Riding the Wave 4.0. Understanding and tackling the technological revolution

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Previous studies have not discussed in detail the transformation brought about on occupations and skills by the technical change. This essay seeks to understand and explain the impact of Industry 4.0's Key Enabling Technologies (KETs) on the digital transformation process and its effects on occupations and skills. Starting from literature findings on how the knowledge, skills, and expertise required by the labour market are changing, the article examines how the educational and learning process should be adequate in order to benefit from them and encourage new forms of employability.

Gli studi precedenti non hanno trattato in dettaglio la trasformazione che il cambiamento tecnico induce sulle professioni e sulle competenze. Questo saggio cerca di comprendere e spiegare l'impatto delle tecnologie abilitanti dell'industria 4.0 sul processo di trasformazione digitale e gli effetti sulle professioni e le competenze. Partendo dai risultati della letteratura su come le conoscenze, le abilità e le competenze richieste dal mercato del lavoro stanno cambiando, l'articolo esamina come il processo di formazione e di apprendimento dovrebbe essere adeguato al fine di trarne beneficio e sollecitare nuove forme di occupabilità.

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Introduction

The rise of the 4.0 paradigm has led to a radical digital transformation of companies that increasingly produces a change in business processes, organizational forms, quality of work and working conditions.

The digital revolution certainly contains an extraordinary potential for human progress and offers numerous opportunities. Among the many well-known descriptions of this optimistic mainstream vision, Asimov's is particularly meaningful: "In a properly automated and educated world, […], machines may prove to be the true humanizing influence. It may be that machines will do the work that makes life possible and that human beings will do all the other things that make life pleasant and worthwhile" (Asimov 1990, 959). According to Asimov and to many scholars, in the future the fourth industrial revolution will not collapse employment and, on the contrary, will have beneficial effects both in quantitative and qualitative terms: it reduces the types of heavy activities on a physical level, repetitive, dangerous, and monotonous on a mental level, allowing workers to devote themselves to performing tasks that require flexibility, creativity, problem solving and communication skills.

Other researchers, however, argue that technological advancement can lead to the replacement of human work by machines, causing job losses and a dehumanization of human labour, as many workers become supervisors of machines, or machines control the workers. The emergence of a huge increase in computing power, artificial intelligence and robotics has increased the possibility of replacing human work to levels never seen before. Machine learning techniques are expanding the range of replaceable tasks, they apply statistics and inductive reasoning where formal procedures are unknown. The belief that technological progress will cause widespread substitution of human labour by machines, which in turn could lead to technological unemployment generated the phenomenon labelled as 'automation anxiety' (Akst 2013, Mokyr *et al.* 2015).

Certainly, the transformation processes seriously question established paradigms and historical practices, not least the system of industrial relations. As the American biologist, writer and mindfulness teacher J. K. Zinn teaches: "You can't stop the waves, but you can learn to surf" (Kabat-Zinn 2005). It is necessary to learn to cope with the continuous changes in the labour market without each time producing trauma or to pass on to the community costs that others have seriously generated. As noted by Pontes *et al.* (2021) "Understanding the relationship between trends, job profiles, skills and training programs can help to encourage and support the creation of a skilled workforce under a lifelong learning system focused on an employability model for the factory of the future".

The aim of this work is to try to understand the evolution of the labour market and which profiles could be replaced or altered by the changes brought about by the Fourth Digital Revolution and the Key Enabling Technologies (KETs), in order to encourage new forms of employability through adequate vocational training initiatives, riding the wave 4.0 rather than being overwhelmed by it.

The article has been organized in the following way. It begins by explaining the impact of Industry 4.0's KETs on the digital transformation process. It will then go on to describe the effect of Industry 4.0 on employment and the growing importance of soft skills. Finally, the last part analyzes the contribution of the eight Italian Competence Centers, that supports companies in the digital transformation process of the adoption of the KETs, through necessary training programmes.

1. The Key Enabling Technologies of Industry 4.0: an overview

This section provides a brief overview of the enabling technologies and their impact on the digital transformation process of companies in the Industry 4.0 era.

The general concept of Industry 4.0 originated in Germany in 2011 as a definition of a trend towards automation and data exchange based on the use of new technologies and their interconnections, where the virtual world of data combines with the physical world of machines (cyber-physical systems) (GTAI 2018). With the introduction of the Internet, recent technological developments in industry had led to the Fourth Industrial Revolution (4IR). The term was coined by Klaus Schwab, founder, and executive chairman of the World Economic Forum during the annual conference in Davos of WEF in 2016.

The 4IR is characterized by automation, digitization, and interconnection. It is *blurring the lines* between digital and physical sphere (Schwab 2016) in manufacturing and in other economic activities and connecting all actors in the value process. The Cyber-Physical Systems (CPS) is one of the main components of the I4.0 paradigm and such a trend is transforming the manufacturing sector by integrating innovative functionalities such as Internet of Things and Web of Things (Lee *et al.* 2014; Lu 2017).

GTAI (Germany Trade and Invest) defines it as follows: "INDUSTRIE 4.0 represents a paradigm shift…refers to the technological evolution from embedded systems to cyber-physical systems" (Germany Trade & Invest 2014).

However, due to its innovative power, the phenomenon is often called "the Fourth Industrial Revolution" as GTAI further adds "put simply, INDUSTRIE 4.0 represents the coming fourth industrial revolution".

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chairman of the World Economic Forum during the annual conference in Davos of WEF in 2016. Klaus Schwab (2016) divides the concept of the Fourth Industrial Revolution into four main trends: advanced robotics, new materials, unmanned vehicles, and 3D printing.

Industry 4.0 affects every production domain and includes advanced manufacturing technologies that capture, optimize, and distribute data (BCG)[1]. Hermann *et al.* (2015) found that the most repeatable components of the new paradigm are: the Internet of things (IoT), cyber-physical systems (CPS), the Internet of services (IoS) and smart factories.

Numerous other descriptions can be found in literature and in industry management.

The most concise definition of the new paradigm is the one provided by the consulting firm BCG which summarizes it as follows: "Industry 4.0 makes factories smart" (Boston Consulting Group).

Although the Industry 4.0 paradigm was introduced in Germany in 2011 as a government initiative to strengthen the competitiveness of the German manufacturing industry (Stentoft *et al.* 2019), Italy presented its National Industry 4.0 action plan in 2016 which was re-named *Enterprise* 4.0 in 2017.

A three-year period (2017-2020) plan based on some pillars ranging from research to tax incentives related to investments in enabling technologies has been a key instrument to sustain the digital transformation of national companies (Ministry of Economic Development – MISE).

The interest and growing political attention towards greater digitalization of companies and society determined that in 2019 a new Ministry for Technological Innovation and Digitalization was established, which in December 2019 has presented *Italy 2025* 'The strategy for innovation and digital transformation of the country'.

Regarding the digitalization of companies, in 2020, the Italian government launched the new '*Transition 4.0*' plan, with a greater focus on innovation, green investments and the participation of SMEs and it is also the first brick on which the Italian Recovery Fund plan is based with an investment of about 24 billion Euros.

The MISE plan includes several lines of intervention and among new measures including research and development we also find Training Tax Credit 4.0[2]. The implementation of the plan will cover a period of almost three years, ending in June 2023.

Together with Innovative Investments we find the creation of the Digital Innovation Hub and Competence Centers I4.0, as a strategic guideline for intervention. At a national level, in Italy, the digital transformation accelerated in 2017, driven by organic and complementary measures to encourage investment in innovation and competitiveness.

The KETs are the fundamental key to the advancement of the technological level of companies in Italy and play an important role for industrial competitiveness in the digital transformation process. They are one of the crucial points of the MISE for the Transition 4.0 plan.

What is a KET? There is no agreed definition in the academic literature on what constitutes an 'enabling technology' because it results in the European policy arena to profile technology clusters that can innovate and enhance productivity in different economic sectors (European Commission 2017).

According to Teece (2018) in an industry, an enabling technology can be used to drive technological change and applied for a variety of uses.

The European Commission describes the concept of KETs as "...knowledge intensive and associated with high R&D intensity, rapid innovation cycles, high capital expenditure and highly-skilled employment" (Commission of the European Communities 2009). It has identified six 'key enabling technologies' (micro and nanoelectronics, nanotechnology, industrial biotechnology, advanced materials, photonics, and advanced manufacturing) defined as "...multidisciplinary, cutting across many technology areas with a trend towards convergence and integration" (*Ibidem*).

Through the Horizon 2020 Program (European Commission 2017) the KETs have been part of investments for the EU Industrial policy.

We will provide an overview of each group of enabling technologies, starting from those identified by MISE with the National Industry 4.0 Plan: Advanced manufacturing solutions, Additive

1 BCG's Perspective on Industry 4.0.

2 See MISE, Credito d'imposta formazione 4.0, https://bit.ly/3D33IjH.

manufacturing; Augmented reality; Simulation; Horizontal/Vertical integration; Industrial Internet of things; Cloud computing; Cybersecurity and Big Data & Analytics.

More specifically the Key Enabling Technologies of Industry 4.0 are:

Advanced Manufacturing Solutions (Interconnected and rapidly interprogrammable collaborative robots, cobots). The collaborative robots are a form of robotic automation intended to interact with human operators in a shared workspace in industrial sectors. Collaborative industrial robots are used in manufacturing and in a wide range of applications and industries (automotive, pharmaceutical and chemical, electronics, plastics are some of the most common) (Association for advancing automation[3]). Simões *et al.* (2020) in a recent review of the literature on this topic concluded that the objective of introducing cobots in the manufacturing processes reported by companies is basically to improve quality, flexibility, and productivity.

Additive Manufacturing (also known as AM - primarily within the manufacturing industry; or three-dimensional printing). According to Hassanin and Jiang (2015), AM can be defined as "a group of fabrication processes where three-dimensional partes are constructed by adding layers of materials on point, line or planar surface". AM finds applications in many different sectors as automotive manufacturers, healthcare, aerospace companies.

Burckhard and Wampol (2018; cited in Chiarello *et al.* 2021) pointed out that additive manufacturing in general is having a strong impact on the way products are prototyped.

The Additive Manufacturing Market Report (2021) values the entire AM market at 7.17 billion euro in 2020[4].

Augmented reality (AR). In the Encyclopedia of Multimedia, Springer (2006) we find the following definition "Augmented reality is a system that enhances the real world by superimposing computer-generated information on top of it". According to Van Krevelen and Poelman (2010) an AR system has three features:

1. combining real and virtual objects in a real environment;
2. aligning them with each other and
3. running "interactively, in three dimensions, and in real time".

'The Worldwide Quarterly Augmented and Virtual Reality Headset Tracker' examines augmented and virtual reality markets with a five-year perspective. According to the International Data Corporation (IDC) the worldwide shipments of augmented reality and virtual reality (AR/VR) headsets reached 8.9 million units in 2019, up 54.1% from 2018. Over the 2019-2023 forecast period this strong growth is expected to continue as global shipments climb to 68.6 million in 2023. More than half of all headsets will be shipped to commercial markets in 2023. According to the IDC the types of industries and use cases for these deployments will vary dramatically from training and services to retail and design[5]. Van Krevelen and Poelman (2010) list a varied range of fields where AR will support us in maintenance, education, design, and reconnaissance, just to name a few. Some areas of application which benefit from augmentation are personal information systems, personal assistance and advertisement, navigation, touring and industrial (assembly, maintenance) and military applications.

Simulation. It is the fourth enabling technology of I4.0. Jerry Banks in *The Handbook of simulation* defines simulation as: "...the imitation of the operation of a real-world process or system over time. Simulation is an indispensable problem-solving methodology for the solution of many real-world problems... is used to describe and analyze the behavior of a system, ask what-if questions about the real system, and aid in the design of real systems" (Banks 1998).

Imitating a real-world system or process allows the practitioners to study the various phenomena in a safe environment.

The area of application: a simulation software platform can assist and support in modeling and analyzing virtually any problem in any kind of industry, including manufacturing, material handling, logistics, supply chain, crowd simulation, etc.

Horizontal/Vertical integration. Firms, departments,

3 See Emerging Markets: Collaborative Robots, https://bit.ly/3GOG4Ji.
4 See AMPOWER Report on the Additive Manufacturing market, https://bit.ly/3EQWGiC.
5 IDC's Worldwide Quarterly Augmented and Virtual Reality Headset Tracker provides details on vendors, technology, market opportunity, and trend analysis in the newly created augmented reality and virtual reality device market.

functions, and capabilities are increasingly integrated and consistent as cross-enterprise data integration networks evolve and enable fully automated value chains. In brief "Horizontal integration is when a business grows by acquiring a similar company in their industry at the same point of the supply chain. Vertical integration is when a business expands by acquiring another company that operates before or after them in the supply chain"[6].

Industrial Internet (of things) (IIoT). IoT applications in relation to I4.0 are called 'Industrial Internet of Things' and they are under the 'Cyber-Physical Systems' paradigm.

The main application area of IIoT and where they play a decisive role are described below:

'Smart Factory': production progress control, safety at work, maintenance, material handling, quality control, waste management;

'Smart Logistics': traceability/monitoring of the supply chain through RFId (Radio-Frequency Identification) and sensors tags, cold chain monitoring, safety management in complex logistics centers, fleet management (e.g. via GPS / GPRS);

'Smart Lifecycle': improvement of the new product development process (e.g. through data from previous versions of related products), the end of life management, supplier management in the development phase of new products.

The market for industrial Internet of Things was valued at 77.3 billion U.S. dollars in 2020[7] and is expected to grow by 421.28 billion U.S during 2021-2025[8].

The Internet of Things Observatory of the POLIMI (Politecnico di Milano) conducted a survey involving 100 large companies and 525 SMEs based in Italy, with the aim of understanding the projects carried out with an Industrial IoT perspective and expectations for the future. A double-speed scenario emerges.

On the one hand, 97% of large companies know IoT solutions for Industry 4.0 and 54% have activated at least one industrial IoT project in the three-year period 2017-2019. On the other hand, only 39% of SMEs have heard of these solutions and only 13% have taken initiatives. The mainly lack of cultural and technological skills and barriers limit this phenomenon[9].

Cloud Computing (or the management of large amounts of data on open systems). It is widely known as the provision of different computing services over the Internet (the cloud). These resources include tools and applications such as data storage, servers, databases, analytics, network, and software.

Peter Mell and Timothy Grance (2011) have provided the following definition of the paradigm:

> Cloud computing is a model for enabling ubiquitous, convenient, on-demand network access to a shared pool of configurable computing resources (e.g., networks, servers, storage, applications, and services) that can be rapidly provisioned and released with minimal management effort or service provider interaction.

Some of most effective cloud computing usage for achieve business goals as cost reduction, elasticity, optimal resource utilization and greater flexibility are: Infrastructure-as-a-Service (IaaS), Platform-as-a-Service (PaaS), Hybrid cloud, multi cloud and data backup, to name just a few[10]. The global cloud computing market is growing and is expected to reach 623.3 billion U.S. dollars by 2023[11].

Cybersecurity (security on networking and open systems). The definition of cybersecurity varies in the literature and there is terminological confusion because of its nature. According to Craigen *et al.* (2014) the definitions are *highly variable, often subjective, and at times, uninformative*. The Oxford University Press defines cybersecurity as "The state of being protected against the criminal or unauthorized use of electronic data, or the measures taken to achieve this". Amoroso (2006) argues that Cybersecurity involves reducing the risk of malicious attack to software, computers, and networks.

In their interesting analysis of critical assets and business impacts on cybersecurity in the context of Industry 4.0, Corallo *et al.* (2020) argue that cybersecurity is one of the main challenges that companies are approaching and must deal with in order to preserve their competitiveness.

6 AmericanExpress, Trends and Insight (2019), Should You Expand Through Horizontal and Vertical Integration?
7 Statista, Global industrial Internet of Things market size 2017-2025, https://bit.ly/3H9f3kD.
8 Grand View research (2021), Industrial Internet Of Things Market Size Report, 2021-2028, https://bit.ly/3EUnJta.
9 Osservatorio Internet of Things: la Ricerca 2021-2022, https://bit.ly/3khUrwH.
10 BM (2020), Top 7 Most Common Uses of Cloud Computing, https://ibm.co/3BXS8VS.
11 Cloud Services Global Market Report 2021: COVID 19 Impact and Recovery to 2030, https://bit.ly/31FoQ1D.

Big Data & Analytics. Big Data was defined by Doug Laney in 2001 which described the 3V Model related to big data: Volume, Velocity and Variety. Today Laney's paradigm has been enriched by other variables and for this reason we talk about 6V (or more) of Big Data.

Patgiri and Ahmed (2016) claim that there are many V's in the Big Data paradigm. They are: Veracity, Value, Validity, Variability, Volatility, Virtual, Visualization/Visibility.

However, the most accepted V's are volume, velocity, variety, veracity and value (Ibidem).

To analyze Data, there are four methodologies: 1) Descriptive Analytics – Tools aimed at describing the current and past situation of business processes and/or functional areas; 2) Predictive Analytics – Advanced tools that analyze data to answer questions about what might happen in the future; 3) Automated Analytics – techniques include data/text mining, machine learning, pattern matching, forecasting, visualization. Those three analytics classes are part of the 'Advanced Analytics' category. Advanced Analytics is defined by Gartner Information Technology Glossary[12] as "the autonomous or semi-autonomous examination of data or content using sophisticated techniques and tools, typically beyond those of traditional business intelligence (BI), to discover deeper insights, make predictions, or generate recommendations"; 4) Prescriptive Analytics use of technology to help businesses make better decisions through the analysis of raw data.

A recent bibliographic analysis on the enabling technologies of Industry 4.0 conducted by Bigliardi *et al.* (2020) has found that the enabling technologies most frequently found in the literature are Big Data, Smart products, and Robots.

According to the Digital Economy and Society Index (DESI) – Report which is periodically developed by the European Commission and considers indicators such as connectivity, human capital, the use of Internet services by citizens, the integration of digital technology by companies and the digitalization of public services Italy ranks 20th out of 27 Member States, in the 2021 edition of the Digital Economy and Society Index well below the European average[13] (European Commission 2021).

The same report points out that there are important gaps regarding human capital and the *digital* (digital skills, the digitization of the companies) will play a key role and they are 'crucial' for a 'robust recovery' as a consequence of the impact of the current pandemic.

The World Economic Forum has emphasized the importance of the human capital and the role of innovation as drivers of economic success in the 4th Industrial Revolution and in the latest *Future of Jobs Report* outlined that almost half of all employees around the world will need reskilling by 2025.

The same Report (2020) on key findings points out that companies have estimated that around 40% of workers will require a reskilling of six months or less and 94% of business leaders have reported that they expect employees to pick up new skills on the job, a sharp uptake from 65% in 2018. In the I4.0 vision there is a large consensus on the fact that labour will change, and new skills will be needed (Fantini *et al.* 2020). Furthermore, much of the literature since the mid-1990s emphasizes the importance of technology-skill complementarity. Goldin and Kats (1998) argue that complementarity skills emerged in manufacturing and if there were no relative complements in the past, they are today.

In a recent study, The Infosys Knowledge Institute (2019) report found that one of the greatest barriers to digital transformation that manufacturers faced in 2018 is the lack of talent or skills required followed by the inability to experiment quickly.

Other barriers on the digital transformation journey are insufficient budget, risk-averse culture, legacy system, inability to work across silos, lack of corporate vision for digital, inadequate collaboration between IT and lines of business and the lack of change management capabilities[14].

In part, the Industry 4.0 plan can help retrain and

12 Gartner, Information Technology (IT) Glossary – Essential Information Technology (IT) Terms & Definitions, Gartner, Information Technology, https://gtnr.it/3klfXRA.

13 The DESI report tracks the progress made by Member States in terms of their digitization. It is structured around five chapters: Connectivity; Human Capital; Use of Internet Services; Integration of Digital Technology and Digital Public Services.

14 In 2018 the Institute used a blind format for the online survey. More than 1000 CXOs have responded. They represent multiple industries from Australia, France, Germany, China, India, the UK, and the US.

upgrade the workforce by providing support for the purchase of tangible and intangible capital assets and goods. For example, the cost of the training related to the purchase of a key enabling technology is subsided if it is included as an extra service.

The recent Inapp Report by Inapp (Inapp and Checcucci 2020) suggests that the challenge of Industry 4.0 is often addressed from the point of view of technological innovation and reports that the Fourth Industrial Revolution's most significant influence on the job market will be related to the need for new skills. Therefore, an important role will be played by the competencies of workers, both in relation to the technologies applied to production processes and regard to the so-called soft skills.

Also, the EY Digital Manufacturing Maturity Index 2019, conducted on 150 Italian manufacturing companies, highlights how insufficient skills are one of the weaknesses in digital transformation processes.

The 84% of respondents report a lack of professional figures capable of implementing innovation and only 12% of companies have designed and executed a structured program for the development of digital skills[15].

The World Manufacturing Forum 2019 has shown the importance of the skills for the future of manufacturing and has outlined examples of emerging professional figures that the WMF believes will increase in importance in the future. The emerging roles are:

→ Digital Ethics Officer
→ Lean 4.0 Engineer
→ Industrial Big Data Scientist
→ Industrial Big Data Scientist
→ Collaborative Robots Expert
→ IT/OT Integration Manager
→ Digital Mentor.

Previous studies have established that in order to introduce, implement and use the I4.0 technologies, an educated and skilled manufacturing workforce is needed. Indeed, the skills required of workers will change fundamentally. For example, creative problem solving and the ability to think outside of the box, including proactiveness and a strong entrepreneurial mindset (WMF Report 2019). Thus, the so-called *workforce 4.0* requires not only technical competencies but also managerial and social as problem-solving skills, decision making, communication skills and the maintenance of interpersonal relationships (Grzybowska and Lupicka 2017). As underlined by Moeuf *et al.* (2017) in order to adopt the enabling technologies managerial capacities are required.

A study conducted by Kazancoglu and Ozkan-Ozen (2018) found that the ability of dealing with complexity and problem solving, thinking in overlapping processes, and flexibility to adapt new roles and work environments are the important characteristics of the workforce 4.0.

Another recent study on the identification of critical success factors, risks, and opportunities of Industry 4.0 in SMEs, demonstrated that one of the major risks for adopting I4.0 into SMEs is the lack of expertise and the lack of short-term strategy mindset. The same research indicated that the most important factor for success is *training* (Moeuf *et al.* 2019).

In fact, the same WMF Report (2019) underlines the importance of an educated and skilled manufacturing workforce due to the digitization of manufacturing.

According to the OECD Survey of Adult Learning in Italy (2019), only 20.1% of the adult population in Italy participate in job-related training, i.e. half the share at the OECD average (40.4%).

This heightens the need to train and reskill the current and future workforce, equipping them with the required skills and encouraging *a culture of lifelong learning*.

2. Tasks, knowledge, and skills

The Fourth Industrial Revolution impacts skills, tasks and jobs, and there is a growing concern that both job displacement and talent shortages will impact business dynamism and societal cohesion (World Economic Forum 2019). Some jobs are replaced by machines, while new jobs emerge. Commenting on the effects of digital transformation on the labour market, the World Economic Forum (2019) notes that "a proactive and strategic effort is needed on the part of all relevant stakeholders to manage reskilling and upskilling to mitigate both job losses and talent shortages".

15 EY Digital Manufacturing Maturity Index 2019 – survey on the digitization status of Italian manufacturing companies carried out by EY: a sample of 150 industrial companies with a turnover more than 10 million euros and belonging to different production sectors.

Table 1. Classification of tasks performed by workers

	Routine tasks	Non routine tasks
Manual tasks	Routine – manual: picking or sorting, repetitive assembly.	Non routine – manual: janitorial services, truck driving.
Cognitive tasks	Routine – cognitive: record-keeping, calculation, repetitive customer service (e.g. bank teller).	Non routine – cognitive: forming/testing hypotheses, medical diagnosis, legal writing, persuading/selling, managing others.

Source: elaboration from Autor, Levy and Murnane (2003)

It is necessary to understand how digital transformation will take place and impact people's work, to benefit from it and to solicit new forms of employability, rather than being overwhelmed by it.

For the investigation of the degree of complementarity and substitutability of man with machines, Autor *et al.* (2003) classify tasks as routine and non-routine, manual and cognitive (Table 1). Routine and manual-cognitive dimension are two intertwining and orthogonal units of analysis through which it is possible to determine the degree of the human machine complementarity and substitutability. Routine tasks are those that can be accomplished by following explicit rules.

The manual/cognitive dimension refers to the type of work, physical or intellectual.

Examples of routine activities include: the mathematical calculations involved in simple bookkeeping; the retrieving, sorting, and storing of structured information typical of clerical work; and the precise executing of a repetitive physical operation in an unchanging environment as in repetitive production tasks. Because core tasks of these occupations follow precise, well-understood procedures, they are increasingly codified in computer software and performed by machines. This force has led to a substantial decline in employment in clerical, administrative support, and to a lesser degree, in production and operative employment.

Tasks that can be described through an explicit and codeable procedure lend themselves to being good candidates for automation, since it becomes technologically possible and cost-effective to transfer them from a human operator to a machine, whether it is a manual or an intellectual task. Detailed examination of the determinants of unemployment risk in Italy by Cassandro *et al.* (2020) showed that a large proportion of routine cognitive tasks are exposed to a relatively higher risk of becoming unemployed. Moreover, evidence shows that non-routine workers earn significantly more than routine workers (Vannutelli *et al.* 2021).

This confirms the theory of labor market polarization, that is, the fall in demand for middle-wage jobs, while non-routine cognitive and manual roles are well defended. A greater mass of displaced workers is thus reallocated towards the tails of the occupational distribution (Acemoglu and Autor 2011 and 2012). This concept is explained by Moravec's oddity, which is the discovery by artificial intelligence and robotics researchers that, contrary to traditional assumptions, high-level reasoning requires very little computation, but low-level sensorimotor skills require enormous computational resources. As Moravec writes, "it is comparatively easy to make computers exhibit adult level performance on intelligence tests or playing checkers, and difficult or impossible to give them the skills of a one-year-old when it comes to perception and mobility" (Moravec 1988, 15).

This happens because non-routine tasks are not understood sufficiently to be specified in a code because they refer to the tacit and unexplainable component of knowledge, for which neither computer programmers, nor anyone else can enunciate the explicit 'rules' or procedures. This constraint is known as Polanyi's paradox, "We can know more than we can tell" (Polanyi 1966, p.4; also quoted in Autor 2014 and 2015). According to Polanyi, people are not often aware of the knowledge they possess and use when they perform certain activities. The transfer of this type of knowledge generally requires personal contact and trust, therefore it can become assimilated by actors working near each other.

When we break an egg over the edge of a mixing bowl, identify a distinct species of birds based on a fleeting glimpse, write a persuasive paragraph, or develop a hypothesis to explain a poorly understood phenomenon, we are engaging in tasks that we only tacitly understand how to perform. Following Polanyi's observation, the tasks that have proved most vexing to automate are those demanding flexibility, judgment, and common sense – skills that we understand only tacitly. Polanyi's paradox also provides an explanation to the Moravec oddity: high-level reasoning uses a set of formal logical tools that were developed specifically to address formal problems: for example, counting, mathematics, logical deduction, and encoding quantitative relationships. In contrast, sensorimotor skills, physical flexibility, common sense, judgment, intuition, creativity, and spoken language are capabilities that the human species evolved, rather than developed. Formalizing these skills requires reverse engineering a set of activities that we normally accomplish using only tacit understanding (Autor 2015).

In line with Polanyi's observation, Levy and Murnane suggest that computers cannot completely replace humans, because they are able to follow instructions but not to recognize patterns. They underline that "as the driver makes his left turn against traffic, he confronts a wall of images and sounds generated by oncoming cars, traffic lights, store fronts, billboards, trees, and a traffic policeman. Using knowledge, he must estimate the size and position of each of these objects and the likelihood that they pose a hazard […] the truck driver [has] the schema to recognize what [he is] confronting. But articulating this knowledge and embedding it in software for all but highly structured situations are at present enormously difficult task" (Levy and Murnane 2004, 28).

The same authors also suggest that computers cannot replace humans in complex communications: "Conversation critical to effective teaching, managing, selling, and many other occupations require the transfer and interpretation of a broad range of information. In these cases, the possibility of exchanging the information with a computer, rather than another human, is a long way off" (Levy and Murnane 2004, 29).

Autor *et al.* (2003) characterize non-routine activities that cannot be automated in two main groups. The first are those that require problem solving skills, intuition, creativity, and persuasion, which are defined as 'abstract', typical of professional, technical and managerial figures. The latter include the ability to adapt to situations, to fluently communicate languages, and interpersonal relationships, typical of the catering sector, cleaning services, health care, protection, and safety trades.

Autor *et al.* (2003) argue that there is a substitutive relationship between human capital and technology in the presence of both manual and cognitive routine tasks. There will be complementarity for less predictable tasks requiring analytical and social skill and decision-making but at the same time benefit from the support offered by the technologies in the creation and management of the contents and information in digital format. Finally, automation of routine tasks neither directly substitutes for nor complements the core jobs tasks of low education occupations – service occupations in particular – that rely heavily on 'manual' tasks such as physical dexterity and flexible interpersonal communication (Autor and Dorn 2013).

3. The growing importance of soft skills in an increasingly digital world

As described in the previous chapter, routine activities are subject to being automated, and those that need to carry out activities that require human qualities and therefore the so-called *soft* skills cannot be replaced by machines and are therefore essential for the workforce and the workplace (The Adecco Group 2017). As the World Economic Forum (2019) argues: "Human skills such as creativity, originality and initiative, critical thinking and analysis, leadership, and emotional intelligence are not expected to be automated in the near future".

Commenting on the importance of soft skills to select human resources from the perspective of Industry 4.0, Cotet *et al.* (2017) writes, "the rapid evolution of technologies requires a cluster of psychosocial skills – soft skills – to act holistically to resist technological waves''. Similarly, Wats and Wats (2009) note that:

> The central theme of the emergence of a knowledge economy revolves around the knowledge which may be in the form of complex problem solving, innovation and creativity, visualization of new markets, understanding

Table 2. Examples of soft skills

• Communication skills • Critical and structured thinking • Problem solving skills • Creativity • Teamwork capability • Negotiating skills • Self-management • Time management • Conflict management • Cultural awareness • Common knowledge	• Responsibility • Etiquette and good manners • Courtesy • Self-esteem • Sociability • Integrity / Honesty • Empathy • Work ethic • Project management • Business management

Source: Schulz, 2008

social and global implications, working in new environments and with people of different cultures and countries, developing new products and services, etc.

Possessing these skills is therefore indispensable to not to be cut off from the labour market. For this reason, "the government's urge for vocational training programmes to develop basic skills in the unemployed population has pushed universities to expand specialised vocational training for soft skills to enhance employability of graduates" (Cacciolatti *et al.* 2017).

Soft skills complement technical skills and refer to characteristics that are related to communication abilities and personal attributes that enhance an individual's interactions, job performance and career prospects (Cacciolatti *et al.* 2017). Cotet *et al.* (2017) define soft skills as "a cluster of personality traits which have a synergistic effect, contributing decisively to the personal and professional effectiveness" that "describe the attitude of each of us, our compatibility with others and how we manage social interactions mostly in a professional environment [...].

Unlike 'hard skills', which describe a specific set of technical skills, 'soft skills' are recognized as transversal competences, being found at the junction between the professional and social skills".

Another definition of soft skills is given by the Collins English Dictionary (cited in Robles 2012), that uses the term to refer to "desirable qualities for certain forms of employment that do not depend on acquired knowledge: they include common sense, the ability to deal with people, and a positive flexible attitude" as opposed to hard skills that are defined as "the ability, coming from one's knowledge, practice, aptitude, to do something well; competent excellence in performance; and craft, trade, or job requiring manual dexterity or special training in which a person has competence and experience"[16].

Table 2 offers a list of examples (by far not complete) of soft skills based on the Wikipedia definition: "Soft skills refer to the cluster of personality traits, social graces, facility with language, personal habits, friendliness, and optimism that mark people to varying degrees. Soft skills complement hard skills, which are the technical requirements of a job." (Wikipedia 2007; cited in Schulz 2008).

Andrews and Higson (2008) synthesised the available literature and identified in more detail the key 'transferable' soft skills and competencies that are integral to graduate employability: professionalism, reliability, the ability to cope with uncertainty, the ability to work under pressure, the ability to plan and think strategically, the ability to communicate and interact with others (either in teams or through networking), good written and verbal communication skills, Information and Communication Technology skills, creativity and self-confidence, good self-management and time-management skills, a willingness to learn and accept responsibility.

Cacciolatti *et al.* (2017) argues that educational

16 https://www.dictionary.com/browse/soft-skill.

policies might fail by providing the obsolete skills to the industry and they suggest that "schools and universities should modify their curricula to develop creativity and spontaneity of students to foster an open-minded future workforce with right skills and to assist technological and economic development". In the same vein, Robles (2012) points out that while technical skills are a part of many excellent educational criteria, soft skills need further emphasis in the university curricula and that also in the training of managers, while some money is devoted to complying with workplace rules and teaching them the financial basis, oftentimes little attention is given to soft skills.

In general, non-scientific academic programmes put more emphasis on soft skills, or they are themselves by nature soft skill related (Schulz 2008). For example, Kumar and Hsiao (2007) combined professional practice experience of over thirty years and have observed that engineering classes generally focus on technical skills, and they do not provide soft skills courses. The authors note that the curriculums are often so technically demanding that the students don't have time or money to pursue those courses outside. Even if the primary responsibility of an engineering curriculum is to preparing students technically, the today's competitive and changing work environment, and the challenges that the twenty-first century faces, demand that engineers must possess other skills such as the ability to communicate effectively, to function on multidisciplinary teams, to identify, formulate and solve engineering problems, to understand professional and ethical responsibility and so on (Kumar and Hsiao 2007). In an investigation into the students' perception of the importance of soft skills for education and employment, Majid *et al.* (2012) reported that many students felt that their actual soft skills were less than the desired level. For this reason, Robles (2012) suggests that providing students and professionals with soft skills could make the difference in their being hired for a job in their field. Wats and Wats (2009) used a survey to assess the various initiatives for developing students fully equipped with relevant soft skills and they found that some of the best learning methods for developing soft skills were lectures, going through examples, seminars and debates, team working methods, extra-curricular activities, role playing and demonstration, experiential learning, self-assessment and feedback, computer assisted learning, case studies and problem solving and field visit.

Moreover, companies should develop a culture of lifelong learning with customizable training modules focusing on digital disruption that are available for the upskilling of all employees (World Economic Forum 2019).

4. The role of the Centres of Competence

Competence Centres (CCs) are one of the pillars of the Industry 4.0 plan established by the Government to support and follow companies in the process of digital transformation. Their aim is to guide and train enterprises (particularly SMEs) and to implement innovation, industrial research, and experimental development projects in the field of 4.0.

Their importance was made evident with 21 September 2016, on the occasion of the presentation of the National Industry Plan 4.0 2017-2020 by the Minister of Economic Development Carlo Calenda. With the I4.0 plan, the path to the establishment of Competence Centres, the eight centres of excellence for Industry 4.0, was laid out, in February 2019, in Turin. The CCs are public-private partnerships whose task is to carry out business orientation and Industry 4.0 training activities as well as to support the implementation of innovation, industrial research and experimental development projects aimed at the creation of new products, processes, or services (or their improvement) through advanced technologies in Industry 4.0.

One of the distinctive features of these centres is the area of specialization in Industry 4.0 technologies, as we see below.

In causal order, they are:

1. CIM 4.0 - Competence Industry Manufacturing 4.0;
2. Made - Competence Centre Industria 4.0;
3. BI-REX - Big Data Innovation-Research EXcellence;
4. CYBER 4.0 - Cybersecurity Competence Center;
5. START 4.0 - Security and optimization of Strategic Infrastructure Industry 4.0;
6. SMACT Competence Center;
7. ARTES 4.0 – Industry 4.0 Competence Centre on Advanced Robotics and enabling digital TEchnologies & Systems 4.0;
8. MedITech Competence Center I 4.0.

They will have to provide companies with a service that is based on three guidelines:

1. *Training*, with the aim of promoting and disseminating skills in Industry 4.0 through classroom activities, on the production line, and in practical applications, for example through the use of demonstration production lines and the development of use cases, in order to support the user company's understanding of concrete benefits in terms of reducing operating costs and increasing the competitiveness of the offer.
2. *Orientation*, in particular for SMEs, through the development of a series of tools aimed at supporting companies in assessing their level of digital and technological maturity, following the criteria established in annex G (Technology Readiness Levels) of the Horizon 2020 Work Program 2018-2020 (October 2017).
3. *Implementation of innovation*, industrial research, and experimental development projects, proposed by companies, including those of a collaborative nature between companies, and the provision of technology transfer services in industry 4.0, also by stimulating the demand for innovation of companies, particularly SMEs.

In the first years of activity the CCs provided a total of about 150 training events including courses, webinars, etc[17].

SMEs must be accompanied by the introduction of technological innovation tools that allow them to advance the skills of enterprises. Centres of Competence can help the adoption of KETs within companies.

In a significant study, International Data Corporation (IDC) points out that implementing digital transformation projects for companies and manufacturing sectors requires more than technologies. IDC has called *soft skills* such as interpersonal communication, negotiation, and change management *the silent heroes of digital transformation*[18].

The recent pandemic of Covid-19 challenges the status quo regarding the economy, health, and employment in the coming years. The black swan arrived when most of the companies were still defining their digital transformation strategy (Wuest *et al.* 2020). In this new scenario people and organizations have to deal with many challenges.

During the lockdown, many of the activities of CCs were online.

Several Covid measures such as social distancing, travel restrictions and remote work were introduced, and many companies and factories have struggled to remain operational and competitive. Due to digital technologies, we have continued to work, to study, and to keep our social interactions. A recent study conducted by Excelsior-Unioncamere pointed out that the pandemic has intensified the need for soft skills (Unioncamere 2020) which are considered crucial to maintain the motivation of people and to secure the success of the companies when interpersonal relationships are limited. The same research shows that soft skills have become increasingly complementary to digital skills.

On the other hand, many observers agree that the Covid-19 accelerated digital transformation. For example, McKinsey Global Survey (2020) of C-level executives[19] found out that their companies have accelerated the digitization of their supply-chain interaction and of their operations by three to four years and the use of the more advanced technologies, as well.

Due to the pandemic caused by Covid-19, in 2020 *Fondo Nuove Competenze* (The New Skills Fund) was set up. Its first objective was to combat the economic effects of the virus. The FNC refunds the cost, including social insurance contributions, of the hours of work intended for the attendance of the programs of competencies development by workers. The plan provides EUR 730 million (2020-2021) used to refund employees. The project for the development of skills identifies the learning objectives in terms of competences, the beneficiaries of the project, the provider, the charges, the methods of carrying out the learning path and its duration[20].

The OECD survey (2019) on adult skills shows that Italian workers have a low level of cognitive skills, particularly linguistic and mathematical skills, and are less likely to use certain cognitive skills that are determining factors for the performance of workers

17 MISE, Centri di competenza ad alta specializzazione, https://bit.ly/3DesKMS.
18 Developing a Soft Skills Strategy for Digital Transformation, Ott 2017 - IDC Perspective, Doc # US43104617.
19 McKinsey commissioned a survey of business executives around the world in 2020.
20 Anpal Fondo Nuove Competenze – FNC (2020).

and companies. However, they have been shown to have a relatively high level of predisposition to learning and problem-solving skills. This means that targeted policies in the field of vocational education and training could help to develop more skills and make full use of those already gained (OECD 2018).

According to the OECD Survey of Training in SMEs, there are three major barriers that prevent SMEs from further investing to up and re-skilling their workforce: the lack of a learning culture in these firms, their relative inability to identify skills gaps and attract appropriately skilled workers, and their high sensitivity to the cost of training.

The FNC strument is an important labour market policy that can foster a culture of learning among SMEs in Italy. Furthermore, the majority of SMEs lack awareness of the existing policy instruments such as Tax Credit on Training 4.0, The New Skills Found, etc.

In this perspective the CCs should provide mentoring and coaching activities to raise the awareness of the policy instruments in support of the initial investment in training.

The future of the workforce, especially in the industrial sector will certainly depend on the measures and the policy taken by the government, starting from local and regional to the national level, in particular it needs to ensure that the I4.0 technologies are beneficial for employees, for companies and for society.

Conclusions

The main goal of the current study was to determine to understand and explain the impact of Industry 4.0's on the digital transformation process and the effects on occupations and skills.

This study has shown that technological transformation processes are seriously questioning established paradigms and historical practices, not least the system of industrial relations. The interconnection and integration between digitization (the set of devices and sensors capable of transmitting and processing a huge mass of data at a speed until now unthinkable) and automation (availability of robots capable of replacing men's work with greater speed and productivity) have revolutionised production processes, enabling faster and more flexible production and have led to greater customisation of production. In this dynamic and complex context, the professions at lower risk of being automated are those that require to carry out activities that apply the so-called soft skills. Soft skills are becoming increasingly important, and the government and the public sector play a fundamental role in promoting vocational training courses, helping people to manage transformation under way and to ensure them better lives and better jobs.

In recent years there has been a resumption of reflection on industrial policies and on the link between industrial policies and policies for training. In many cases public policies have tried to identify production systems, sectors, or supply chains on which to leverage to drive development.

The emphasis shifts from the intensity in the execution of an elementary task to the commitment and the participation of the worker. The hypothesis put forward in these pages is that these transformations will have an increasing impact on the way in which the public operators, universities and entrepreneurs also define the training paths and professional profiles considered key.

The analysis of the Competence Centres undertaken here has extended our knowledge of the importance of this type of institution in the regional business fabric in: anticipating digital transformation processes; supporting the technological innovation of companies and increasing the added value of company products, especially for the SMEs.

Due to the complementarity nature of soft and hard skills, it is crucial to provide training programmes to develop them in a combinated way.

However, despite the evidence on the importance of soft skills to resist technological waves, educational institutions continue to focus mainly on the teaching of hard skills.

In particular, we have seen that competence centres play a key role in developing emerging digital skills, but neglect teaching soft skills in most cases.

Given their importance in a digitized world, it is essential that training institutions and companies accompany the evolution of technology with a parallel updating of the relative soft skills of their employees, through targeted training paths, so that human capital does not become a bottleneck for digital development, but an essential element to add value to technology.

Further work needs to be done to establish how the changes that the digital revolution brings in businesses and the economy influence business processes and therefore the labour market and the required skills, and to evaluate the ability of different policies to foster the formation of the emerging skills, to benefit from them and to solicit new forms of employability, rather than being overwhelmed by them.

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