Industry 4.0 and the Global Digitalised Production. Structural Changes in Manufacturing

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Abstract. The globalization process and the new digitalized production have rapidly changed the structural organizational models of the major economies. To avoid the commoditization trap, globalization and price-advantage erosion, the manufacturing industries are moving from mass to customized production. They have servitized business operations, taking advantages of the new emerging and digitized technologies within the scenario of Industry 4.0 (I4.0). This paper recalls the most significant features of the scientific debate on this new industrial paradigm, and investigates the impact on the manufacturing sector, focusing on SMEs. It evaluates the effects on labour division, organizational models of production (agents-machines-organization), the "new" power structure, and the whole economy. It concentrates on the effects of technology on the labour market and organizational models with respect to SMEs and networks, and concludes that I4.0 could be an effective driving force for networking SMEs, despite a reduction of employees in manufacturing is likely to continue.

Keywords: Industry 4.0, servitization; globalization; labour division.

1 Introduction

In the last decades, the process of globalization and the digital transformation of the industrial production have rapidly changed economic systems all over the world, leading to a significant impact on life, the way people work and the functioning of markets. The socio-political context has deeply changed. The large increase on the extent of the market followed the pervasive process of globalization, the new technological opportunities offered by technical progress, and a more genuine attention to the environmental problems defined a new way of producing in the changing world.

Time after time, industries have experienced deep structural changes in the production organization, which affected all of them to some extent at various levels; services have been more incorporated into final outputs, and the most significant driver of change – across all industries – is the changing nature of work itself. The manufacturing industries are currently moving from mass production to customized one, acknowledging a strategic competitive advantage to the talent of providing individually designed products and services to every customer through high process flexibility and integration. We are facing a new "industrial revolution", the so-called Fourth Revolution (FIR), which involves at the same time a radical change in the economic strategies and in the social roots of the society.

The "smart" factory, on which the new paradigm is based, opens outward implementing new production models and exploiting sizes far superior to those known so far. The creation of a global supply chain allows sharing data, information and production systems not only within the single system but networking several organizations in real time, reducing operational costs and increasing productivity. In this new scenario, Industry 4.0 (I4.0) radically reshapes production and market models so far adopted, thanks to its flexibility in connecting worldwide via web not only machinery and plants but also products, workers and consumers.

Over the past two decades, the structural and technological change associated with the rapid progress in Information and Communication Technology (ICT) imposed a deep reconsideration of the theoretical foundations of production and exchange of the entire economic system. The increase in digitalization, the process of progressive globalization of value chains, and the arising interconnection of people and systems through the exchange of information in real time make the difference. It enforces to better define and evaluate the final effects on products, machines and procedures, and their capabilities to adapt them quickly to the new environment. Innovation, as the result of the integration of science and technology, is always more cross-sectoral, and has a simultaneous widespread effect on products, processes and methods to be used. It becomes to be much more invasive for economic operators, deeply changing the traditional relationship between producers and consumers.

Above all, two features of the FIR are still remarkable: the rapid technological change and the growth of inequalities. The final effects on the division of labour in terms of employment and wages caused by the rapid advances and the raised reliance on technology, the expected productivity increases, and cost reductions are still uncertain [1; 2]. In the near future, if industrial policies will not be supported by ad hoc interventions on the supply side of the economy (labour market), the gap between employment and productivity will increase, magnifying but not recomposing, social inequalities [3].

I4.0 identifies the FIR, namely the automation of manufacturing production and the change in the labour market based on the digitization of robotics and automation, using information technologies and intelligent production processes. Recently, the «Centre facilitant la recherche et l'innovation dans les organisations» (CEFRIO) has suggested a more comprehensive definition of I4.0, embracing a series of initiatives to improve processes, products and services that allow decentralized decisions based on real-time data acquisition [4]. Internet of Things (IoT), Industrial Internet, Smart Manufacturing and Cloud based Manufacturing are the key concepts of this construction. The machine-to-machine interaction associated to Internet opens the way for join-interfirm production systems that allow the design and control of the production chain throughout the entire process.

The FIR involves a complex interconnection of the production processes, which starts from development and ends with distribution to after-sales services. Automation uses robots and smart technologies that move and develop through networking. However, the transition from a mechanical production to an “intelligent” one entails a potential loss of human labour (manual), since robots replaced man, causing difficulties in skill-labour upgrading that usually take a long time and, potentially, can drive to technological unemployment.

The devices, and even the products themselves, have chips enclosing information on how they should be processed, when they need to be processed, etc. As a result, archiving systems also send the order by themselves. One of the benefits of automation is the rapid reorganization of cheaper and smaller production runs. Smart and customized products include a deep knowledge of the entire production process and of consumer applications, and independently lead their way through the supply chain. The purpose of the automation pyramid towards the controlling auto-systems manages to a great amount of data to be extracted, visualized and used.

The aim of this work is to investigate the impact of I4.0 on the manufacturing sector, paying particular attention to SMEs, and the effects of technology on work and organizations. Our research hypothesis is to investigate the relationship between production organization and the "new" power structure determined by I4.0, and its effectiveness on the economy. In a word, the political economy of industry. What are the changes in the organization of production (agents-machines-organization)? What is the final effect on the social division of labour after the introduction of the FRI? Does it hurt the development of capitalism, as we know it today? Does it create a larger disparity between worker classes?

The paper is structured as follows. Section 2 provides an overview of the relevant literature on I4.0 paradigm. Section 3 offers some descriptive evidence on the effects of technology on work and organizational models with respect to SMEs. Section 4 presents the strategic benefits in terms of value creation associated to networking. Section 5 discusses the economic insights related to the transformation of organizational models in the labour market, while Section 6 concludes.

2 The Industry 4.0 Paradigm

The term I4.0 was introduced at the 2011 Hannover Messe, in Germany [5; 6], and denotes the transformation of "traditional" industries by the IoT, data and services[1]. It relates to the FIR, which offers - in terms of industrial policy - very different features with respect to the three previous revolutions, since it is characterized by the production of cybernetic systems based on heterogeneous data and knowledge integration. The core of this radical transformation of production systems is the ever-closer integration of digital technologies in manufacturing processes [7].

On the other hand, also the three industrial revolutions of the past were all triggered by fundamental technical changes: the introduction of water- and steam-powered mechanical manufacturing at the end of the 18th century, the division of labor at the beginning of the 20th century, and the introduction of programmable logic controllers for automation purposes in manufacturing in the 1970s. They revealed to be a sequence between different forms of manufacturing "regimes" in the production organization they followed. The present revolution is encouraged by the Internet, which allows

[1] Even the form of numbering (4.0) it uses, the same as for software release, has a significant meaning: it emphasizes more the high computer content and the digital character of this revolution.

communication between humans, as well as machines, controlled or monitored by computer-based algorithms throughout large networks.

The definition of I4.0 proposed by Kagermann et al. [8] is very promising: "a new level of value chain organization and management across the lifecycle of products". Applying the new paradigm, firms are willing to achieve a higher level of operational efficiency and productivity, as well as of automation, not only using Internet technologies and advanced algorithms, but also adding value and managing knowledge inside the production process. A major objective of this industrial strategy is the simultaneous integration, within a single network, of large and small firms, helping the latter to overcome the traditional lock-in access to new technologies.

Among the main pillars of I4.0 are digitization, optimization and customization of production, automation and adaptation, human-machine interaction (HMI), added value services and activities, automatic data exchange and communication. The theoretical foundations of I4.0 have the great advantage of scalability (Cloud Computing), which it makes possible to increase or decrease the use of resources, according to the production schemes. Other added value are interoperability, i.e. "the ability of two systems to understand each other to use functionality of one another" [9], virtualization, decentralization, real-time capacity, service orientation and modularity [10].

Although I4.0 produces value creation results, because of gains in productivity and efficiency, developing "new" business models, it could have both, positive and negative effects, on employment and wages due to the disruptive outcome of the technological change on the labour market. Technological progress biased toward hi-specialization (or skill biased) can lead, at the same time, to a higher wealth effect on behalf of a low number of people, where substantially reducing the employment opportunities of others [11]. Today, automation systems can easily replace repetitive jobs at a much lower cost per hour than a worker salary.

Figure 1 shows active workers in the most innovative technological sectors. At a first glance, it would seem that Big Data, mobile Internet, IoT and robotics have the potential to create "new" jobs. On the contrary, the negative value of geopolitical volatility risks being the greatest threat to job creation and employment itself. The negative values of artificial intelligence and 3D printing would be explained as the typical results of highly technological and competitive sectors, which, as such, require specific skills. The changes imposed by I4.0 could bring new employment opportunities and/or they result in a shift of retrained workers.

Nowadays, the main challenge is "job restructuring", since some of the less skilled jobs will quickly disappear in the near future. On the one hand, productivity gains achieved through the use of "smart" technologies can help to increase employment and the demand for consumers with additional income (compensation effect), whereas on the other hand the use of new technologies and production processes can also destroy jobs (redundancy effects). No systematic evidence exists whether the latter applied on I4.0 will prevail in the long term, leading to technological unemployment [5]. Moreover, even the digitalisation of business processes entails the automaticity of workers, whose added value will be the creation of "new" output and solutions. The digitalization also helps to determine changes in "traditional" business models, and introduces the "smart" economy as a way of creating value.

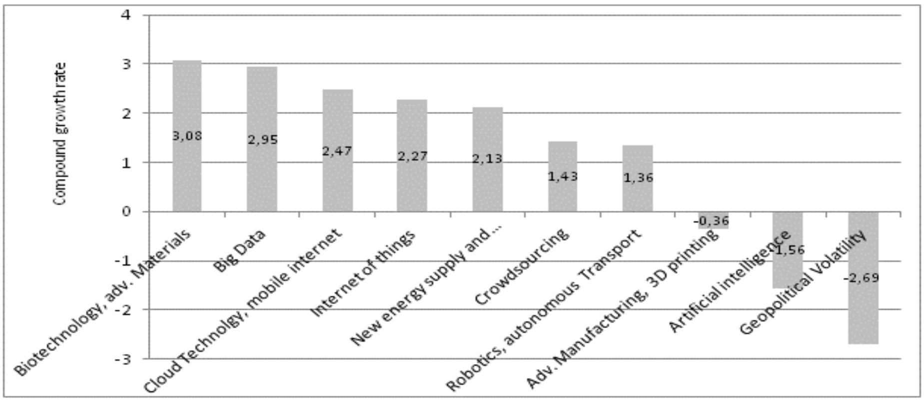

Fig. 1. Drivers of change-effect on employment. Compound growth rate[2] *(2015-2020), in %*
Source: Elaboration on World Economic Forum (2016)

The I4.0 paradigm deals with:

1. *Supply chain and logistics*: technology and IoT, in particular, improve supply chain efficiency by providing more detailed and up-to-date information, mitigating the "bullwhip effect", reducing supply chain inefficiencies with adequate forecasts, and lessening copying due to product traceability [12];

2. *Security and privacy*: since all devices are wireless, they are highly exposed to information intrusion. The growing global networking increases the need to protect industrial systems, production lines, and plants from Cyber-attacks. The data transfer and their storage in the cloud must not be subject to unauthorized access;

3. *Intelligent infrastructure*: "smart" devices improve flexibility, reliability and efficiency in infrastructure operations. Here, the added value is in terms of reduced operating costs and improved safety, and refers mainly to smart, cost-efficient, high capacity, user-friendly transportation infrastructures, smart cities, and intelligent mobility management;

4. *Healthcare*: sensors, integrated in domotics environment or smartphone applications, screen patients and send information to specialists. They are integrated in many different "things", and are able to generate and transmit "granular" information in real time through software and hardware technologies using Big Data and automatic systems, thus improving the quality and variety of the offer. The result is a positive network effects with increasing returns from data production, as in all markets where knowledge comes from them [13; 14][3].

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[2] The 2015–2020 compound growth rate, real and estimated, shown on Y axis, describes the effects of the drivers of change on employment. Estimated employment effects have been converted into compound growth rates, i.e. the mean growth rate over the specified period of time if employment had grown or declined at a steady rate, which is unlikely to be the pattern observed in reality. A compound growth rate can be thought of as a useful measure of growth over multiple time periods.

[3] Big Data Analytics transform data into soft information in real time, which, applying automation and artificial intelligence techniques, favors decision-making.

The integration and real-time analysis of a huge amount of data will optimize resources in the production process, and enable better performances. The development of algorithms to manage data is one of the main challenges of I4.0, as the pervasive integration of ICT into production components always generates more and more larger, different data sets. By facilitating information and knowledge, the IoT improves the efficiency and effectiveness of knowledge development and management in I4.0. Therefore, manufacturers and retailers will not dominate production decisions. Instead, IoT and I4.0 will make customers more involved in quality decisions and product customization. The disadvantages of heterogeneous data will compromise industrial development, but Big Data management (data mining, data classification and data storage) can be helpful to mitigate the problem [15].

The use of artificial intelligence in production processes involves an innovation in terms of organizational culture. It increases creativity and result orientation. Moreover, Háša and Brunet-Thornton [16] argue that managerial innovation involves fast time-to-market approaches through the creation of intelligent, flexible and qualified production structures, suitable for overcoming risky and heterogeneous step-by-step markets. It is therefore essential to implement qualified strategies for human capital formation, so that not only the manager, but also the entire workforce will be competitive[4].

3 The Industry 4.0 Action and the Small-Medium Enterprises

According to the traditional paradigm of the value creation process based on a strict good-dominant logic [17], large firms are more competitive in R&D capabilities and complementarities, therefore are able to outperform small firms. The in-house activities are the most important source of innovation that validates the existence of a lock in closed innovation model. The consumer-agent remains outside the enterprise and does not contribute to co-create new value for the manufactured output, tangible or intangible. However, over the past several decades, new perspectives have emerged that have a revised logic focused on intangible resources, the co-creation of value, and relationships. The globalization process with the opening to the outside world has its advantages. In a global market with a rapid circulation of knowledge flows, rich in venture capital and in massive labour mobility, firms could not indeed afford to innovate themselves. The service-dominant (S-D) logic becomes prominent due to the increasingly use of data-intensive technologies. As a result, open innovation systems arise [18].

A closed innovation model is based on innovations developed exclusively by firms themselves; it is costly and requires control. The innovation process is only settled within clearly defined company boundaries, as it is (and remains) an internal action where R&D investments are a strong entry barrier to outsider competition. When the innovation process opens up beyond company boundaries, from the generation of ideas to development and marketing, innovation arises through the interaction of internal and external ideas, taking advantages of the potential strategic use of the environment,

[4] Schneider and Spieth [26] sustain that the innovation of business models is one of the main sources of unique sales proposals and strategic differentiation, particularly in highly competitive market contexts.

technologies, processes and sales channels [19; 20]. In both cases, the aim of the firm is the same to develop promising innovative products, services or business models, in order to increase one's own innovation. It is an example of nice collaborative networking made by the integration of science and technology[5].

In a global market with a rapid circulation of knowledge flows, abundant presence of venture capital and labour mobility, firms could not afford to innovate themselves. This issue was examined by Gassmann [21], and subsequent theoretical papers, who considers open innovations as fundamental, especially for management innovation; Lichtenthaler [22] recalls that the existence of a new paradigm for open innovation implies either technology exploitation, or technology acquisition. This is true for small firms too [23; 24]. Networks are able to use outside knowledge for a specific need of internal network enterprises, without passing for the internal vertical integration. In this context, I4.0 could be crucial in SMEs development.

I4.0 could help SMEs by improving the flow of information across the entire system, allowing better control and real time adaptability to the variable demand. However, despite the tools of I4.0 requiring large investments and a high level of competence [25], the decentralization of information and decision-making would allow SMEs with a greater flexibility and competitive capacity, as well as a better managerial capabilities.

Finally, the conceptual paradigm of I4.0 can also be used to transform the nature of products and services provided by organizations. Porter and Heppelmann [27] explain how artificial intelligence change the current process control system, overcoming the traditional approach to production planning and control, and reaching different levels of performance. Setting simple monitoring tools help to reach the most complex goals. Since each level requires investments and specific skills, it is essential to classify I4.0 initiatives in terms of the desired goal to which a given management capacity corresponds. To this end, I4.0 initiatives for SMEs can be implemented through technological groups (Internet of objects, Big Data or Cloud Computing (CC)), in which each of them represents different means to implement the desired capacity [4].

In order to improve the instrumental skills of SMEs, a three-step process could be undertaken: monitoring (analysis of the decision-making process); control (use of algorithms for historical data analysis; [28]); optimization and autonomy (analysis of monitoring data and consequent autonomy of behaviour; [29]). Furthermore, since performance indicators are expression of corporate strategies, SMEs could improve their indicators (lower costs, better quality, greater flexibility and productivity, reduction in delivery times) resorting to technological investments [30].

One of the main goals of I4.0 is the synchronization of flows along the entire supply chain (flexibility). CC platforms should be used as collaboration structures between firms [31]. Bonfanti et al. [32] show that Italian artisan enterprises and small businesses who introduced and implemented new digital tools (e.g. 3D digital model) recorded a reduction in operational costs, and an increase in production demand. On the one hand, CC is widely used between SMEs and, mainly, it regards document sharing, servicing, collaboration, distributed production, and resource optimization. In practice, CC

[5] Among the determinants that leads to the open innovation logic, Chesbrough [19; 20] clearly specifies the increasing mobility of workers and the division of labour. In the last decades, the technological success of several open source software, such as web applications and operating systems apps (Android and iOS), has played an important role in spreading open innovation culture.

platforms introduce a new business culture, from corporate individuality to network sharing between partners, moving first from partner search, to risk sharing, to the CC platform at the end. Bonfanti et al. [32] give evidence that CC allowed Italian artisan firms to offer products and services online, thus strengthening customer loyalty and providing access to new markets.

With respect to productivity, an increase could take place at the plant level, or at the level of calculation (algorithms) of the production plans forecasting internal flow disturbances and changes in customer requests, or calculating algorithms based on IoT data on a CC platform. Its use shortens design time, promotes collaboration between all network partners, and facilitates the synchronization of the entire production processes. Concerning the use of Big Data in I4.0, Ren et al. [31] suggest a CC platform dedicated to SMEs that exploits IoT data using MapReduce algorithms. However, due to the their traditional low investment in R&D, there are no successful cases for the planning or control of production processes through the use of these technologies which help to organize data.

Simulation models for SMEs have also been proposed. Barenji et al. [33] present a method (Prometheus) to develop a software application for planning simulation, based on both dynamic demand, and production variations. Denkena et al. [34], on the contrary, start from the idea that most SMEs do not have reliable data to introduce the IoT and RFID technology to manage the flows and facilitate the implementation of Lean Manufacturing. Constantinescu et al. [35] develop the Just In Time Information Retrieval (JITIR) to eliminate the problem of excess data that flow into the IoT.

In relation to CPS (Cyber physical systems), or complex systems that incorporate processing algorithms, the cases of applicability to SMEs are known. Givehchi et al. [36] refer that SMEs apply CPS for production planning and control. The main limitation lies in the low level of their internal skills, and consequently in the lack of ability to process complex algorithms.

4 Network of SMEs in Industry 4.0

The network of legally independent organizations that share common skills in order to exploit a business opportunity are identified as virtual companies [37]. Collaborative Manufacturing [38] and Collaborative Development Environments [39] are important for SMEs strategies since they increase flexibility. In a collaborative network, risks can be balanced and combined resources expand the range of perceivable market opportunities [40]. The organization in networks amplifies the available capacities without the need for further investments. Therefore, firms in collaborative networks can adapt to volatile markets and reduce product life cycles with ease.

A strong coordination capacity is needed to aggregate spatially separate production processes and to integrate information (data) that comes from the different production sites [41]. Clusters of SMEs, and networks in particular, manage to implement product and process innovation, resulting in “open winners”, as the case of the industrial districts.

The availability of product data throughout the network is essential for the global optimization of the production processes. The maintenance of the global competitive advantage occurs for the enterprises in collaborative networks, for the single unit through the maintenance of the basic competences, for the group through the externalization of other activities [42]. The key features of networks are generative knowledge and cognitive clusters (accessible from anywhere). However, in the era of I4.0, the operating chains that manage the multilocalized and interconnected transformation of intangible products and services could represent the key feature. If the more technological sectors seem to be able to cope well with the FRI, also the Italian manufacturing industry seems to organise itself to the transformation and innovations imposed by the markets. The creativity and flexibility of man will be an added value: therefore the study and analysis of systems for the valorisation of people in factories remains of great relevance. The new evolution will not only touch all industrial sectors, as it embraces transversal technologies, but it will have a strong impact on processes and products.

The main problem related to virtual networks is information sharing, as leaders/owners of SMEs do not share information they preserve [43]. Therefore, while, on one hand, information sharing can lead to innovation, on the other it could generate asymmetric action due to opportunistic behaviour (learning tenders), and higher coordination costs resulting from antagonisms and competition between firms.

Advanced visualization techniques of context-sensitive data via virtual reality can be used to illustrate information for effective collaboration. Local availability and understanding of global production data is essential for real-time intervention in a changing environment. The idea of I4.0 is based on the concept of a modular enterprise that combines new business models for "smart" supply chain management. Thus, the importance of a flexible network of relationships consisting of autonomous, but interdependent, fragments of production within the organizational structure usually connected through ICT systems.

For this reason, I4.0 seems to be a valid tool to activate processes of reindustrialisation and industrial competitiveness all around the world. It uses cyber-physical systems and dynamic production networks to create flexible and open value chains, as well as 3D printing, Big Data, IoT and the Internet of Services, which are all facilitators of intelligent production and logistics processes [8].

However, despite I4.0 points towards horizontal integration, value chains could develop complex and intertwined manufacturing networks, where supply chains could be fragmented [44]. Division would reduce barriers to entry for SMEs, and could lead to the creation of new business models. It calls for the Italian economy to recover from the slowdown and speed up. The production development cycle will lower its costs, reduce delivery times, the potential of 3D printer and manufacturing will increase; the spread of robots proceed at very high rates. From the growing diffusion of digital technologies, it is reasonable to expect significant network effects: companies will have to adapt their business models, above all, to manage the Big Data available.

The new I4.0 paradigm is a positive opportunity to globalization because it amplifies positive trends, making it possible to resort to suppliers (source of localization) and to share knowledge in manufacturing activities. Thus, it is the necessary link between man and machine, and the training and requalification of digital workers are the required step to compete. In addition, digital platforms are a strong means of cooperation among firms, which co-located SMEs can exploit to compete at a broader level. In this process, the role of policy makers and institutions is fundamental, since it should support the migration from a traditional way to do business to a "new" technological one.

5 The Industry 4.0 and the Labour Market

Along with FIR characteristics, one of great relevance is the convergence between industrial production technology and science, which allows entrepreneurs the opportunity to choose tools that are more suitable, i.e. those offered by their integration, to gain a better competitive position in the "new" value chains. Innovation, as the result of science and technology integration, is a crucial element for the development of the global industry.

Recently, the Italian Ministry of Economic Development [45], in order to spread I4.0 culture, identifies three different areas for policy actions. These are the scientific and technological strategy of culture innovation, promoting measures for supporting investments in human capital digitalization and in firms' innovation; the political perspective towards innovation, encouraging public incentives for supporting "I4.0 firms"; the perspective of business management towards digitalization, favouring innovation hubs, and high competence centres for the local dissemination of basic knowledge on I4.0 technologies. However, the applicability of I4.0 policies has many limits, such as the digital organizational form (agents-internal-work organization), the implementation of *ad hoc* policies, and the interaction between them.

The transformation of organizational models follows the growing fragmentation of production in several global value chains, where the single production process is the result of the convergence between the "real" world of manufacturing plants and the "virtual" world of IoT. Consequently, a system of goods and services suitable for I4.0 challenges should be flexible and adaptable to both, the external and internal environment. Inside the "black box", in a cyber-physical atmosphere, economic operators interact together and with a complex network of machines, physical goods, and digitalized devices. Entrepreneurs must manage the pre-existing organization and digitalization of markets in real time, and I4.0 tools embody the opportunity to adapt the firm's organizational system. A new (advanced) business model should reconsider both, the role of the individual agent in the digitalization, and the entire organizational structure. Products are not only gradually assembled along the production chain, like before, but using digital devices all means of production (workers, machines, network) can intercommunicate and specify detailed further steps of activities. "Technical" division of labour goes under stress.

Frey and Osborne [46] highlight some criteria to identify which jobs are exposed more than others to the risk of automation. These are routine (manual and cognitive tasks involving explicit rule-based activities) and non-routine (digital intensive) jobs and, following recent technological advances, digitalization is now spreading to non-routine extents. In this respect, because of the technological evolution, the effects on I4.0 labour division is very significant, and it is in large part related to the process of deskilling, especially if we consider the technologies adopted by Big Data and IoT. Thanks to them, a wide range of non-routine cognitive tasks could be digitalized with a scalability of human labour. The continuous identification and resolution of digital problems, due to a fast technological progression, will lead to a growing specialization of digital work. The man-machine replacement can be limited by identifying elements that only the worker-man possesses, such as the ability to manipulate or assemble objects in a singular and non-automatic way (finger and manual dexterity), creative (ability to present clever ideas) and social intelligence (persuasion, assistance).

In advanced manufacturing, machines can easily replace jobs that require routine and standardized tasks. Jobs losses are mainly due to inadequate skills of the workers, who are unable to keep up with the innovation rate of growth. In fact, on the one hand investments in education-digitalization are low but, on the other hand, the speed at which technical progress moves does not allow the demand for skill-labour to be able to adapt quickly.

In Italy, several reforms have been introduced in recent years (e.g., Jobs Act, 2014 for the labour market, La Buona Scuola, 2015 for education; school-work transition projects, at regional level). In the period 2017-2020, thanks to I4.0, incentives for 13 billion Euros have been allocated to firms to be invested in technologies in order to qualify them with the high skills required. According to a survey of the Italian Ministry of Economic Development (IMED) [45], a large number of firms used human capital training (43.6% of the answers), and preferred outsourcing solutions (37.7%) to overcome the obstacles in the application of I4.0 (Table 1).

	Size classes in number of persons employed (%)				
	1-9	*10-49*	*50-249*	*+250*	*Total*[6]
New employees	11,1	33,7	50,7	55,7	17,7
Qualification of workers	37,2	60,1	69,0	78,8	43,6
External collaborations	35,9	42,1	47,7	43,3	37,7
No actions	32,0	10,8	5,7	3,2	26,2

Table 1. Italy. Firms' actions for facing the lack of I4.0 skills, 2017 (in %)
Source: Elaboration on Italian Ministry of Economic Development (2018, Table 4.10)

Only less than one third of all responses (26.2%) provided by the firms confirmed that they have not yet implemented any corrective action, while a 17.7% of the respondent decided to hire new employees. Indeed, from a dimensional point of view, some substantial differences emerge. Larger firms are more reactive; they rely mainly on staff training and new employees, while micro and small ones, in addition to training, use relatively more services and external collaborations. The smaller firms (10-49 employees), accounting for less than 11% of the total, fail to take actions to solve positively the "digitalization problems"; instead, only 11.1% of the micros (1-9 employees) make new hires, while 32% choose not to take action.

Following the IMED survey [45], in 2017, the so-called "I4.0 firms", because of the adoption at least of one of the new technologies considered in FIR, cover only 8.4% of the entire population of active enterprises in industry, excluding construction, substantially differing from 86.9% representing the traditional firms that do not use new technologies and confirmed not to be intended to use it in the next three years. Data

[6] In Table 1, the total exceeds 100% because the interviewed firms involved in the survey had the option of choosing more than one answer.

concern a well-structured, small but representative sample of 23.700 industry and service firms of different sizes distributed throughout the country.

Regions	*Traditional firms*	*Traditional firms with planned I4.0 measures*	*I4.0 Firms*
Piedmont	81,8	6,4	11,8
Aosta Valley	91,0	2,6	6,4
Lombardy	86,1	4,2	9,7
Trentino A.A.	83,9	5,2	10,9
Veneto	80,5	7,8	11,7
Friuli V.G.	86,4	4,1	9,5
Liguria	91,7	3,3	5,0
Emilia R.	85,1	4,3	10,6
Northern Italy	*85,8*	*4,7*	*9,5*
Tuscany	92,1	3,3	4,3
Umbria	90,0	3,2	6,8
Marche	89,5	3,5	7,0
Lazio	86,7	5,3	8,0
Central Italy	*89,5*	*3,8*	*6,5*
Abruzzi	89,4	3,7	6,9
Molise	88,3	3,0	8,7
Campania	88,7	5,3	6,0
Apulia	90,2	5,1	4,6
Basilicata	91,7	3,7	4,6
Calabria	88,3	4,8	6,8
Sicily	91,0	2,0	7,0
Sardinia	91,5	2,6	5,9
Southern Italy	*89,8*	*3,7*	*6,3*
ITALY	*86,9*	*4,7*	*8,4*

Table 2. Italy. I4.0 Technology disseminations by regions (%), 2017
Source: Elaboration on Italian Ministry of Economic Development (2018; Table 4.2)

At regional level, I4.0 technology is more widespread in the Northern and Central Italy; Piedmont, Trentino and Emilia R. stand out, both in 4.0 "smart manufacturing", and in firms that have planned to introduce 4.0 technological actions (Table 2).

On the other hand, the innovation of intelligent production systems faces limits due to the rapid migration of data, the integration of new systems in existing production facilities and databases (which already have very high entry costs). Concerning organization, the main problem is that intelligent systems based on decentralized and automated self-organization collide with the traditional organizational scheme of production, causing paradox of (organizational) inertia. SMEs with limited resources could fail in a “smart” factory perspective, but networking would allow sharing and/or training of the necessary skills. With respect to the geographical macro-areas, the South shows a higher proportion (89.8%) of traditional firms compared to a below country average of 85.8% in the North, with more than three points higher percentage (9.4%) due to the presence of I4.0 firms than in the South. Southern and Central Italy differ slightly from the North due to firms that have introduced I4.0 measures.

Technology, machines and algorithms complete human work in data and information processing, technically supporting humans for some complex assignments integrating numerous physical and manual tasks. Nowadays, the limit of machines and algorithms concerns some work activities with high communication and interaction. Therefore, where for some fields it is possible (Figure 2: Information and data mining, job related information, technical activities performing, and so on) to foresee that in the near future machines and algorithms can increasingly replace human work, for others (Figure 2: Administering, Managing and Advising), this substitution is not so easy. Some work tasks have thus far remained overwhelmingly human. According to the World Economic Forum estimates [47], the information, processing and transmission of an organization's data and research activities will be performed by automation technology with a potential average increase (30%) of labour productivity in all sectors. Since I4.0 represents an opportunity for firms to compete at increasing speed, the challenge will consist in the ability to apply the 4.0 paradigm also to the intentional and decision-making processes of men.

Although I4.0 may lead to a decrease in the employment levels of less qualified workers, higher skills can stimulate competition. Bogers et al. [48, p. 225] argue that “a move from centralized to decentralized supply chains, where consumer goods manufacturers can implement a ‘hybrid’ approach with a focus on localization and accessibility or develop a fully personalized model where the consumer effectively takes over the productive activities of the manufacturer”.

Big Data and algorithms could allow testing new products and services on customers anywhere in the world, customizing the company offer, reducing development costs, product launch and adaptation. The growth of digital platforms for product distribution (e.g., Amazon) can facilitate the entry of small businesses into global markets. On an institutional level, new internal and external structures must emerge that are suitable for the regulation of a more complex reality where, within the smart manufacturing, products, people and machines can be related via internet and interact simultaneously. The result, at the industrial policy level, is a reduction in organizational costs as integrated firms, since hierarchies are able to better control the production process at all levels thanks to the increasingly complete integration between science and technology.

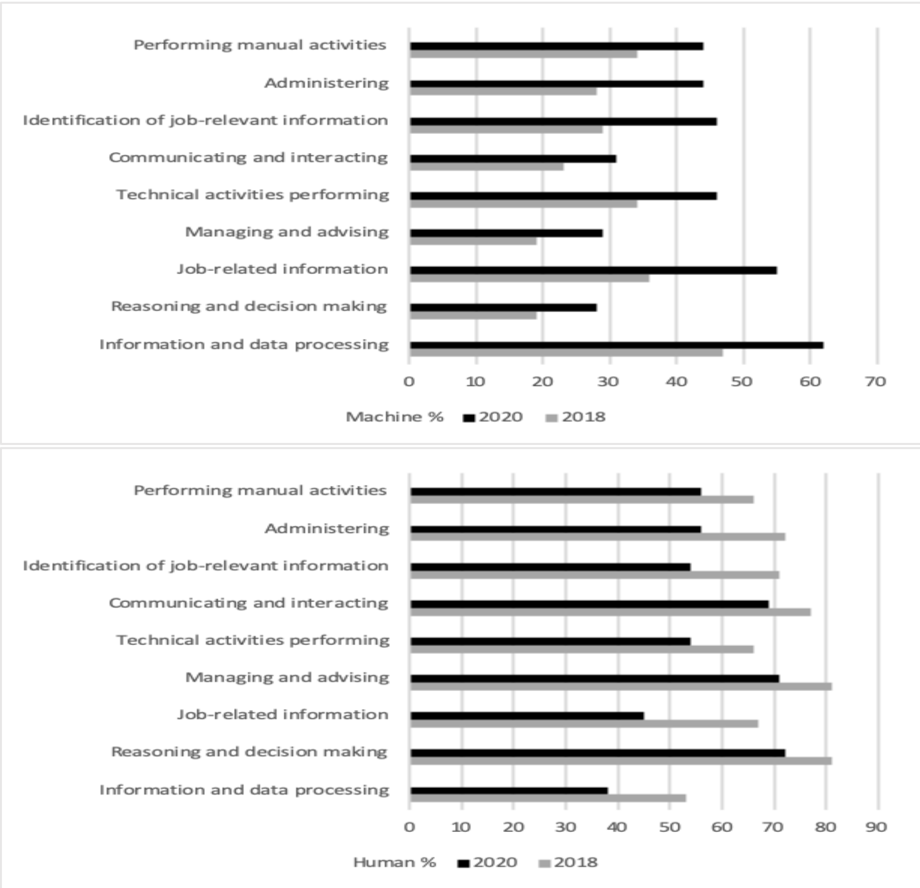

Figure 2. Human/Machine (hours worked) - Projections %
Source: Elaboration on World Economic Forum (2018)

Some interesting features arise from the analysis of WEF 2018 survey data [47]. I4.0 disrupts as well as creates jobs for improving both, productivity and quality, of existing work of human employees. Figure 2 shows the projections of hours worked by man and machine in the period 2018-2020 explaining the potential of new technologies towards jobs innovation. At a first reading, data on human labour indicate a decrease in almost all the economic sectors. The most involved are Information and data processing, Job related information, Identification of job relevant information and Technical activities performing, and in general those which require a highly automation processes, where the presence of man can be easily partially replaced by the machine.

On the contrary, the predominance of man over the machine would persist in the planning and strategic sectors (e.g. managing and advising; reasoning and decision making) where, despite an expected absolute decrease in human presence over the period, it is possible to believe that the complete machine-man substitution cannot take place as they are areas in which human abilities still act as a fly-wheel.

6 Conclusions

In the new competitive environment, I4.0 has been changed competition scheme, as the competitive phenomenon also extends to supply chains. Innovation and time, i.e. the frequency by which new or significantly updated product versions are introduced, denote the real competitive advantage, as they have an insightful effect on the life cycle of outputs [49], changing the firm production and organizational structure.

What are the major changes? When a firm uses I4.0 tools, it assumes that it is open to cultural changes, to operate new management strategies. Men and machines have an essential role in doing this. The acquired knowledge that represents the "social capital" of the firm, using Big Data and the IoT, is able to compete in a global perspective, in which the value chain of production changes radically.

Consequently, smart firms will face a persistent increase in the knowledge content of outputs, strengthening the prominence of intangible assets in production. The main reasons lay in the increase in the extent of the market induced by globalization that pushes firms to boost the knowledge content of products, including more innovation, so to remodel them frequently and exploit new competitive advantages [50]. A clear consequence is the changes in the international economic scenario, which have gradually shifted the foundations of industrial competitiveness from a static cost competition to a dynamic one that companies attempt to implement, improving their learning skills and "creating" knowledge faster than the competitors do.

Such an increasingly complex competitive setting has its origins in different phenomena such as market globalization, continuous socio-cultural changes, political-financial instability and the increasingly abrupt development of new technologies. These events are inevitably leading to a significant improvement in the ability of firms to innovate their production processes, goods and services, and to approach new markets in a new and unconventional way.

The division of labour will be still affected: the decrease of employees in manufacturing is likely to continue as machines will replace workers, and the remaining ones must be qualified to a higher level of education and capabilities in order to handle the new technologies. Unfortunately, many Italian firms, especially of medium-small size, are still vulnerable to face the new challenge and show a severe handicap compared to their foreign competitors. It seems they are far from understanding the ongoing culture according to which "smart" factory opens outward using new model and dimensions, superior to those previously known. The firm becomes an "open place" that looks to the future, closely connected to the territory, the research system, the entire community.

Skills gaps in human capital formation remain one of main problem of Italy, both with respect to workers and managers. This lack would accelerate in some cases the trends towards automation, but it also block the adoption of new technologies and, therefore, hinder business growth. A solution might be both investments in the formation of specific skills, suitable for worker recycling, and in favoring collaborative practices between small firms. The changes due to the introduction of new technologies aim to increase labour productivity in all sectors, in order to move competition among firms from the reduction of the labour cost to the ability of exploiting new technologies to integrate and improve human work. The traditional business models are under stress, and the technological progress open the opportunity for the firms to reduce working time and to grow and expand rapidly.

In order to spur innovation within emerging sectors fostering development, new industrial policies are needed. On one hand, they will involve activities where knowledge networks are still weak; on the other hand, they will concern to the open question that technological and digital diffusion entails. Moreover, the FIR has bounded new paths in the mobility of workers and in the international division of labour. A further research direction that has not yet fully tested and explained might be the total effect on the labour market, since it is still persistent a deep heterogeneity and asymmetry in human capital formation among countries. The introduction of suitable strategies to favour new relationships between manufacturing and services following the theoretical scheme of S-D logic will play an important role, as well as strategies for a more complete international opening.

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