of orders (e.g. email)	CAD - CAM	Partially or fully integrated CAM	Automated devices to support sales	Enterprise resource management in a few areas
G3	Digital system for processing orders, stocks & payments	Integrated data product system	Automated process execution system	Internet-based support for sales & after sales services	Integrated platform to support decision-making
G4	Real-time web-based relations	Virtual modelling	Machine to machine - M2M system	Client relationship based on line monitoring product use	Business management supported by big data analytics

(*) DT generations were specified with the support of specialized engineers. The best foreseeable technologies in 2017 were considered to consist of G4.
Source: Authors' elaboration based on IEL (2018).

The surveys took into consideration that different generations of digital technologies may co-exist in different organizational functions within a firm. They sought to capture information on digital technologies currently being used by firms, the perceptions of entrepreneurs on the future use (5 to 10 years) of digital technologies and which efforts firms are currently mobilizing (if any) to achieve the projected digitalization in the future. Based on this information, the firms' current and future stage of development (digital generation) can be determined as well as their readiness to prepare for the future.

For analytical and comparison purposes, a stylization of digital technology generations and internal business functions was carried out (see Table 1). G1 and G2 have been around for as long as numerical control programming systems have existed (late 1950s), although devices, such as

[1] The 4h generation of the proposed framework corresponds to the German framework Industrie 4.0.

CAD have grown exponentially in recent years on account of parametric engines. The evolution from G1 to G2 generally does not require major organizational changes, even though the efficiency and quality of processes are substantially improved. For firms to move from G2 to G3, however, significant changes are necessary: to fully integrate organizational functions, a comprehensive and effective standardization of the firm's processes and information systems is required. The changes that need to be implemented are even more substantial when advancing from G3 to G4. G4 implies, inter alia, the use of advanced communication devices, robotization, sensorization, big data and artificial intelligence. G4 solutions are most likely introduced gradually, but the end result is an integrated, interconnected and "intelligent" business model, quite different from a G3 firm.

In addition to generic questions on the firm's economic data (number of employees, sales, etc.), the surveys in Argentina and Brazil had one common denominator and one basic difference. The common denominator was questions on the adoption of digital technologies for conducting business functions (see Table 1). Firms were asked which digital technologies were being used at the time the survey was being conducted, and which generation was expected to be in use within the next 5 to 10 years. The respondents were also asked about the likelihood of advanced technologies taking the lead in their industry in the near future.

In an effort to "ground" future expectations, firms were then asked whether measures were already being taken towards achieving the implementation of the projected future digital technologies based on four levels of readiness: 1) no action, 2) ongoing preliminary studies, 3) planning that is already underway or being formalized and 4) plans that have been formalized and are already being implemented. The Argentine survey also included questions on the current and potential impact of digital technologies on labour and skill demand and addressed such topics as employment trends and the relative importance of different skill sets.

The Argentine survey was conducted in the second half of 2018 and included 307 firms from six different manufacturing industries: 1) processed foods products, 2) basic inputs, 3) light vehicles and parts and accessories, 4) textile, 5) agricultural machinery and 6) biopharmaceuticals.

The Brazilian survey was carried out between May and October 2017. Information from 711 firms was collected. They belonged to from the agroindustry (food products, beverages and tobacco), the automobile industry (motor vehicles and auto parts), basic metals (iron, steel, pulp, cement), capital goods (electrical machinery, machinery and equipment), chemicals (petrochemicals, rubber and plastic products), consumer goods (textile, garments, footwear, durable goods) and ICT (office and computing machinery, communication instruments) and other industries.

The data collection process included both personal and telephone interviews, and each respondent was given the option to share his/her contact details only if he/she wanted to. The survey's main purpose was to analyse both the current and the expected state of technological diffusion of 4.0 technologies.

Despite our best attempts to make these studies as comparable as possible, the surveys' sectoral coverage differed. While the Brazilian survey covered all manufacturing industries, the Argentine one included only six industries. Moreover, the size of the firms surveyed varied considerably. While the Brazilian survey only covered firms with at least 100 employees, the Argentine survey included firms with at least 11 employees. The differences in coverage and firm size may explain some of the divergences found in the present analysis. It is nonetheless an insightful analysis of the current situation of both countries' manufacturing sectors.

The following section presents the results of both surveys. The first subsection provides a general and descriptive overview of the cases of Argentina and Brazil.[2]

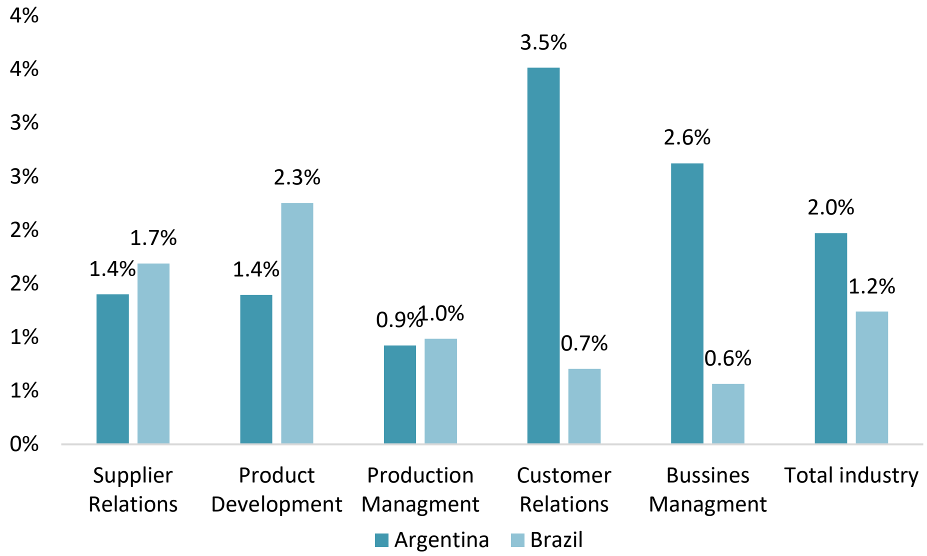
4. Results

4.1. Generic and descriptive results: current and expected adoption of digital technologies in Argentina and Brazil

The analyses carried out in Brazil and Argentina reveal that both countries' situation is similar in terms of the diffusion of Industry 4.0 technologies. In both cases, 4.0 technologies play only a marginal role in firms' production structures. Figure 1 shows that the share of firms that use such technologies is very low across all business functions and that the average adoption rate is 2.0 per cent and 1.2 per cent for Argentina and Brazil, respectively. Due to the nature of the surveys and the specificities of the economic structure of emerging economies, it is difficult to establish a benchmark based on global trends. As a proxy, consider that in a McKinsey survey conducted in 2017 (McKinsey, 2017), 20 per cent of respondents stated that they had adopted one or more AI-related technologies at scale or for a core part of their business. The penetration of Industry 4.0 is still incipient in both South American countries.

[2] The data for both countries was presented jointly. The surveys have specific sectoral and size coverage.

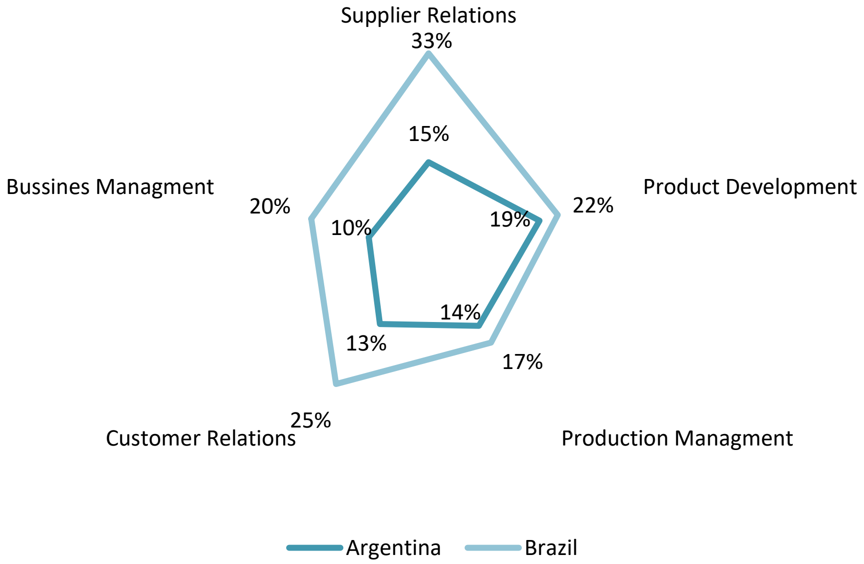
Figure 1: Share of firms that use 4.0 technologies in Argentina and Brazil



Source: Ferraz, Kupfer, Torracca, & Britto (2019) and Albrieu et al. (2019)

The picture changes when we turn our focus to 3.0 technologies: Argentina is lagging behind Brazil. In fact, when the use of both 3.0 and 4.0 technologies is considered, Brazil leads Argentina in every single business function, as illustrated in Figure 2. This is particularly evident in the case of supplier and customer relations, where the use of G3 and G4 in Brazil's firms is double that of Argentina's firms.

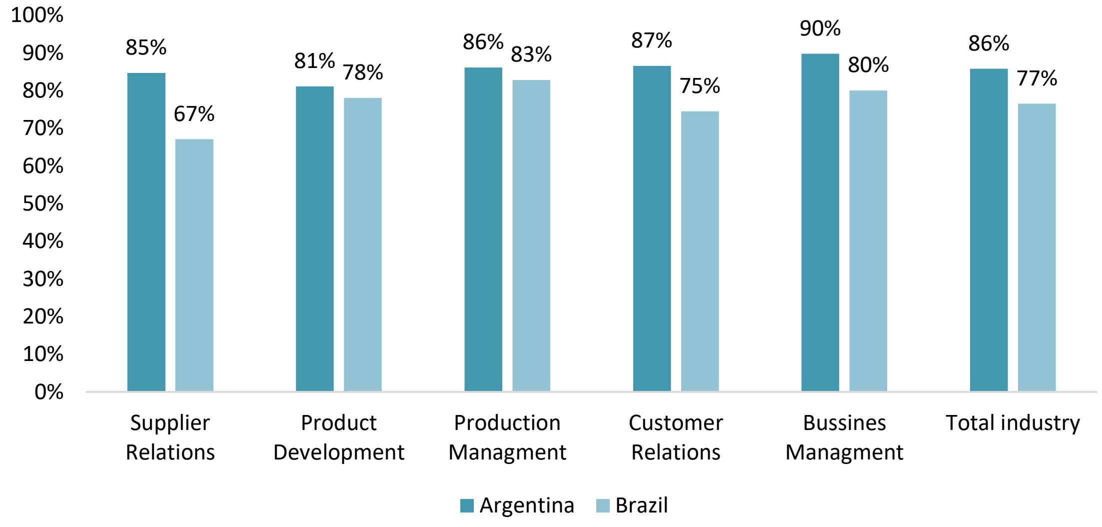
Figure 2: Current adoption of 3.0 and 4.0 technologies in Argentina and Brazil



Source: Ferraz, Kupfer, Torracca, & Britto (2019) and Albrieu et al. (2019)

It follows that both countries primarily use G1 and G2 technologies but, consistent with the higher technology adoption rate in Brazil, the percentage of firms lagging behind in terms of technology is lower than in Argentina. Figure 3 shows that while 86 per cent of Argentine firms, on average, use old technologies, this percentage drops to 78 per cent in Brazil3. The figure also reveals that technology adoption is more heterogeneous in Brazil. While the use of 1.0 and 2.0 technologies ranges from 81 per cent (product development) to 90 per cent (business management) in Argentina, it ranges from 67 per cent (supplier relations) to 83 per cent (production management) in Brazil. This suggests that, unlike in Argentine firms, some business activities in Brazilian firms have a high level of readiness for technological change.

Figure 3: Current adoption of 1.0 and 2.0 technologies in Argentina and Brazil.

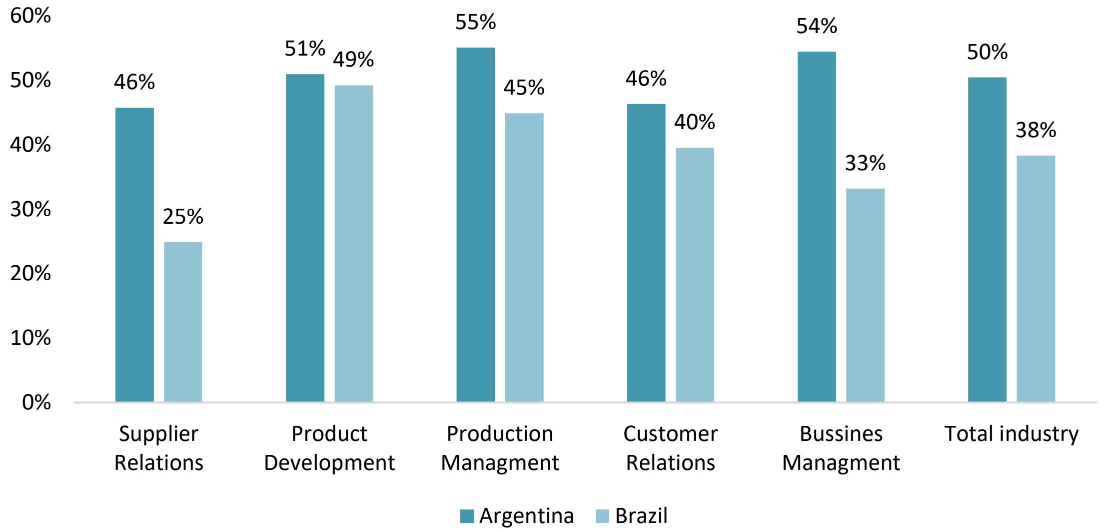


Source: Ferraz, Kupfer, Torracca & Britto (2019) and Albrieu et al. (2019)

As regards the future of technological development, the firms in both Argentina and Brazil expect to bridge their technological gaps. The percentage of firms that expect to use 3.0 and 4.0 technologies in the next decade is twice the number of firms that are currently using them for all business functions in both Argentina and Brazil. Figure 4 shows that the expected use of 1.0 and 2.0 technologies drops significantly.

[3] It is worth noting the percentages in the Brazilian survey were computed without taking "Don't know" responses into account. Hence, for comparison purposes, the results of Argentina's survey presented in this paper were calculated accordingly.

Figure 4: Expected use of 1.0 and 2.0 technologies in the future



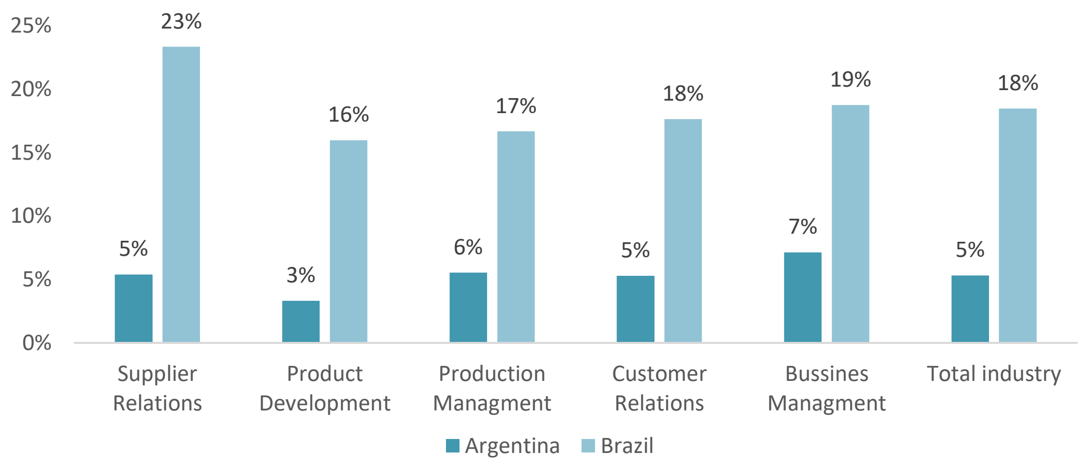
Source: Ferraz, Kupfer, Torracca, & Britto (2019) and Albrieu et al. (2019)

It is noteworthy that both countries expect to close their technological gaps to a similar degree. The percentage of firms using 1.0 and 2.0 technologies amounts to 86 per cent in Argentina and to 76 per cent in Brazil, but the percentage that expects to keep using these technologies in ten years drops to 50 per cent and 38 per cent, respectively. That is, in both countries, more than 1 out of 3 firms plan to cease using these outdated technologies in the future. Given that Argentina currently lags behind Brazil in terms of technological adoption, the use of 1.0 and 2.0 technologies would have to decrease at a greater rate in Argentine for the two countries' level of technology diffusion to converge. Still, Argentine expectations of reducing its technological gap are akin to those of Brazil.

The situation differs, nonetheless, when we consider the measures Brazilian and Argentine firms are currently pursuing to bridge their technological gap and to foster technology adoption. Figure 5 illustrates that the number of firms currently implementing formal plans to adopt higher technologies in Brazil is, on average, more than three times higher than in Argentina. The divergence is even larger in some business functions. For instance, Brazilian firms implement measures in supplier relations and product development more than four and five times, respectively, than is the case of firms in Argentina.

Despite the differences between the two countries, the number of firms currently adopting measures in the face of technological change is very low. This trend is particularly worrisome for Argentine companies, given their current technological lag.

Figure 5: Percentage of firms implementing formal plans to adopt new technologies in Argentina and Brazil



Source: Ferraz, Kupfer, Torracca & Britto (2019) and Albrieu et al. (2019)

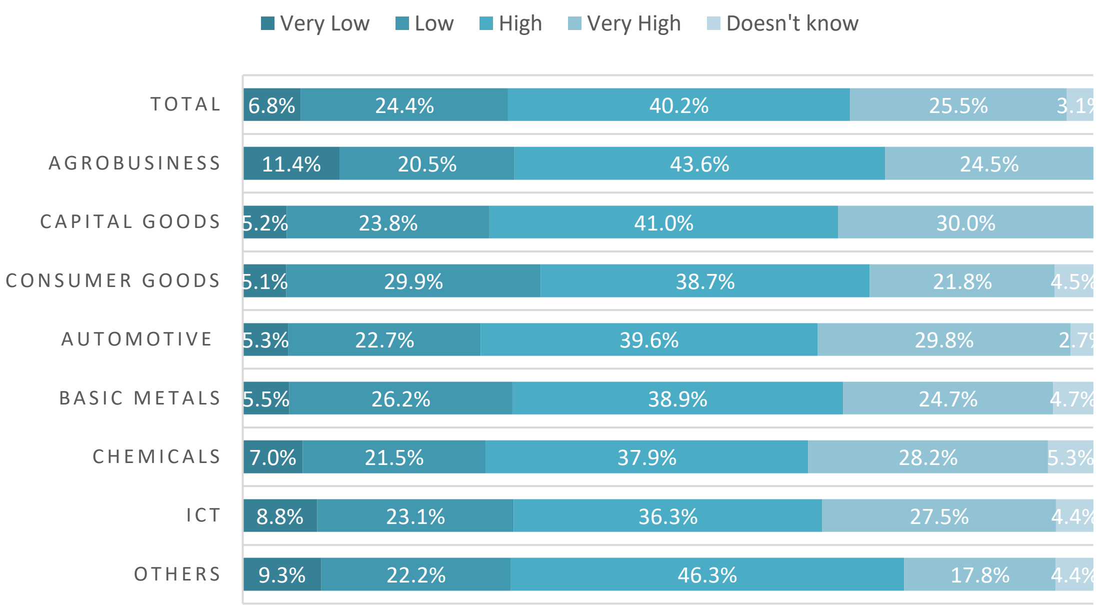
To sum up, four major findings emerge from the comparative analysis of Argentina and Brazil. First, 4.0 technologies only represent a marginal share in the production structures of both Argentine and Brazilian firms: around 4 per cent of all firms surveyed use G4 technologies for their business functions. Secondly, a vast majority of firms in both countries use outdated technologies: 86 per cent of Argentinean and 77 per cent of Brazilian firms use 1.0 and 2.0 technologies. Thirdly, firms that are currently implementing measures to adopt technologies are scarce: less than 23 per cent in Brazil and 7 per cent in Argentina are realizing formal plans of technology adoption for certain business function. Finally, yet importantly, Argentina lags behind Brazil not just in terms of current technology adoption but also in terms of measures being pursued to promote future adoption of new technologies. The number of firms that use outdated technologies is higher in Argentina and the number of companies implementing formal plans for 4.0 technology adoption is lower. Brazil's industrial sector is better prepared to embrace the fourth industrial revolution: a considerably higher percentage of its firms already use 3.0 and 4.0 technologies and the number of firms implementing measures to close their technological gap is, on average, three times that of firms in Argentina.

4.2. In-depth analysis of the Brazilian survey[4]

The Brazilian survey aimed at investigating the extent to which firms' structural and behavioural profiles affect the adoption of digital technologies. To arrive at results, an econometric exercise (ordered logistic regression model) was carried out to link firms' adoption of digital technologies to their structural (sector, size) and behavioural (capabilities and readiness level to prepare for the future) features.

A starting point for our analysis was how business executives perceive the future of their industrial sector. They were asked about the likelihood of G4 becoming the leading technology in their industry in the future based on four levels of probability: 1) very high, 2) high, 3) low and 4) very low. The executives' sectoral expectations for all five business functions are presented in Figure 6. It shows that the majority of respondents (around 65 per cent) stated that the likelihood of 4G technologies taking the lead in their industries is high or very high. Some differences emerge depending on the industry: executives in the agro- and in the automotive industries tend to project a higher level of diffusion of G4 technologies compared to executives in consumer goods industries.

Figure 6: Likelihood of 4G technologies becoming the leading technology in the firm's industrial sector (in all functions) – Total for industry and production systems (in % of respondents). N=711



Source: Ferraz, Kupfer, Torracca & Britto (2019)

[4] This section is based on Chapter 2 of the report *Industry 2027: risks and opportunities for Brazil in the face of disruptive innovations* (IEL, 2018) and on Ferraz, Kupfer, Torracca & Britto (2019).

When the focus is placed on the individual firm in Brazil (see Table 2), we find that advanced digitalization is currently very low in all business functions. With regard to the future, the respondents' expectations of the level of diffusion of digital technologies are very positive, especially for external relations (with suppliers and clients). This implies that firms are more interested in the digitalization of value chains than is reflected by their internal efforts – which would require a more complex set of decisions, capabilities and measures, not only investments in internal organizational functions which firms would naturally have more influence over.

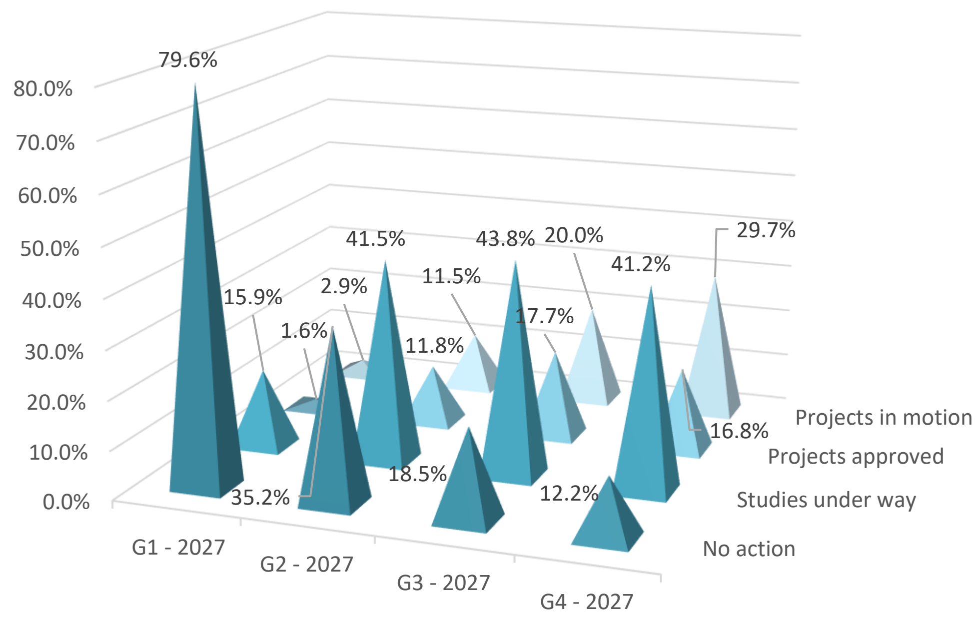
Table 2: Brazil: distribution of firms by generations of DT and business functions2017 and 2027

Business Function	2017				2027			
	G1	G2	G3	G4	G1	G2	G3	G4
Relations with Suppliers	40,9%	26,2%	31,2%	1,7%	11,1%	13,8%	38,1%	37,0%
Product Development	49,8%	28,3%	19,7%	2,3%	23,9%	25,3%	28,6%	22,2%
Process Management	40,4%	42,5%	16,2%	1,0%	14,6%	30,2%	38,3%	16,9%
Relations with Clients	43,2%	31,4%	24,8%	0,7%	13,8%	25,7%	37,0%	23,5%
Business Management	13,2%	66,8%	19,4%	0,6%	5,6%	27,6%	45,3%	21,5%

Source: Ferraz, Kupfer, Torracca & Britto (2019)

Figure 7 illustrates the extent to which future expectations are grounded in current measures, an indication of the readiness level of firms to build their future. The majority of firms that expected that they would continue using either G1 or G2 technologies in the future have not introduced any measures, a sign that they have not been engaged in any transformation over the years. Those firms expecting to use either G3 or G4 technologies in the future are slightly more proactive: a group of firms (just below 40 per cent) are either planning or have already implemented measures to achieve their future objectives. In short, there seems to be a correlation between a firm's projected level of digitalization and its level of readiness: the higher the expected level of future digitalization, the higher the firm's level of readiness and vice versa.

Figure 7: Digital technology generation in the future *vs.* measures currently underway to achieve it (in % of respondents). N =711



Source: Ferraz, Kupfer, Torracca & Britto (2019)

Because of a greater dispersion of responses, consistency tests (regression analyses) were conducted to determine whether the differences among the firms can be explained by their structural or behavioural characteristics. The analysis in IEL (2018) and Ferraz et al. (2019) reveal that larger companies can mobilize the necessary resources (financial and others) required for investments in digitalization with relatively greater ease. Similarly, firms in industries with a technological foundation that have already incorporated the digital paradigm are also likely to move more swiftly towards modernization. Firms of other sizes and industries can also, of course, move forward. Modernization strategies focused on specific activities, such as external relations, with the aim of strengthening linkages with suppliers or customers, or internal relations, with the aim of developing products or managing digital technology-intensive processes, are suitable for smaller companies or for those engaged in lower technology industries.

In addition, firms' behavioural characteristics seem to be equally or even more relevant in explaining advanced digitalization. That is, investments in capacity-building and a proactive attitude to prepare for the future explains the differences between firms' push towards modernization to a great extent. The Brazilian survey shows that: (i) firms with lower capability and readiness levels also currently have lower levels of digitalization and expect these to remain lower in the future; such firms are and may continue to lag behind in the future compared to their peers; (ii) by contrast, firms with higher competences and readiness levels are and intend to evolve more rapidly in all of their business activities; these firms are forging ahead in their push towards modernization, regardless of their sector of origin and firm size; (iii) even if structural features have a lower explanatory power relative to firms' behavioural features, the ICT, consumer goods and automotive firms are more likely to engage in a push towards modernization compared to firms from other industrial sectors.

4.3. In-depth analysis of the Argentine survey

The survey in Argentina yielded four key results on both the current and expected state of technology adoption. First, the study revealed that there is hardly any diffusion of 4.0 technologies. Only 27 out of 293 surveyed firms (less than 10 per cent) use such technologies in at least one business function. Of those, nine use G4 technologies in two or three business functions and no firm uses such technologies in more than three business functions. In fact, there is no evidence of firm that exclusively use 4.0 technologies in Argentina's manufacturing industry.

Secondly, only a small group of firms are close to the technological frontier, with the majority of firms lagging behind. When we look at the current rate of technology adoption, the study finds that over 80 per cent of Argentine companies use 1.0 and 2.0 technologies: 40 per cent use 1.0 and 40 per cent use 2.0 technologies.

Some heterogeneity exists across business functions, but it is largely insignificant. The percentage of firms using outdated technologies ranges from 84 per cent to 89 per cent, with the exception of product development. Only 70 per cent of firms engaged in product development use 1.0 or 2.0 technologies, but this might be related to the fact that a larger share of firms did not know what type of technologies they were using. Interpreting "Don't know" answers is difficult. Another possible interpretation is that it reflects the lack of knowledge about technology alternatives and as such is a sign of technological backwardness. In that case, even though the percentage of companies using 1.0 and 2.0 technologies is lower in product development, the fact that 14 per cent of firms do not even know which technology they are using speaks for the technological backwardness in this business function.

The study yielded a third result on the expected technology adoption. The general expectation is that the technology gap will shrink significantly over the next decade. Firms expect to substantially increase their use of 3.0 and 4.0 technologies. While only 14 per cent of the firms use these technologies, as much as 44 per cent expect to use them in ten years. This anticipated increase is of course remarkable, but not sufficient to ensure that new technologies will prevail.

The situation differs across business functions, especially between internal activities–business management, production management and product development– and external activities (customer and supplier relations). Firms expect increased use of new technologies in external business functions, with around half of the firms expecting to use 3.0 and 4.0 technologies in the next decade.

Hence, although Argentina's manufacturing industry is currently lagging behind the technological frontier, its firms are optimistic about closing the technology gap in the next ten years. What are Argentine firms doing to close this gap? A fourth conclusion based on the survey results is the prevailing inaction of Argentine firms when it comes to promoting technological development. Over 60 per cent of the firms are not taking any measures at all to encourage technology adoption. This poses a tremendous challenge as technological change can only take place if a strategy is in place to foster technology adoption. The survey shows that only 5 per cent of Argentine firms are currently taking concrete measures to promote technology adoption, while another 25 per cent is exploring measures they can take.

In sum, the survey of Argentine firms identified four stylized facts about the country's manufacturing industry: 1) Only a small group of firms uses 4.0 technologies; 2) Most firms lag behind the technological frontier; 3) There is a general expectation that the technology gap will be substantially reduced; and 4) The majority of firms are not taking any measures to promote technology adoption. We arrive at these four conclusions by looking at two aspects: i) which technological generation they are currently using for each of the business functions, and ii) their expectation in terms of closing their technology gap and what measures they are taking to achieve this.

To better understand Argentina's business environment and its relationship with new technologies, the firms are classified into three groups based on two indexes. The first index, the 'adoption index', measures the current level of technology adoption. The second index, the 'dynamism index', measures how dynamic a firm is. A firm is considered dynamic because it not only expects to close its technology gap but also because it is taking concrete measures to achieve this. Argentina's manufacturing industry consists of three broad groups that are comparable in terms of their characteristics based on a concept proposed by Abramovitz (1986): forging ahead, catching up and lagging behind.

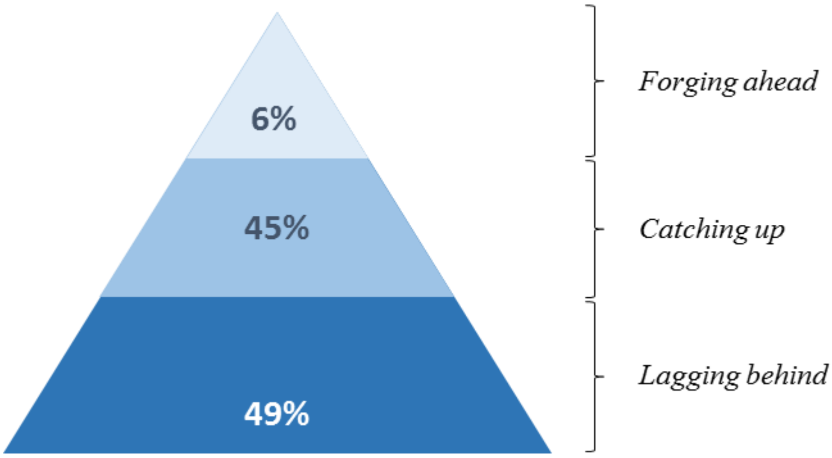
Although there are no firms that exclusively use 4.0 technologies, a small group of firms is technologically developed, using mostly 3.0 technologies and even some 4.0 technologies in certain business activities. These firms represent Group 1 or the group of firms that is *forging ahead.*

A second group of companies that uses 2.0 and 3.0 technologies can also be identified. This group also includes firms that despite not being as technologically advanced are taking concrete measures to catch up with the technology frontier. These firms represent Group 2 or the group of firms that is *catching up.*

The final group of firms lags even further behind in terms of technology adoption and is not taking any measures to change this situation. These firms represent Group 3, the group of firms that is *lagging behind.*

Based on this classification, the Argentine manufacturing industry can be characterized as a pyramid (see **Error! Reference source not found.**). The base of the pyramid is comprised of firms that are lagging behind the technology frontier and represent nearly half of the firms in the industry.

Figure 8: Composition of Argentine manufacturing industry by group of firms



Source: Albrieu et al. (2019)

Most of these firms are micro and small enterprises in the (non-tradable) food processing industry and invest very little, especially in activities related to their technological development, like R&D, fixed capital or hiring service companies specialized in digital technologies. When asked about the obstacles they face in the adoption of technology, apart from funding, they mention obstacles within their own firms, such as lack of knowledge about new technologies or even the firm's business culture.

At the top of the pyramid is a small group (around 6 per cent) of technologically developed firms that are taking action to forge ahead and converge with the technology frontier. The vast majority are medium or large companies that engage in trade with the rest of the world and invest a large amount in their technological development, by, for instance, hiring service companies specialized in digital technologies. Although funding was pointed out as being a major obstacle, the most pressing issue seems to be the lack of adequate digital infrastructure.

A large group (around 45 per cent) of firms with an intermediate level of technological development, which is taking measures to catch up, lies between these two groups. It consists of small and medium sized companies (non-tradable), though the share of firms that trades with the rest of the world is bigger than in Group 3. Many belong to the basic inputs industry. Apart from investing more in R&D and fixed capital than the firms that are lag behind, they invest the most in human resources and skills acquisition to master the new technologies. This is consistent with their statement that apart from being particularly affected by the lack of funding for new technologies, they identify the lack of human resources capable of using such technologies as being the main obstacle to technological development.

Classifying the firms is useful not only to identify their challenges and opportunities but also to expose the true challenges of Argentina's manufacturing industry: inverting the pyramid.

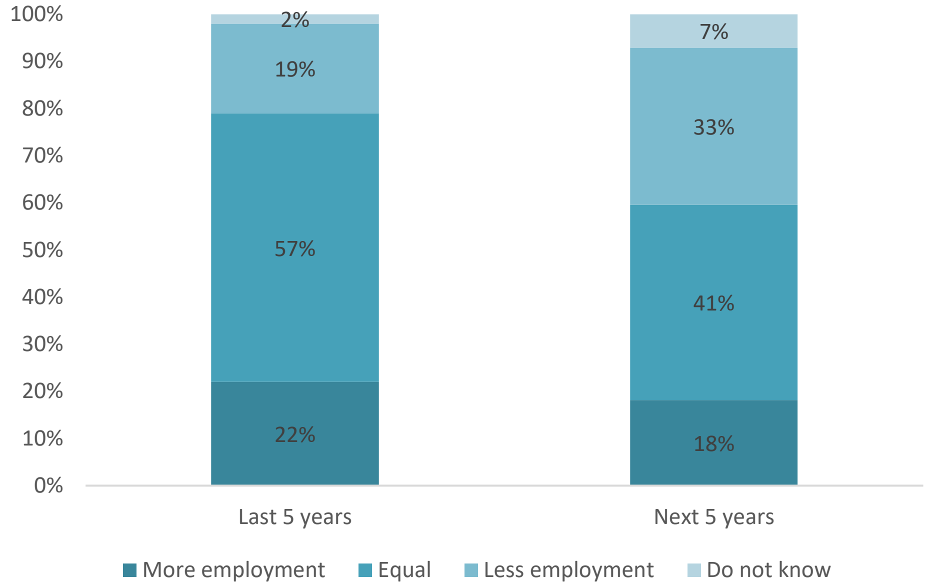
4.4. Digital skills in Argentina

This section explores the impact of technological change in labour and in the skills requirements of workers in Argentina's manufacturing industry. Which skills are and will be required by companies in the face of the Fourth Industrial Revolution? To what extent will firms demand knowledge and experiences in the use of digital technologies? Is the impact of automation on employment inevitable? What is the role public policies play in promoting an inclusive transition towards automation in Argentina's manufacturing industry?

4.4.1 Jobs—does automation destroy or create jobs?

In the last five years, technological change has created and destroyed jobs (Figure 9). While 19 per cent of firms state that they have decreased staff due to automation, 22 per cent claim they have increased their staff. The majority of firms (57 per cent) assert that automation had no impact at all on their workforce. This could be related to the slow pace of technological transformation in Argentina.

Figure 9: Percentage of firms in which automation has affected employment (last 5 and next 5 years)



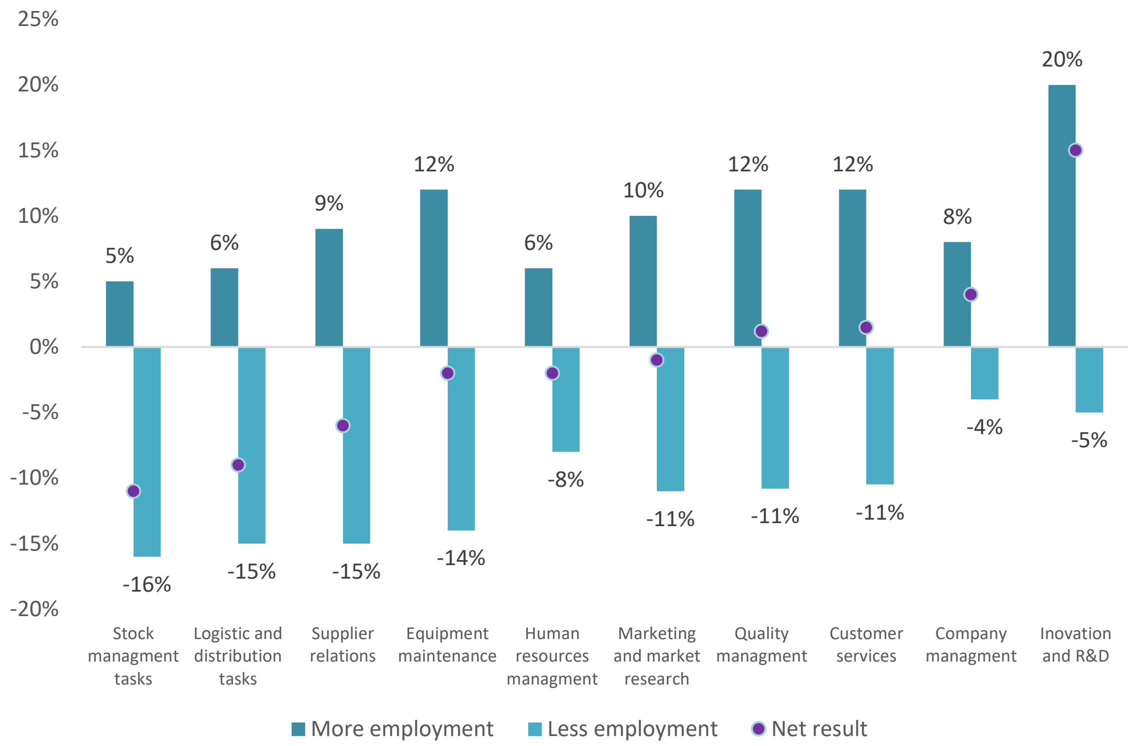
Source: Albrieu et al. (2019)

In the next five years, this trend could, however, be reversed. The percentage of firms expecting no changes to their workforce decreases to 41 per cent, while 33 per cent expect that they will reduce their staff while only 18 per cent expect to increase it. The expected acceleration in the pace of technological adoption would be consistent with the perception of less stability and more negative expectations about the effects of automation on employment.

Small companies are more pessimistic about the future, especially in the food processing and textile industries, where the percentage of companies that expect a reduction in their workforce is nearly 40 per cent and 50 per cent, respectively. By contrast, exporting companies have significantly more optimistic expectations about the future, especially in agricultural machinery, where half of the companies anticipate that automation will increase employment.

In the last five-year period, automation has mostly affected routine and repetitive tasks with low cognitive content, including management of stocks and logistics, distribution, supplier relations and maintenance of equipment. The number of firms engaged in such activities reduced more staff than the number of firms that increased their staff (Figure 10).

Figure 10: Percentage of firms in which automation has created or destroyed jobs (last 5 years)

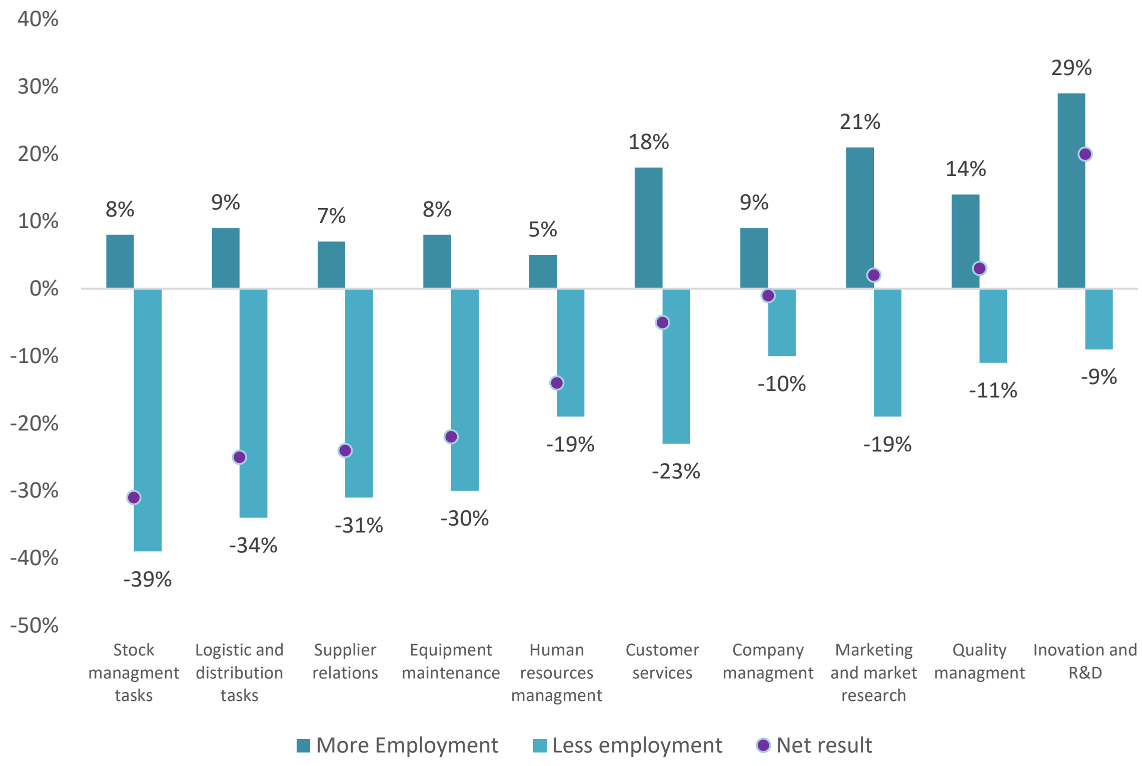


Source: Albrieu et al. (2019)

By contrast, in firms that engage in activities with higher cognitive and relational content or in which social capital plays a more important role, the impact of automation on employment was neutral or in some cases even positive. For instance, 20 per cent of firms engaged in innovation and R&D increased their staff, while only 5 per cent of firms involved in the same field reduced their staff. Automation also had a positive effect on employment in firms engaged in business management and customer relations.

In the near future (next five years), firms expect that this situation will deteriorate, with an increasing number of companies engaged in stock management, logistics and distribution, supplier relations, equipment maintenance and human resources management expecting to further reduce their staff in contrast to a minority of around 5 per cent to 9 per cent of firms that expect to increase their staff (Figure 11).

Figure 11: Percentage of firms in which automation will create or destroy jobs (next 5 years)



Source: Albrieu et al. (2019)

It is noteworthy that one-third of companies expect to increase employment in innovation and R&D whereas only 9 per cent expect to reduce it. These positive expectations are replicated both in small and large firms, exporting and non-exporting and across sectors. This suggests that there is in fact a common objective in the manufacturing industry of moving towards knowledge-based activities and of fostering the internal development of capabilities and technologies.

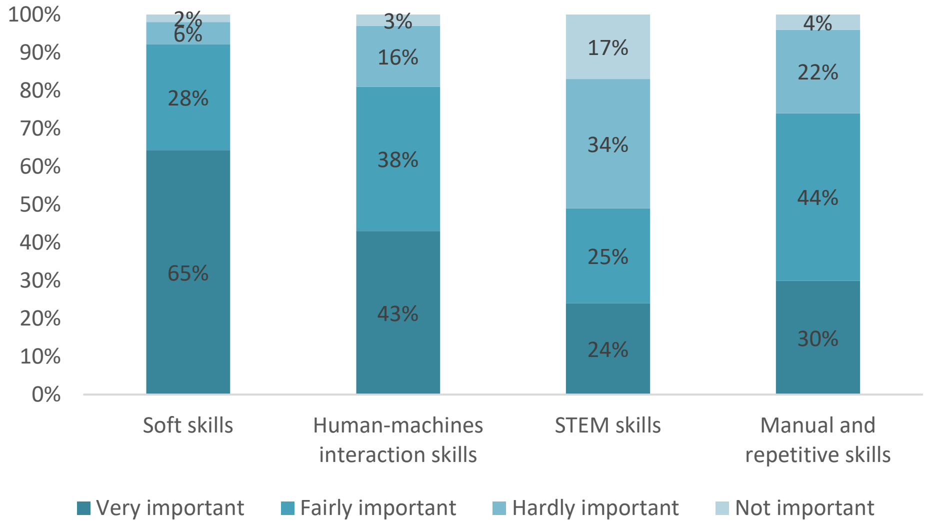
Optimism is more widespread in quality assurance, marketing and market research, though only among exporting companies. It is not surprising that these tasks are especially relevant for exporting companies, which have more incentives to enhance and adjust their products and services to different markets and different quality standards.

4.4.2 Skills—soft skills at the top

The number of companies stating that they have prioritized soft skills such as teamwork, communication, flexibility, etc. when hiring workers over the last two years is noteworthy: 65 per cent of firms assert that soft skills are very important and 93 per cent state that soft skills are relatively important or important when hiring employees (Figure 12).

The significance of soft skills in the Argentine manufacturing industry, even at the expense of technical skills, is compatible with the findings from other surveys around the world and with the increasing evidence of the importance of such skills in the future (Deloitte, 2018b; LinkedIn, 2016; Sarkar, 2018). Why are these skills more important for 4.0 technologies than for previous technologies? Daugherty & Wilson (2018) shed some light on the changing nature of skills that are relevant in the era of 4.0 technologies. The ability of humans to lead, to empathize, to create and to judge is key for engaging in the new division of tasks in the production process.

Figure 12: Distribution of importance given by firms to different types of skills (last 2 years)[5]



Source: Albrieu et al. (2019)

In line with Daugherty & Wilson (2018), companies in Argentina have also highlighted the importance of skills related to human-computer interaction, that is, skills related to development, training, use and the management of technological systems: over the last two years, 43 per cent assert that such skills have been very important and 81 per cent state that they have been relatively important or important in their decision to hire workers.

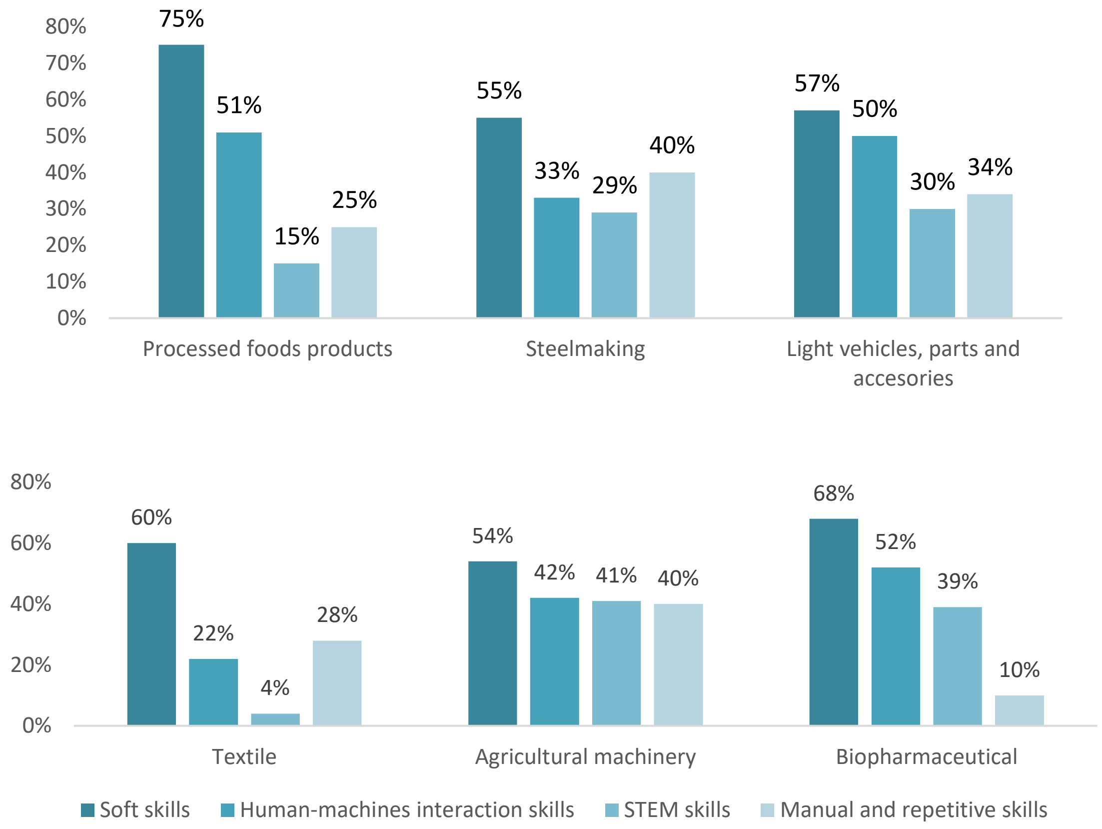
4.4.3 Towards less repetitive skills

Interestingly, STEM skills have had no relevance in the last two years. Only 24 per cent of companies claim that such skills have been very important in the hiring process and less than half

[5] Results do not take into account "Don't know" responses.

consider them to be important or relatively important. Demand for STEM skills has been especially low in the textile and food processing industries, as shown in Figure 13.

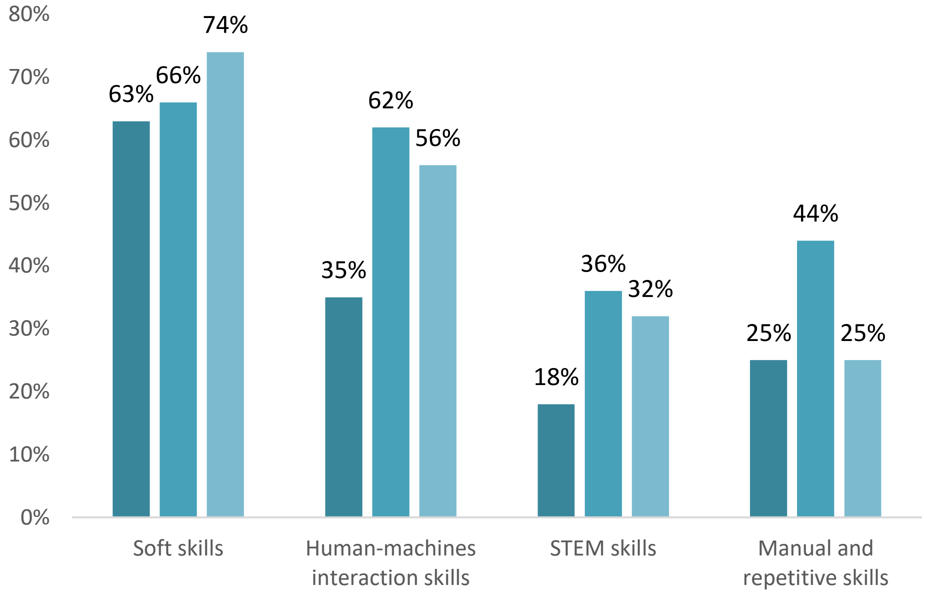
Figure 13: Demand for skills by industry (last two years, % of 'very important' responses)



Source: Albrieu et al. (2019)

What about firm size? Although soft skills are very important for all firms, they are particularly important for large firms (Figure 4). Human-machine interaction and STEM skills are less significant for SMEs, and this divergence will continue in the near future: while STEM skills will play a very important role for 54 per cent of large firms, this share drops to 42 per cent for SMEs (not shown in the figure).

Figure 14: Demand for skills by firm size (last two years, % of 'very important' responses)

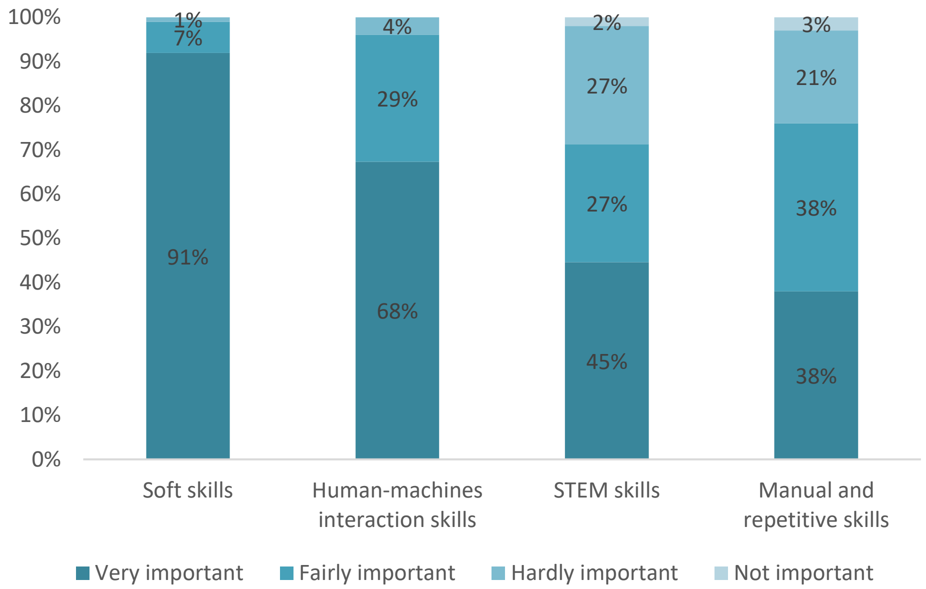


Source: Albrieu et al. (2019)

Skills required for manual or repetitive tasks have been more relevant than STEM, which is consistent with a technological underdeveloped industry that uses mechanical technologies, which are scarcely automated. Nonetheless, as technology adoption increases, work tends to shift to less routine and repetitive tasks and activities that involve human interaction, the usage of new technologies or STEM knowledge increase in relevance.

As regards expected skill demand in the next five years, 99 per cent of respondents claim that soft skills will be relatively important or important and 91 per cent state that they will be very important (**Error! Reference source not found.**). Similarly, 68 per cent believe that skills related to human-computer interaction will be very important while 96 per cent state they will be relatively important or important in the future. In other words, almost all companies agree that these skills will play an important role in the near future.

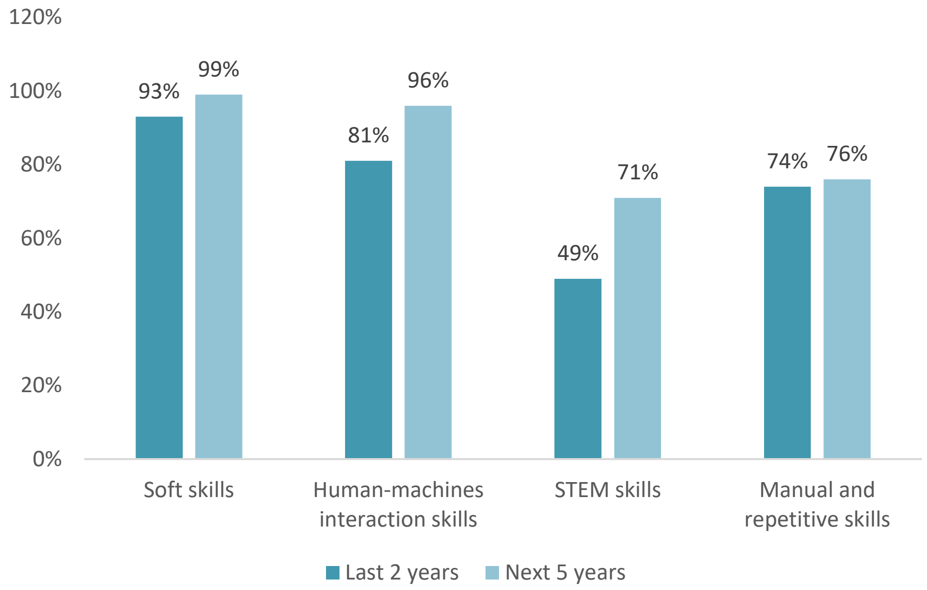
Figure 15: Expected importance of different skill types in the next 5 years



Source: Albrieu et al. (2019)

When the current and expected importance of skills is considered, repetitive skills are expected to lose in relative importance compared to other types of skills. On the contrary, as technological adoption increases, so does the relative importance of STEM skills. **Error! Reference source not found.** shows an expected increase of 22 per cent from the last two years to the next five years among firms that consider such skills to be 'very important'. STEM skills are expected to become the most relevant skills set in the near future.

Figure 16: Percentage of responses "relatively important" and "important" (last two years and next five)[6]



Source: Albrieu et al. (2019)

Another factor that seems to affect STEM skills demand is tradability. Six out of ten exporting firms expect that STEM skills will become very important in the next five years, whereas only 37 per cent of non-exporting firms agree. This difference could be explained by the existence of high-quality standards in international markets, which makes companies adjust their products accordingly.

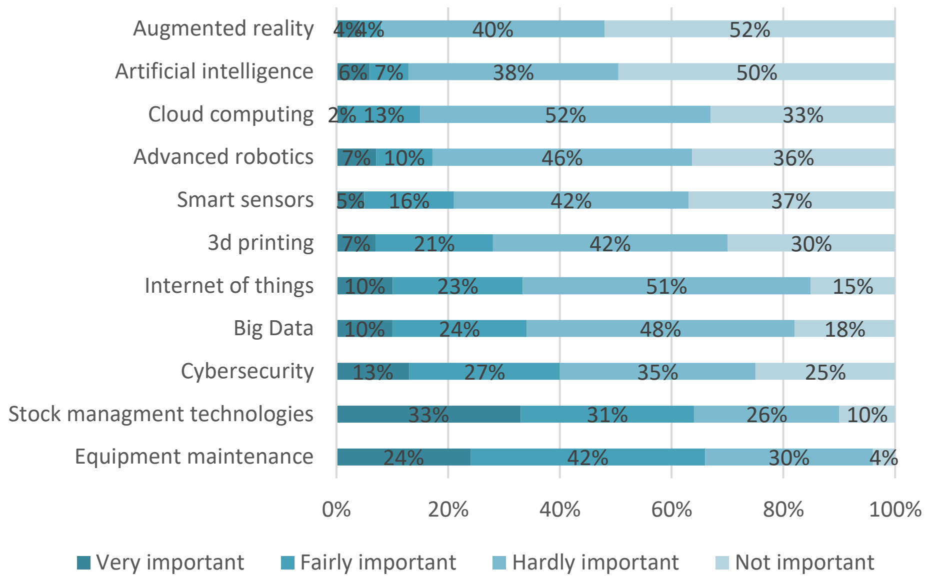
Both repetitive and routine skills as well as STEM skills continue to be relegated in the near future compared to soft skills and the capability to use new technologies, which are less likely to be automated.

4.4.4 IT skills

Another part of the survey analysed the importance of skills related to the interaction between people and 4.0 technologies. The technological lag in the industry goes hand-in-hand with a low demand for skills related to new technologies. Figure 17 shows that the bulk of companies surveyed gave little or no importance at all to the use of 4.0 technologies in the preceding two years.

[6]Results do not take into account "Don't know" responses.

Figure 17: How important has the use of different technologies been in the hiring process over the last two years?



Source: Albrieu et al. (2019)

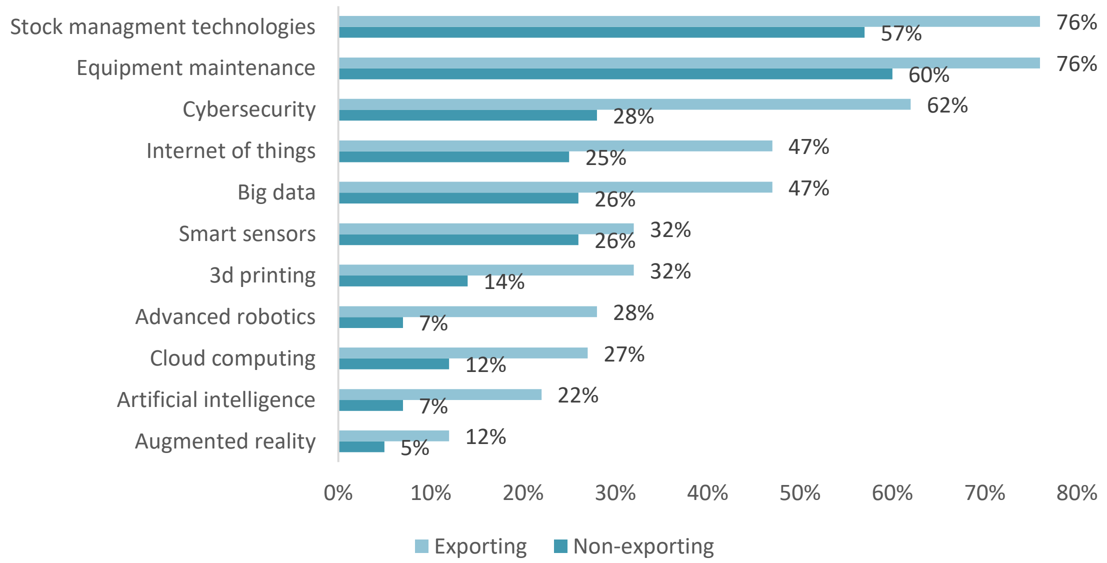
More specifically, only between 10 per cent and 15 per cent of firms considered the use of technologies such as cloud computing, augmented reality or artificial intelligence to be important or relatively important in the last two years. Other 4.0 technologies with a more immediate and evident application in industrial processes, such as internet of things, big data, 3D printing, intelligent sensors or cybersecurity, are regarded as being more important. Still, less than 15 per cent of firms deemed them to be very important.

The only technologies that have been widely regarded as important or relatively important are machine maintenance and technologies for stock management. These technologies are more easily applied to traditional industrial processes and unlike artificial intelligence, augmented reality or cloud computing, do not require large-scale digital transformation, both in industrial processes and businesses, to make them profitable.

Heterogeneity also exists across sectors and firm sizes. Light vehicles, parts and accessories and steelmaking generally have a higher demand for skills in new technologies, especially in 3D printing, advanced robotics and artificial intelligence, whereas demand for such skills is lower in the textile or food processing industries. While skills associated with predictive maintenance and stock management are relevant for all firms, more complex skills such as those related to artificial intelligence solutions or advanced robotics are not particularly important for SMES.

Furthermore, exporting firms assign more importance to knowledge about new technologies than non-exporting ones. This is compatible with the existing correlation between technology adoption and tradability (De Negri et al., 2007; Hahn & Park, 2012; Lin & Tang, 2013; Mairesse, Mohnen, Zhao & Zhen, 2012; Sharma, 2017). As Figure 18 illustrates, the difference between exporting and non-exporting firms is considerable for cloud computing, internet of things, big data and cybersecurity.

Figure 18: Percentage of exporting and non-exporting firms that consider technologies to be "Very important" or "Relatively important" (last two years)

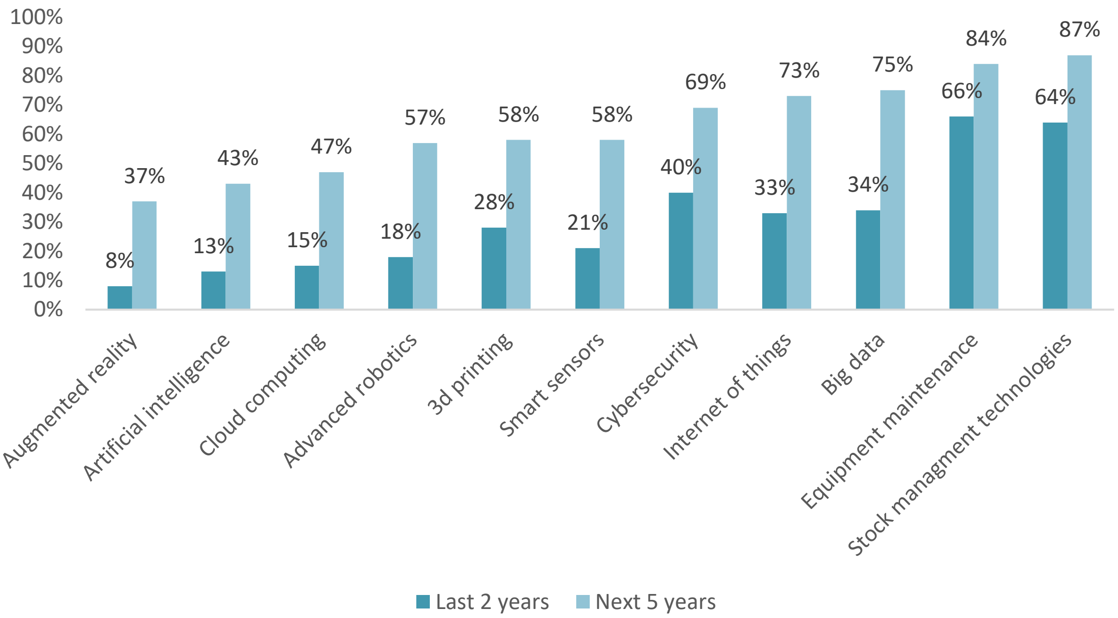


Source: Albrieu et al. (2019)

More strikingly, while 62 per cent of exporting firms consider cybersecurity to be important, only 28 per cent of non-exporting companies do. This difference might relate to the fact that exporting firms need to deal with a huge amount of information and follow data privacy regulations.

The results also show that skills demand will shift towards abilities to use new technologies. Figure 19 demonstrates that the importance given to such skills is expected to increase dramatically in the next five years compared to the last two years, especially with regard to big data, advanced robotics, internet of things and smart sensors.

Figure 19: Percentage of firms that consider technologies to be “Very important” or “Relatively important” (last 2 years and next 5 years)



Source: Albrieu et al. (2019)

Frontier technologies like augmented reality or artificial intelligence will also become more relevant in the next five years, especially for exporting firms. In fact, 58 per cent of them claim that skills associated with artificial intelligence will be very or relatively important, while only one-third of non-exporting firms believe the same. Likewise, 53 per cent of exporting companies state that augmented reality will become important in the near future, while only 28 per cent of non-exporting firms agree with this statement. Nonetheless, it is remarkable that skills related to equipment maintenance and stock and logistics management will continue to be the most relevant in the next five years: 8 out 10 firms state that such skills will be very or relatively important.

These findings suggest that demand for digital technologies-related skills will increase dramatically in the short run, which in turn reinforces the need to develop a labour force capable of using these new technologies. Failure to do so only implies more obstacles in the long and winding road towards technological change.

5. Windows of opportunity and policy implications

5.1. Windows of opportunity

An acceleration of the modernization process entails challenges, risks and opportunities for the manufacturing sector of developing countries, especially as the international technological frontier is currently fundamentally transforming. Brazil and Argentina cannot simply wait for the risks associated with the development and dissemination of new technologies to pass, nor rely on the islands of modernity to build up the archipelago. Not keeping pace with the international technological frontier may obliterate part of the local production and create obstacles to a productivity leap crucial for remaining competitive and continuing to grow. Ongoing changes in the technology landscape opens up windows of opportunity that must be explored.

Digital technologies provide opportunities to introduce new processes, resulting in efficiency gains and increasing the capacity to offer new goods and services and provide opportunities for business expansion and catching-up with international competitors. Demand for digital technologies is more likely to occur: (i) where technological progress within the activity demands investments in complementary technologies, such as specialized and advanced knowledge activities (aerospace & defence, pharmaceuticals); (ii) where investment in digital technologies to total investment ratio is low, as is the case of most producers of intermediate, process-intensive goods; (iii) where demand-driven markets are expanding and the propensity to invest is positive, for example in industries such as agricultural machinery and equipment for renewable energy; and (iv) in market niches associated with high knowledge-intensive services for growing markets such as agritechs and fintechs.

It is also important to consider the impact of digital-based technologies in the context of integration of these countries into global production flows, particularly in the light of a geographical position that does not seem particularly favourable. Despite the heterogeneity of Brazil and Argentina’s innovation ecosystems, disruptive technologies offer their industries opportunities to improve their integration in global value chains (GVCs), thereby strengthening and recovering their positions on the world map of industrial production. The initiatives of local companies to exploit new business opportunities afforded by GVCs should be flexible to ensure that they are not pushed out of the market or are taken over by competitors. This requires firms to have the ability to harness their own resources and develop alliances with other companies and institutions with complementary skills to address the risks and costs of innovation. Some local producers have consolidated competitive positions in upstream links of GVCs—such as in the production of basic inputs, in agricultural commodities and agroindustry products—and disruptive innovations can increase the competitive advantages of those producers in the global market, in a context in which efficiency and environmental sustainability have gained importance as factors of competitiveness. The ecosystems linked to the activities of these producers can evolve with the new technological frontier set by disruptive technologies and preserve the competitive position of local firms in these GVCs.

At the same time, the integration of local firms in manufacturing activities that reflect the downstream links in GVCs tend to be more heterogeneous, with some manufacturers enjoying solid positions in some niches, while in others, they have faced a loss of competitiveness against China and other Asian countries. In this context, new technologies tend to relativize the advantages of cheap labour and of scale, which sustain competitiveness, as they intensify the automation and customization potential of products. On the other hand, they intensify the use of capital, which might be costly, and require capacity to use digital technologies as well as the adoption of organizational innovations and new business models. Notwithstanding these challenges, achieving productivity gains, developing innovative products and taking advantage of opportunities derived from customization needs could open up exciting opportunities to recover positions in global production flows.

One main challenge for less competitive manufacturing segments in Brazil and Argentina is to overcome the limits of a very lagged and unequal dissemination of new technologies among enterprises. With extremely unequal capacities and competencies to move towards a new generation of technologies, large capital goods enterprises and foreign or domestic subsidiaries coexist with small and medium-sized technology-based companies and with less sophisticated manufacturers. Thus, gaining and even maintaining market positions depends on the scope of and speed at which new technologies are acquired and absorbed by companies other than those belonging to the group of leading companies, so that productivity gains can spread more broadly among manufacturers at large. As a matter of fact, this is a common challenge many countries face in their efforts to strengthen the engineering and R&D capacity of their small and medium enterprises (SMEs).

5.2. Policy implications

Industry 4.0 has not yet arrived in Brazil and Argentina. This is one of the main findings of this article, which reflects the existence of a high percentage of firms in the manufacturing sector that are lagging behind technologically as well as a high share of firms that remain idle, not taking any concrete measures to close their technology gap. The comparative analysis reveals that 4G technologies are scarce in both countries. Manufacturing industries in Argentina and Brazil consist primarily of firms that use older digital technology generations. Very few corporations are taking actions to overcome this situation, though Brazilian companies seem to be relatively more dynamic in terms of both G3 and G4 technologies.

Our analysis suggests that Brazilian and Argentine firms face multiple and diverse challenges. It was possible to identify common opportunities and challenges in both case studies among firms organized in three different groups. The first group consists of firms that are "forging ahead", i.e. firms that are closest to the technological frontier. At the other extreme are firms with lower levels of digitalization and readiness, namely firms that are "lagging behind". Finally, between these two groups lies a group of firms with a lower level of technology adoption than that of firms that are forging ahead, but that are currently taking concrete measures to bridge their technology gap. These firms are "catching up". What distinguishes firms from one another is their level of competence and readiness; firms that have accumulated technological capabilities that correspond to digital solutions and are preparing for the future may be better placed to reap benefits from emerging technologies.

Notwithstanding the risks and opportunities individual firms are exposed to, Brazil and Argentina's manufacturing industries face a common challenge: to overcome a widespread technological gap. This is a subject matter for public policies.

To this end, proposals for a wide range of policies can be put forward. Putting aside operational details, digital-oriented policies should be based on three strategic principles.

Firstly, Industry 4.0 does in fact open windows of opportunities for the manufacturing industry. The digitalization of business functions could spur a high increase in the manufacturing sector's productivity with potential spillovers for the entire economy. However, technological adoption is a necessary albeit not sufficient condition to increase productivity and economic growth. To exploit this opportunity, other conditions must be met as well.

Secondly, the model of passive technological transformation must be abandoned, where the diffusion of technologies is a by-product of inertia. This model leads to slow technological transformation driven by the replacement of obsolescent equipment and machinery. These inertial dynamics tend to widen the technological gap between and within companies and sectors. Moreover, these dynamics may lead to a transformation on the surface only, which would not allow an exploitation of the full benefits of Industry 4.0. This passive model may also imply a reduction in the number of firms, industries and value added of surviving firms.

Third, any policy should be designed in a segmented manner, as opposed to across the board or universal designs that are characteristic of many industrial policies. The stimuli and public goods required by the identified groups differ and should respond to their initial technological condition and investment plans. Moreover, as highlighted in the Brazilian study, firms' behavioural characteristics are particularly relevant for explaining advances in digitalization. Thus, it is of paramount importance to understand the obstacles the different firms face to invest in technology adoption. Accordingly, the Argentine survey sheds light on the challenges the different groups of firms face and paves the way for the design of a specific mix of measures for each group (forging ahead, catching up and lagging behind).

Strategies and policy interventions should be based on these principles and on the classification of companies by stage of technological development.

Policies for firms that are forging ahead should focus on removing barriers to sustain the pace of technology adoption. These firms require policies that reduce the cost of capital, improve their access to external financing sources and decrease the tax burden on capital formation. Industry 4.0 involves more capital-intensive techniques and capital goods that tend to depreciate faster with higher costs of maintenance. Marginal production costs will likely decrease, but fixed costs will tend to rise. That is why the cost of capital is perceived to be a key factor in accelerating the transformation process and gaining the upper hand in the market. These companies will also need better digital infrastructure. More specifically, they need a reliable electrical grid and communications network, the main inputs for database management.

Policies for firms that are catching up should focus on accelerating and deepening the transformation processes already taking place within the firms. These companies show potential but there is no guarantee that transformation will be successful without external support. These firms need to upgrade their supplier and customer relations and adopt a business model that is compatible with Industry 4.0. Several initiatives can be explored. For example, improvements in the management of production lines aimed at reducing down times and defects in manufacturing processes. 4G technologies can be applied to produce instruments to this end. The commercialization of operations are another source of opportunity for manufacturing firms. The digitalization of operations offers a huge pool of data to explore consumer wants and needs, optimize the supply of products and its logistic, increasing the firm's profitability.

Policies for firms that are catching up must go beyond the mere replacement of tools and machines. The renewal of production and marketing systems must be carried out in parallel with the revision of business models. Hence, successful policies should combine incentives to acquire new capital goods and to improve managerial capabilities. The direct involvement of top management is a necessary condition. Only with the involvement of business leaders will companies be able to keep pace with global technological progress, with the support of their productive and innovative ecosystems.

In addition, policies oriented towards improving human capital will be key since, apart from being the ones affected the most by the lack of funding, they identify the shortage of human of resources capable of using new technologies as the main obstacle to technological development. Hence, policies should strengthen entrepreneurial and technological capabilities to be able to manage more sophisticated production systems.

Finally, policies oriented towards the development of companies that are lagging behind will imply a complete redefinition of business models and an increase in management capabilities as a step that must precede the transformation of the production systems. The policy challenges are far more complex for this group of firms than for others because they are very far from the technological frontier. These companies use outdated technologies, far-removed from digital ones. Furthermore, when asked about the obstacles they face in adopting digital technologies (apart from funding), firms in this group mentioned obstacles within their own firms, such as lack of knowledge about new technologies or even the business culture.

It should, however, be highlighted that these firms own specific *know-how* that should not be dismissed. They have been able to do business in highly volatile economies. Moreover, they are part of supply chains that require a minimum quality and range of skills to participate at all. Hence, this could be a potential basis to transform their business models based on new technologies or, at least, it could serve to prevent a further widening of their technological gap relative to firms that are forging ahead and catching up.

The detailed analysis of Argentina's manufacturing industry reveals that technological gaps go hand-in-hand with both low demand and scarcity of skills in new technologies within a context in which technological change is not usually neutral in terms of skills demand (Acemoglu, 2002).

Instead, it tends to favour workers who have skills that complement the new technologies to the detriment of those who work in jobs that could be automated. Policies seeking to foster technological development should be coupled with education and training policies that are aimed at preparing the labour force for the new industrial revolution.

The survey conducted among Argentine firms shows that enhancing both socio-emotional and cognitive skills and other complex skills related to the use of new technologies is a necessary condition to successfully navigate the fourth Industrial Revolution. Flexibility and adaptability are also crucial, attributes that are only possible if expertise is acquired throughout life (lifelong learning) rather than during a specific phase or period of life only. The reskilling of current and future workers will be key for the promotion of high-quality jobs in the future. This represents a major challenge as it involves numerous learning stages, from early infancy to professional training. More specifically, a set of policies aimed at adapting the stock of skills must include the following:

- A comprehensive diagnosis about the state of knowledge and workers' skills.
- Early childhood learning: the brain structure is being established at that time and it is a key period for developing basic cognitive and socio-emotional skills.
- Higher quality of education: it is necessary to acquire better and more advanced skills and knowledge (IT skills formation is key).
- Adapt higher education to facilitate the transition to the labour market: learning mechanisms and professional training systems should be enhanced.
- Regularly update training systems within firms to cope with rapid technological change.

These policy guidelines represent a huge challenge for governments. Technological changes require an institutional transformation in the design, implementation and evaluation of policies. A sophisticated systemic approach and a complex degree of articulation are crucial. Designing policies for firms that are lagging behind technologically and that are financially vulnerable is certainly more challenging than for other firms. Moreover, being prepared for future shifts in skill demand poses a major challenge, considering the current stock of skills.

In the words of Abramovitz (1986): to make a difference, policy design, goals, objects and instruments must catch-up with ongoing changes and must even anticipate trends. This is certainly not a simple endeavour. To avoid lagging behind, the needs and challenges related to the economy must be addressed by policies focused on intensifying learning processes.

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