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"FROM INDUSTRY 4.0 TO SOCIETY 5.0:
DIGITAL MANUFACTURING TECHNOLOGIES
AND THE ROLE OF WORKERS"

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1. INTRODUCTION

"People need the right digital skills to find jobs and capture opportunities". The proposition is the basis of the European Union's Digital Single Market Strategy, which is part of a broad context aimed at promoting the unification of European markets, with a particular focus on digital technologies. The key purpose is to promote and allow the maximum exploitation of the digital technologies, seen as a tool for growth. Preparing for the future of work is one of the defining business challenges of our time. In pursuing this objective, two directions of intervention can be identified. One linked to the business world, with investments in innovation, and the other linked to the workers, with interventions related to increasing the level of digital competence and the construction of an increasingly inclusive society.

This transition to increasingly smart industrial systems passed through the implementation of systems for collecting and interpreting big data, cloud computing, artificial intelligence and robotics. In this way, more companies moved to industry 4.0, which is built on a new generation of interconnected machines and brings higher levels of automation, autonomous processes and machinery, and data exchange in manufacturing. In fact, industry 4.0 is fuelled by advances in artificial intelligence (AI), robotics, additive manufacturing and the internet of things (IoT).

However, technologies and production departments have profoundly changed compared to the early years of Industry 4.0, transforming the environment in which they are located up to what we call Smart Factory. Evolution and integration have made technology the real protagonist, but at the same time it has emerged how essential the combination with the human factor is for proper management and for achieving the best results. Creating intelligent machines based on collective human–machine dynamism provides an opportunity to enhance human labour with new robot and AI tools instead of substituting human labour with robots (Directorate-General for the Internal Market, 2019).

This is also the motivation for the already upcoming fifth industrial revolution, or industry 5.0, which is focused on the cooperation between humans and machines (Directorate-General for Research and Innovation European Commission & Vanderborght, 2020). The industry 5.0 broadens the scope of 4.0, underlining the human-centred collaborative economy in an increasingly populated, resource-constrained and interconnected world. Factories of the future will have to adapt their work organisation and manufacturing systems, so workers get more meaningful, valuable and healthy jobs.

Recently, the vision report of the industry 2030 high-level industrial roundtable positions the European industry as a global leader that will responsibly deliver value for society, the environment and the economy, embracing the idea of Society 5.0 (Directorate-General for Internal Market, Industry, Entrepreneurship and SMEs, 2019).

Introduced by the Japanese government during the 5th Science and Technology Basic Plan in 2016, the concept of Society 5.0 outlines an ideal vision for the society of tomorrow. It is a real leap forward in human evolution oriented towards the well-being of people and driven by scientific and technological transformations. In the coming Society 5.0 era, operations managers should strike a balance between machines and humans, and focus on more holistic practices and social responsibility to create the "Super Smart Society", a concept developed by Keidanren, the Japanese Federation of Enterprises (Hitachi, 2020). It opens up many new challenges related to technology, socio-economy, regulation and governance: Which skills need to be developed? What kind of rules have to be defined? Which impact may AI have? Which conflicts may arise between humans and AI? (Paschek et al., s.d.)

1.1 Structure of the thesis

The thesis starts with the introduction of the concept of Industry 5.0, performing a brief literature review on the core elements and the advantages, while similarities and connections with the Industry 4.0 is pointed out with the description of the cutting-edge technologies used, increasingly adopted worldwide. Technological advances of the Industry 4.0 era will evolve into another new generation (Anokhin et al. 2021) with more human–machine collaborations and the development of an industrial system with a special emphasis on human–machine interfaces through enabling technologies (Ivanov et al. 2021).

The third chapter focuses on exploring the new role of workers: increased reliance on complex technologies will require new skills and more profound changes in how the workforce is organised will present themselves, challenging industry workers' traditional education life cycle of training and work. After an analysis of the potential work-related diseases brought by new technologies, the most feasible solutions to the risks are introduced, in order to prepare the future of the work.

The fourth chapter describes the Society 5.0 as the extension of the concept of the Industry 5.0 to the society. Two examples are reported as the best in class in the field, Hitachi and Toyota.

Finally, the last chapter implements an empirical analysis on the Italian companies to discover their behaviour towards workers. The worker assumes a central role in the Industry 5.0 and his satisfaction becomes strategic to ensure a competitive advantage for the company. It is therefore important to be able to clearly identify the various strategic levers available to the company to satisfy its workers and make them feel comfortable in the workplace.

The first part simply assesses the adoption of new technologies by the manufacturing firms and the advantages they bring on the productivity. However, the increase in the productivity is not only due by the technologies, because we know that the real engine of a company is the worker. For this reason, with the second part the thesis discovers how much the attention to the worker affects the adoption of new technologies through an empirical analysis on the databases available. Only with the acceptance of the new technologies by the employees is possible to realize a complete “Super Smart Factory”.

2. THE NEW INDUSTRIAL REVOLUTION: INDUSTRY 5.0

2.1 Industry 5.0: concept

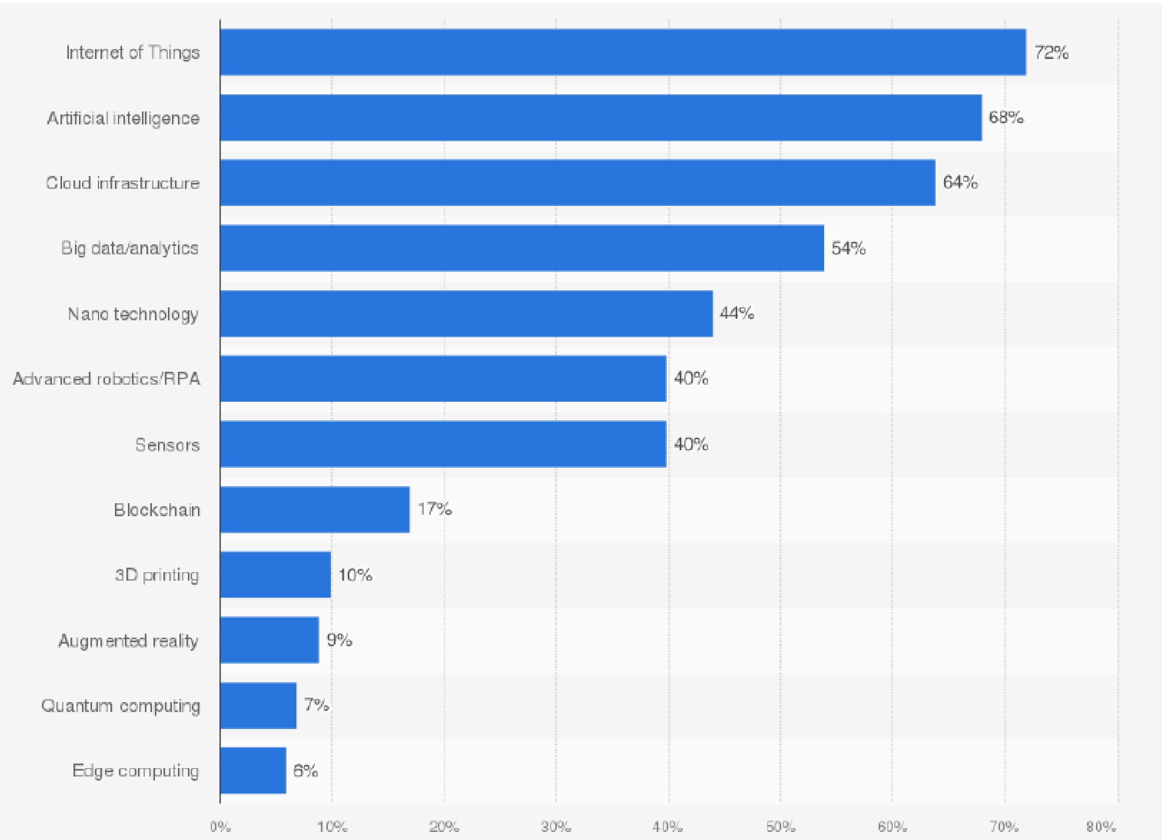
The Fourth industrial revolution is based on the idea of merging the physical and virtual worlds through cyber-physical systems, and interconnecting humans, machines, and devices through the Internet of Things. This horizontal and vertical interconnection across entire value chains, from customer to supplier, across the entire product lifecycle, and across different functional departments forms new value networks and ecosystems. The creation of added value can be made more efficient, personalised, of higher quality, service-oriented, traceable, resilient, and flexible. For this reason, technological advances in the Industry 4.0 era will evolve into another new generation (Anokhin et al., 2021) with more human–machine collaborations and the development of an industrial system with a special emphasis on human–machine interfaces (Ivanov et al., 2021).

The concept of Industry 5.0 was discussed amongst participants from research and technology organisations as well as funding agencies across Europe in two virtual workshops organised by Directorate "Prosperity" of DG Research and Innovation, on 2 and 9 July 2020. In this way, the European Commission formally called for the Fifth Industrial Revolution with the following definition: '*Industry 5.0 recognises the power of industry to achieve societal goals beyond jobs and growth to become a provider of prosperity, by making production respect the boundaries of our planet and placing the wellbeing of the industry worker at the centre of the production process*'. The need to better integrate social and environmental European priorities into technological innovation and to shift the focus from individual technologies to a systemic approach were discussed (Directorate-General for Research and Innovation European Commission & Müller, 2020).

2.2 Industry 5.0: cutting-edge technologies

According to the statistics provided by Statista, as of 2020, new cutting-edge technologies (CET) are projected to have the largest influence on businesses all around the world, as shown in Figure 1. Industry 4.0 is relying heavily on Internet of Things, Artificial Intelligence, cloud infrastructure, and big data/analytics, forming the big four technologies. IoT is on the top of the list, widely considered as one of the most crucial areas of current and future technology with nearly 72 percent of the respondents acknowledging this would be one of the most impactful industry 4.0 technologies within their organization. The second technology that highly impacted organizations worldwide is AI robots, nearly used in every field to increase efficiency and complement human skills (Statista, 2020).

Figure 1: Industry 4.0 technologies with the greatest impact on organizations worldwide as in 2020



Source: Statista 2022

The technologies at the core of Industry 5.0 are largely congruent with Industry 4.0, but with a stronger focus on human-centred technologies. To better explain, where Industry 4.0 has the smart technology at the forefront of manufacturing, 5.0 is based on an increased collaboration between humans and smart systems. For this reason, Industry 5.0 should not be understood as a replacement nor an alternative to, but an evolution and logical continuation of the existing

Industry 4.0 paradigm. This paradigm shift is based on the idea that technologies can be shaped towards supporting values, while the technological transformation can be designed according to the societal needs, not vice versa. This is especially important as ongoing societal developments in the fourth industrial revolution change the way value is created, exchanged, and distributed. Further, technologies in Industry 5.0 must be regarded as part of systems that are actively designed towards empowering societal and ecological values, not technologies that determine societal developments. For example, the primary focus of technologies used should not be to replace the worker on the shop floor, but to support the workers' abilities and lead to safer and more satisfying working environments. New skills are necessary, but the collaborative workplace will be beneficial for all in the long term. According to Atwell, marrying the two will merge the high-speed accuracy of industrial automation with the cognitive, critical thinking skills of humans (Atwell, 2017).

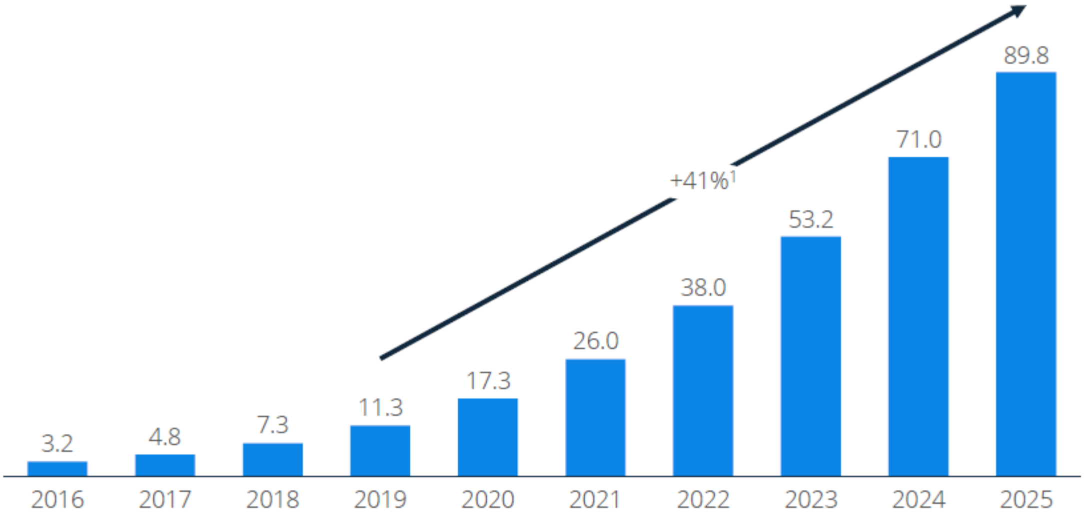
In fact, according to a 2016 study conducted by the MIT, teams made of humans and robots collaborating efficiently can be 85% more productive than teams made of either humans or robots alone. In addition, Ostergaard (Universal Robots' Chief Technology Officer) pointed out that the next Industrial Revolution will be necessary to meet consumers' high demand for individualized products. Only human problem-solving skills, value-adding human creativity, and the critical and exclusively human ability can enable to deeply understand customers (Østergaard E. H., 2017).

From these initial studies, companies started to understand the advantages of Industry 5.0 and the investment on collaborative robots (i.e., cobots), AI and IoT increased.

In February 2020, the General Directorate for Research and Innovation published a report on the potential of collaborative robots for economy and society while embracing European values. This report offers a vision on collaborative industrial robotics based on ten assessment criteria, with seven recommendations as a contribution to the preparation of the strategic plan of Horizon Europe. The report states that industrial collaborative robots are a unique technology that has the potential to improve both the economy and society while embracing Europe's values if conducted by a proper management (Directorate-General for Research and Innovation European Commission & Vanderborght, 2020).

In fact, according to Statista, the revenues of the combination of AI and robotics expected to grow at a CAGR of 41% during 2019-2025 (Figure 2).

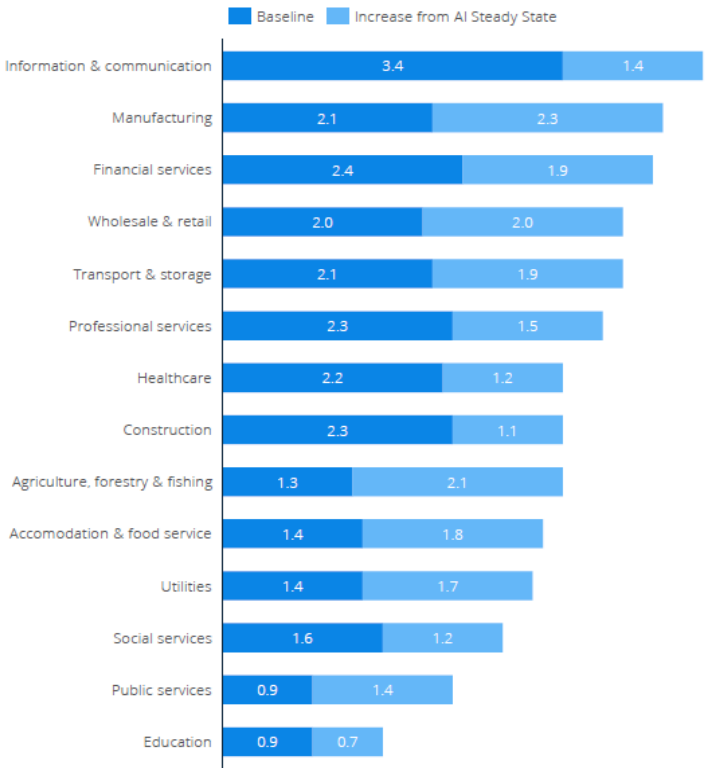
Figure 2: Global revenue projections in billions US$



Source: Statista Digital Market Outlook, In-depth: Industry 4.0 2021

In particular, a study from Accenture and Frontier Economics assessed the impact of AI in different industries. They took into consideration the values of the GVA growth rates, which represents a close approximation of a country‘s GDP. The results underline that the manufacturing industry expects to have the biggest impact of AI on real GVA by 2035 (Figure 3).

Figure 3: Potential impact of AI on real GVA by 2035 in % of growth in by industry



Source: Statista Digital Market Outlook, In-depth: Industry 4.0 2021

Regarding the IoT, it is not a novel technology, because sensors have been in use for over fifteen years. It is only the recent drop in their prices, enhanced computing power, advances in data connectivity in the cloud, and machine-to-machine communication that have stimulated their use in smart factories. When Kevin Ashton coined the term Internet of Things (IoT) in 1999, he ushered in a new era in computational technology. Computers no longer needed to be programmed for each use case but could simply feed off the information being given out by devices connected to each other through the internet. The use of this technology gained momentum in the manufacturing industry, thus setting the stage for the next industrial revolution known as the Industrial Internet of Things (IIoT). Latest advances in connected devices through smart sensors that result in the real time exchange of data is probably the most important cog in the digitalization of manufacturing. This is mainly because it is the use of these sensors to connect various devices across the value chain that is responsible for the convergence of previously standalone production technologies.

According to a 2020 survey of mainly North American respondents conducted by Plataine, a provider of optimization solutions based on IIoT and AI, the manufacturing industry's IoT adoption had tripled as compared to 2018. Moreover, 66% of respondents also stated that they found IIoT to be one of the key technologies for the future of their company's success and profitability. According to the World Economic Forum (WEF), IoT investment in production doubled from US$35 billion in 2016 to US$71 billion by the end of 2020, with three key functions driving investments: asset tracking, condition-based maintenance, and robotics processing. In today's production scenario, IoT systems have three key uses:

- Smart enterprise control.

IoT allows smart connected machines and connected manufacturing components to be linked to a central computing system, which results in efficient production and lower costs.

- Asset performance management.

Wireless sensors, cloud connectivity, and data analytics will result in a more efficient real time flow of information on the working of connected machines and lead to accurate predictions of machine breakdowns and thus aid predictive maintenance.

- Augmented operators.

Even though there has been speculation on machines making humans redundant in the smart factory, future employees are expected to make use of IoT technologies to instead assume specialized roles, thereby making the manufacturing plants more user-centric and less machine-centric.

2.3 Industry 5.0: enabling technologies

Humans define the strategy, give supervision, and contribute creative input, while technology does the dull, repetitive, and error-prone activities: technology enables, people lead.

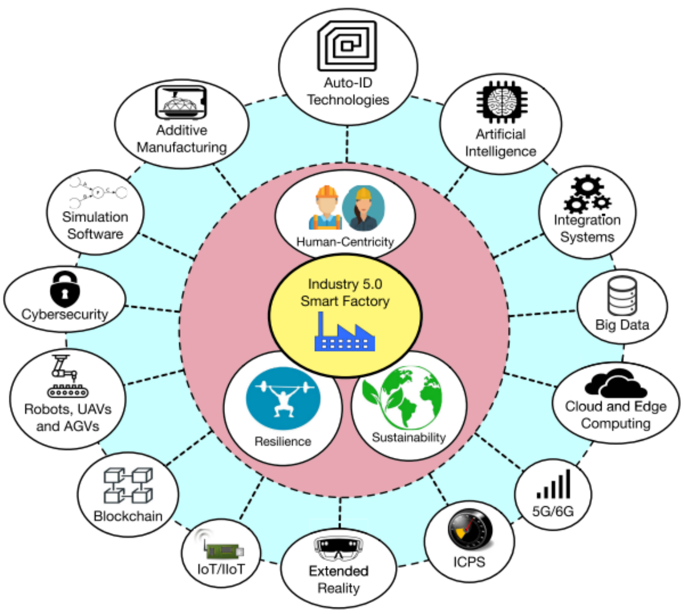
This is the reason why the enabling technologies are a key characteristic of the industry 5.0. They are a set of complex systems that combine technologies of the industry 4.0, such as smart materials, with embedded, bio-inspired sensors. Six categories have been identified, each of which is considered to unfold its potential combined with others, as a part of technological frameworks (Directorate-General for Research and Innovation European Commission et al., 2021):

1) Individualised human-machine-interaction that interconnect and combine the strengths of humans and machines;
2) Bio-inspired technologies and smart materials that allow materials with embedded sensors and enhanced features while being recyclable;
3) Digital twins and simulation to model entire systems;
4) Data transmission, storage, and analysis technologies;
5) Artificial Intelligence;
6) Technologies for energy efficiency, renewables, storage and autonomy.

In the following paragraphs the main technologies included in these six clusters will be investigated deeper to better understand their peculiarities and applications.

A graphic representation is made in the Figure 4.

Figure 4: Key enabling technologies for Industry 5.0



Source: ResearchGate, Scientific Diagram

2.3.1 Individualised Human-machine-interaction

The following technologies support humans in physical and cognitive tasks, used to combine human innovation and machines capabilities:

 Multi-lingual speech and gesture recognition and human intention prediction;

 Tracking technologies for mental and physical strain and stress of employees;

 Robotics: Collaborative robots, which work together with humans and assist humans;

 Augmented, virtual or mixed reality technologies, especially for training and inclusiveness;

 Enhancing physical human capabilities: Exoskeletons, bio-inspired working gear and safety equipment;

 Enhancing cognitive human capabilities: Technologies for matching the strengths of Artificial Intelligence and the human brain (e.g., combining creativity with analytical skills), decision support systems;

There are several examples and cases about these technologies.

Recently, Esselunga has introduced a robotic exoskeleton in collaboration with Comau (a company controlled by the Italian-French group Stellantis), and Iuvo (a company of the prestigious Scuola Superiore Sant'Anna university) to improve the well-being of workers by reducing the sense of fatigue in the lumbar area. Comau and Iuvo have already launched Matext on the market, an exoskeleton for the upper limbs. It has been designed to support the operator during the execution of manipulation activities that require raised arms. According to data collected by numerous companies that use this technology, it has been shown to reduce operator effort by approximately 30% and improve productivity by approximately 10%.

"The collaboration with Esselunga, a point of reference in the large-scale distribution sector in Italy, for the creation of an exoskeleton for lumbar support, confirms Comau's commitment to the development of new technologies capable of guaranteeing better ergonomics and the well-being of the operator when carrying out heavy-duty activities", declared Giacomo Del Panta, Comau's chief customer officer. "By paying great attention to the health and well-being of workers, it also confirms its commitment to developing sustainable and human-focused production processes", concludes Del Panta (Carrà, 2022).

2.3.2 Bio-inspired technologies and smart materials

Bio-inspired technologies and processes stemming from the concept of Biological Transformation can be integrated with, for instance, the following properties:

 Self-healing or self-repairing;

 Lightweight;

 Recyclable;

 Raw material generation from waste;
 Integration of living materials;
 Embedded sensor technologies and biosensors;
 Adaptive/responsive ergonomics and surface properties;
 Materials with intrinsic traceability.

Several operational efficiencies, such as labour, logistics, and quality control costs are improved with sensor deployment. Sensors have improved inventory counting, material sorting, and automation, leading to greater productivity. Further, they are also helpful in identifying root errors in manufacturing while driving better product design. For example, assembly lines for wearables can send pictures to design engineers in real time through smart-sensor technology. This allows engineers to identify any manufacturing issues at the time of assembly before they become a point of failure, thus saving a lot of time.

Leading players, such as Mitsubishi, are investing to boost automation systems, because embedded sensors can enhance the manufacturing process at every stage:

▪ Improving operational efficiency.

Sensor-enabled labour monitoring helps reduce idle workforce time by optimizing assignments. Sensors used for quality inspection on assembly lines close the physical-digital loop for manufacturing issues in minutes.

▪ Improving asset management.

Critical equipment is connected and monitored through sensors to proactively address potential interruptions.

▪ Real-time inventory tracking.

Radio frequency identification (RFID) sensors used for low-cost, touch-free item identification and tracking can potentially reduce the risk of inventory shrinkage or loss. Smart sensors for omnichannel retailing, such as products and packaging embedded with smart sensors, make automatic reorders and refills possible.

▪ Product design.

Connected products offer insights into customer behaviours and preferences, allowing for more responsive product development (Boukhalfa, 2021).

2.3.3 Digital twins and simulation

Digital twins and simulation technologies fuse ideas including artificial intelligence, the internet of things, metaverse, and virtual and augmented reality (VR/AR) to create digital models of real-world objects, systems, or processes. Simulations help to understand what may happen in the real world; digital twins allow to compare and assess what may happen alongside what is happening. Both optimise production, test products and processes and detect possible harmful effects, for instance:

 Digital twins of products and processes;

 Virtual simulation and testing of products and processes;

 Multi-scale dynamic modelling and simulation;

 Simulation and measurement of environmental and social impact;

 Cyber-physical systems and digital twins of entire systems;

 Planned maintenance.

While an advanced simulation can analyse thousands of variables, a digital twin can be used to assess an entire lifecycle. This was demonstrated by Boeing, who integrated digital twin into design and production, allowing them to assess how materials would perform throughout an aircraft’s lifecycle. As a result, they were able improve the quality of some parts by 40%.

Businesses around the globe are looking to deploy Digital Twins across a broad range of applications, ranging from engineering design of complex equipment and 3D immersive environments to precision medicine and digital agriculture. However, to date, applications have been highly customized and only accessible for high value use-cases, such as the operations of jet engines, industrial facilities and power plants.

In the manufacturing industry, Tesla creates a digital simulation of its cars, using data collected from sensors on the vehicles and uploaded to the cloud. These allow the company's AI algorithms to determine where faults and breakdowns are most likely to occur and minimize the need for owners to take their cars to servicing stations for repairs and maintenance. This reduces cost to the company of servicing cars that are under warranty and improves user experience, leading to more satisfied customers and a higher chance of winning repeat business (Marr, 2022).

2.3.4 Data transmission, storage, and analysis technologies

Energy-efficient and secure data transmission, storage, and analysis technologies are required, with properties such as:

 Networked sensors;

 Data and system interoperability;

 Scalable, multi-level cyber security;

 Cyber security/safe cloud IT-infrastructure;

 Big data management;

 Traceability (data origin and fulfilment of specifications);

 Data processing for learning processes;

 Edge computing.
Many multinational companies collect large amount of data to disclose patterns and trends after a proper analysis. In this way, they can make adequate decisions in less time and meet their customer's needs as soon as possible.
Amazon is a well-known e-commerce platform. It stores every single piece of information related to its customer as a means of figuring out how customers are spending their money on an individual product. All this information is being collected to use in social media advertising algorithms that can be further used to expand customer relations, recommending products, improving customer experience and services. For example, when a customer adds a product to the Wishlist or buys it, then Amazon recommends some items related to the product or it shows items bought together with that product. In this way, Amazon uses big data in leveraging recommendations to facilitate immediate purchases from a customer and increases the entire shopping experience. Moreover, Big Data is used to handle the prices of products to pull in more customers and rise the net profit.
Another good example is Apple, an expert in using advanced technology. The data collected is used by the company to consider the best approach towards consumers with its new products and services: Apple can find how people are using apps in real life and change future designs to fit with customer preferences. For instance, the Apple watch is not just a wearable, but it also has the ability of data gathering (Kumari, 2021).

2.3.5 Artificial Intelligence

Artificial intelligence, nowadays often still referring to advanced correlation analysis technologies, must be developed further in several regards:
 Causality-based and not only correlation-based artificial intelligence;
 Show relations and network effects outside of correlations;
 Ability to respond to new or unexpected conditions without human support;
 Swarm intelligence;
 Brain-machine interfaces;
 Individual, person-centric Artificial Intelligence;
 Informed deep learning (expert knowledge combined with Artificial Intelligence);
 Skill matching of humans and tasks;
 Secure and energy-efficient Artificial Intelligence;
 Ability to handle and find correlations among complex, interrelated data of different origin and scales in dynamic systems within a system of systems.

Ideally workers need easy access to the right information at the right time to get their work done, because the context-switching involved in jumping between applications to access the information they need can cost productive time. Manually that is near impossible, but AI in systems like Guru and Microsoft Viva can automate much of that work. According to Alan Pelz-Sharpe, founder and principal analyst at Deep Analysis, “Scale rather than complexity is the key”. He said, “Humans can do incredibly complex work, but they don’t scale. AI can. So, with knowledge management, you have a decades-old concept that is only now able to come to fruition; as though in concept it worked, in practice it could not scale." (Dom Nicastro, 2021)
Complementing real-time communication with a collaborative knowledge base is key to keeping teams aligned and productive. Guru’s app for Microsoft Teams can make both real-time and asynchronous collaboration easier by bringing knowledge directly to the place where people already work. In fact, with the updated integration for Teams, workers can access and share verified knowledge from Guru and collaborate with their teammates within the Teams workflow. With AI, updates don’t go unnoticed and teams spend less time searching for information and more time delivering value (Microsoft Teams, 2021).

2.3.6 Technologies for energy efficiency, renewables, storage and autonomy

As most technologies mentioned requires large amounts of energy to operate, the following technologies and properties are required to achieve emission neutrality:

- Integration of renewable energy sources;
- Support of Hydrogen and Power-to-X technologies;
- Smart dust and energy-autonomous sensors;
- Low energy data transmission and data analysis.

The italian start-up Greenled Industry specializes in long-lasting smart lights and lighting controls for extreme industrial conditions and for smart city applications. Its solutions focus on achieving maximum light intensity with minimal power consumption, mediated by smart zoning, occupancy sensors, and performance monitoring. The main technology it uses is the motion sensitive smart lighting, which helps to save energy and maintenance costs by regulating brightness automatically based on room occupancy, level of activity, time of the day, and through remote control. Moreover, wireless connections assist in establishing strong communications between smart lighting components (StartUs Insights, 2019).
Integrating the advantages of LED technology with light management systems allows for benefits that go beyond simple lighting. State-of-the-art infrastructures and new technologies take on a fundamental role in improving the quality of life, promoting the well-being of people, and developing companies that are more sensitive to culture, the environment and innovation.

3. THE ROLE OF WORKERS IN THE INDUSTRY 5.0

The highly transformative impact of a digital, data-driven and interconnected industry is bolstered in the concept of the fourth industrial revolution. Then, Industry 5.0 accentuates a clear change from mass automation to the process of enhancing the capabilities of human workers. A transformed industry will have a transformative impact on society as well. This is foremost true for industry workers, because a more diversified workforce and higher expectations are required. Jobs have become increasingly service-focused and cognitively complex and demanding.

All these events happen very fast and bring with them important advantages, but they can have also other consequences: stress and work-related diseases.

In fact, in the Industry 5.0 technologies such as human-machine-interfaces, merging human brain capacities with artificial intelligence or collaboration with robots and machines were introduced within industrial assembly lines to improve productivity and support workers through an interactive process. This should allow safer, more satisfying and more ergonomic working environments, in which humans can use their creativity in problem-solving, adopt new roles, and enhance their skills: the core idea behind Industry 5.0 is to choose technologies based on an ethical rationale of how those support human values and needs, and not only based on what they can achieve from a purely technical or economic perspective (Directorate-General for Research and Innovation European Commission and Müller, 2020).

However, the literature reports that nearly 50–75% of implementations of automation have failed in terms of quality, flexibility and reliability (Chung, 1996). It is clear that more profound changes in how the workforce is organised presented themselves, challenging industry workers' traditional education life cycle of training, work and retirement. First of all because changing roles and increased reliance on complex technologies require new skills. Indeed, it is important to consider human-related issues (Castrillón and Cantorna, 2005; Ghani and Jayabalan, 2000) and human factors that might result in unsuccessful implementations, as people will tend to feel frustrated, neglected, and overpowered by the technology (Kinzel, 2017). The influence of technology on workplace mental health depends on how it is implemented, organisational norms around its use, and employee perceptions of its effect on their role. A negative attitude toward technology could prevent its acceptance and adoption, although it is intended to help workers in specific tasks (Faccio et al., 2022).

This thesis wants to discover how the role of workers change in context that use these technologies. The question behind is: will workers be empowered in their industrial work and attracted to work in new high-tech environments?

3.1 Stress and work-related disease

The concept of stress is usually linked to a negative concept that should be eliminated. Instead, a certain level of stress is necessary to focus on the working activity, to be active and reach successful objectives. The World Health Organization defined mental health as "*a state of well-being in which every individual realises his or her own potential, can cope with the normal stresses of life, can work productively and fruitfully, and is able to make a contribution to her or his community*".

Recently, the word "stress" was introduced in Italy, which literally means "effort, squeeze". The term was initially used in the engineering to explain the strain that a body can withstand before its breakdown. It spread during some congress in the medical field organized by Hanz Selye during the 1950s. Hanz Selye identified two types of stress: a positive stress called eustress and a negative one called distress. The former is linked to pleasant situations, seen as challenging and to which people and workers react with energy and vitality. It is considered to be constructive environmental stimulation. The latter is linked to situations perceived as destructive. It manifests itself in the form of anxiety, worry and a widespread sense of discomfort associated with negative consequences for the emotional and mental state.

The European Agency for Safety and Health at Work (EU-OSHA) has been underlining how the development of digital technologies is changing the nature, the location, the subjects, the times and the methods of organization and management of work activities. It is such a significant topic that a new European campaign "Healthy and safe workplaces" will be held from 2023 to 2025, with a focus on the creation of a safe and healthy digital future and on the prevention of risks associated with technological and digital evolution.

In fact, occupational safety and health experts are increasingly concerned about the possible effects of new procedures, new roles, and new digital tools on the worker's physical and mental health. Several studies have investigated how other automating technologies have reshaped the work environment in the past decade. These studies show that rapid advances in technology and automation reduce informal learning, motivation, and interdisciplinary cooperation among workers, and that they lead to rising levels of uncertainty, lower situation awareness, and distrust towards automation (Bakker and Demerouti, 2017; Bonekamp and Sure, 2015; Cascio and Montealegre, 2016; Ghislieri, Molino, and Cortese, 2018).

The first risk considered in this context is related to the use of the internet. The negative effects of an inappropriate use of the internet include technological dependence, lack of work-life balance, and inappropriate behaviour in the workplace (Abubakar, A.M. and Al-Zyoud, M.F., 2021). In fact, it has an impact on a relational level because activities become more abstract, physical interactions at work decrease, data and information increase exponentially.

Relationships mediated mainly by digital devices reduce personal contacts by generating misunderstandings and increasing the risk of sending or receiving negative messages.

Other consequences include the development of the always-on feeling and technostress episodes, phenomena that occur in strictly technological environments where workers are always connected, 24 hours a day, 7 days a week and it can lead to a feeling of detachment from reality. The aspects that influence technostress can be *cognitive*, information overload due to information characterized by a quantity and speed that require an expenditure of cognitive resources that is difficult to manage; *organizational*, new possibilities of virtual interchange that allow to always be reached; *social*, uninterrupted flow of communication and constant contact between users; *cultural*, absence of a culture of health and safety related to this new reality.

As more jobs become cognitively complex and demanding, researchers observe that workers experience distress about job insecurity, being insufficiently trained: the fear of losing one's job as many activities and operations, which previously were the responsibility of workers, may be automated in the future (Brougham and Haar, 2018; Nazareno and Schiff, 2021).

All these aspects lead to psychological stress, which includes conditions such as anxiety, mental fatigue, the possible feeling of frustration or isolation, and, generally, excessive cognitive workload. Excessive cognitive load, linked to the use of technology, can reduce the levels of attention with respect to the main task to be performed, generate physical fatigue, have negative effects on long-term memory and decrease mental acuity. Safety experts pay particular attention to the above-mentioned conditions since they can cause accidents within industrial plants, increasing the risk of injury. For these reasons, the introduction of digital technologies in the organizational field has to be preceded by a careful assessment of the possible effects on health and safety and adequate training of workers.

However, it is important to underline that people can react in a different manner to similar situations, in different moment of life. For example, Rossato et all investigated in which extent the age affects the acceptance, usability, and task load related to cobot usage. Initially, higher frustration was reported by senior operators and the tasks were accomplished more slowly than adult workers. This could be related to their lower experience. However, they reported a sufficient or good performance and a good degree of confidence in using this tool after the experiment (Rossato et al., 2021). This means that the adoption of new technologies in the workplace is highly unpredictable, and therefore can be either detrimental or beneficial, depending strongly on how it is deployed, how the process is monitored, and which policies are in place to ensure sustainable employment (Graus et al., 2021).

3.2 New and emerging risks in detail

Nowadays, new technologies represent an important innovation, and they can significantly change the way of working. It is clear how technology affects workers in today’ workplace and will continue to do so in the future, as described in the previous paragraphs.

Inail, as part of the Scientific Research activities in collaboration - BRIC2019, funded the ID 50 project entitled "Risk analysis and mitigation tools for the protection of the health and safety of workers in work contexts subject to digital transformation".

The general objective of the project was to carry out a detailed analysis of the impacts that digitalisation may have on the protection of workers' health and safety, by identifying priorities for action and defining specific mitigation tools to respond to new emerging risks. In particular, it was examined the most widely implemented technologies in the manufacturing field: they are most of all enabling technologies of the Industry 5.0.

Interesting for this thesis is the assessment of the organizational and psychosocial hazard provided.

Organizational hazards occur when the source of risk is connected to procedures, methods, criteria, and organization solutions that are not related to the worker’s actions.

Psychological hazards derive from the worker’s subjective perception of the work and the interaction with the digital technologies.

The results are divided into the six technological categories examined and they are presented below.

3.2.1 Smart wearables

Smart wearables are intelligent, consumer-connected electronic wearables that can be worn on the body as an accessory or incorporated into clothing. They are often used in production environments to monitor working conditions and report risky situations, when necessary. Smart wearables can send alarm signals to one worker or to the people responsible for monitoring the working conditions of a specific production area (Gnoni et al., 2020). According to the existing literature, it is possible to implement several solutions in this regard. The most widely used solutions are the GPS monitoring of the workers’ position, and the monitoring of biological and physical parameters, e.g., heart rate monitoring, number of steps, speed, the level of exercise and other activity values with smart bracelets (Lööw et al., 2019).

Further smart solutions include the use of smart helmets and smart belts. In fact, by simply implementing an electronic system in a regular helmet it is possible to detect different parameters in the working place, such as brightness, temperature, and humidity. Moreover, it is also possible to insert led lights that switch on every time a worker on the side of the helmet operates in a particularly dark area, as well as a sound amplifier that allows hearing inaudible alarm signals. Smart belts, on the other hand, implement RFID technologies to control the workers' access to different buildings and to report hazards, i.e., falls and incorrect contacts with the machines.

In this context, organizational hazards are connected to the prolonged use of the devices, with consequent muscle fatigue, postural damages, muscle destabilization, and technostress (Ehrlich et al., 2018; Walter et al., 2018; Lunetto et al., 2019). In addition, the fact that safety condition monitoring is performed mainly by machines may expose workers to greater risks, reducing the overall surveillance level and, sometimes, even private medical checks. The continuous monitoring and personal data registration, i.e., localization, give rise to a fear of privacy violation (Khakurel et al., 2017; Choi et al., 2017).

If not adequately trained, workers may not fully understand the devices' behaviours and, consequently, they may be more exposed to hazards. Finally, the continuous use of different technologies may lead to the development of a form of addiction and separation anxiety from such devices (Ehrlich et al., 2018; Lunetto et al., 2019).

3.2.2 Robots and Cobots

The implementation of automation and robotics within production systems can minimize the need to work in hazardous working environments, like in narrow or high-altitude spaces. Moreover, these technologies allow to perform routine or repetitive tasks on fast, precise, and tireless machines, and they also facilitate access to work for people with physical or structural impairments. Although the objective of automation and technologies is to support workers in different circumstances, these technologies may pose several hazards for the users, especially in human-machine collaborative activities or activities where the two subjects work nearby.

Organizational hazards concern repetitive tasks performed at the pace of robots and cobot, potentially causing fatigue, musculoskeletal stress, psychological stress and physical overload (Faria et al., 2020; Dombrowski et al., 2018), as well as additional damages caused by a monitoring decrease (Moore, 2019; Gualtieri et al., 2020).

Contrastingly, a reduction of the activities performed by humans and the consequent decrease in the attractiveness of the job can produce a cognitive underload and damages connected to a decrease in the concentration levels of the operators (Steijn et al., 2016; Meissner et al., 2020). Furthermore, workers may experience significant mental stress when performing operations in the proximity of the machines, since collisions are a possible consequence (Bragança, 2019). When operators and robots share working spaces, they may collide directly or indirectly, for example with falling objects (Jansen et al., 2018). Moreover, robots may also be implemented in spaces different than those they were designed for, hence leading to possibly dangerous situations, for example damages caused by the unpredictable behaviour of the machine or by collisions due to the inadequate workspace (Steijn et al., 2016). Additionally, inadequate robot movement fluency may cause discomfort, cognitive stress, and collisions (Rojas et al., 2020).

If not adequately trained, employees may see robot and cobot implementation as a threat, and they may fear redundancies or subjugation, unpredictable behaviours of the machines, and the possibility to develop a dependency from third parties, namely repair workers (Meissner et al., 2020). To avoid unexpected behaviours of the machines, device configuration parameter changes should always undergo an authorization phase, which can also prevent errors made by operators during the amendment phase or the implementation of the machine.

Unexpected behaviours of the machines could be also caused by vague or unclearly transmitted instructions (Pérez et al., 2020); by actions performed by the devices as a result of the operators' behaviour, which may scare and shock the workers; or by the machine's ability to learn in an autonomous and automated way, which may cause damages to the operators (European Commission, 2018).

Finally, psychological hazards are connected to the implementation of robots and cobots. These hazards are particularly significant since the interaction with different devices and the reduced contact with the co-workers may lead to social isolation, to a feeling of inferiority and subordination to the machines, which can operate faster and are ever more often implemented in workplaces. Possible damages in this context include increased psychophysical stress, caused by the perception of inadequate safety conditions, increased collision occurrences, caused by the excessive reliance on the devices' ability to detect humans and to think (Murashov, 2016) and feelings of mental stress, fear, and insecurities, caused by the variability and unpredictability inherent with robots and cobots (Digmayer et al, 2019).

Standards for the implementation of these solutions already exist. However, it is possible to note a lack of guidelines or regulations that comprehensively address all the issues connected to the hazards deriving from the implementation of robots and cobots in industrial settings.

3.2.3 AR/VR

The implementation of augmented reality (AR) and virtual reality (VR) systems is often beneficial, supporting workers during different working phases. Nevertheless, the use of AR and VR systems poses new hazards for the workers.

Organizational hazards are mainly related to the varying lighting conditions of the workplace, which may cause, for instance, eye dryness, glare damages, and visual discomfort due to the need to adjust to the different light levels (Marklin et al., 2020). As far as organizational hazards are concerned, the extended use AR and VR devices may lead to discomfort, eye fatigue (Stoltz et al., 2017; Friemert et al, 2020), nausea, dizziness, disorientation, motion sickness, headache, social isolation (Barrett, 2004; Spiegel, 2018), increased heartbeat and breathing rate, as well as gastric damage, damages caused by distraction and unpredictable long-term musculoskeletal consequences (Gross et al., 2018). Furthermore, the significant information load may lead to damages caused by cognitive overload (Friemert et al., 2019); screen latency, that is the difference between the operator's head movement and the image display on the screen, may provoke headaches; while the overlap between virtual images and real objects may cause eye fatigue due to the different focal lengths (Gallagher et al., 2018).

AR and VR technologies are also frequently used to instruct workers in real-time. However, despite the numerous advantages, the implementation of these technologies can lead to an excessive psychophysical workload. AR and VR technologies may lead to a despecialization of job duties, which may consequently cause a decrease in the skills of the operators, thus posing serious risks for the workers. Inadequate training may lead employees to handle devices without fully understanding their potential and possible responses (European Commission, 2018). According to the analysed literature, users may also fear privacy violation since the implemented devices can capture images and record videos (Stoltz et al., 2017).

Finally, psychological hazards should be taken into account as well. Operators may grow accustomed to employ such technologies, thus developing a form of addiction and separation anxiety, while the excessive physical and mental load can cause technostress, and the frequent use of technological devices may lead to social isolation (EU-OSHA, 2019).

In conclusion, AR/VR devices raise several issues for workers' health and safety. In this context, the most thoroughly investigated topic concerns the impact of technology on the musculoskeletal system. In fact, it was proven that some activities and the poor postures workers have while using the above-mentioned technologies can cause musculoskeletal disorders, which can have adverse effects in the long term.

3.2.4 Exoskeleton

The implementation of exoskeletons in the workplace raises questions about the workers' health and safety. On the one hand, exoskeletons can help reducing muscle tension in the workplace by physically assisting workers, preventing possible WRMSDs (Work Related Musculoskeletal Disorders), or supporting workers with impairments. On the other hand, however, exoskeletons may pose new hazards for workers.

Operators wearing such devices often have limited mobility and are therefore unable to avoid the collision with falling objects, or, contrastingly, they may perform improper movements or overexert themselves, thus provoking muscle damages. Moreover, the additional weight of the devices and their dimensions may lead to complications, i.e., damages caused by the difference in art-leg kinematic, musculoskeletal issues, muscular fatigue, minor damages and pressure injuries, nerve compression, respiratory fatigue caused by a decreased chest excursion and by an increased chest pressure (Howard et al., 2020) discomfort, cardiovascular issues, wrong weight redistribution between different body parts (Peters et al., 2019), spine overload or damages connected with bad posture, with reduced reactivity, with collisions with other operators or robots, and with imbalances, slips, trips, and falls (Steinhilber et al., 2020). Furthermore, the increased directional load may cause damages linked to dynamic events (Sunwook et al., 2018).

As far as organizational hazards are concerned, because of the device's ability to monitor personal data like localization, operators are concerned with privacy violation issues (Khakurel et al., 2017). Moreover, the general increase of the exoskeletons' physical capabilities may cause cognitive overload, while the inadequate employee training may give rise to fears and insecurities both at a personal and professional level.

Finally, the implementation of exoskeletons also poses psychological hazards. The operators' excessive reliance on the devices may lead to a decreased attention to security measures, and a muscle density loss. In this context, as a consequence of the constant use of exoskeletons, operators may develop a fear of stigmatization in the workplace, and they may be afraid, for instance, of being perceived as technology-dependent (Howard et al., 2020, Peters et al., 2019).

In conclusion, the hazards related to exoskeleton technologies seem to have a significant impact, especially in the long term. Consequently, the workers' health and safety conditions can be estimated but they cannot be adequately specified yet. Scientific evidence and practical experiences in this field are still limited. Therefore, further studies on exoskeletons should take into account the aspects concerning the user's safety.

3.2.5 Digital Twin

In the existing literature, the issues related to Digital Twin technological solutions are mainly connected to their implementation efficiency. For instance, the main problems associated with IoS (Internet of Simulation) solutions concern the choice of the simulation's objective, the trade-off between the desired quality and the simulation's execution speed, and cost assessment. Specifically, this last point implements economic feasibility analyses in order to understand the simulation reproducibility of the environment under analysis, which has a significant impact on the realism of the obtained results (McKee et al., 2017). However, the analysis of the existing studies did not reveal significant health and safety hazards for workers.

3.2.6 Wireless communication technology

The use of wireless technologies poses new hazards for the workers, who are exposed to new possible hazards.

On an organizational level, since health and safety conditions are monitored by the devices, operators are exposed to risks caused by a general decrease in supervision (Khakurel et al., 2017). Moreover, since operators are constantly monitored by technology, they may suffer significant psychological pressure, which is one of the possible psychological hazards connected to the use of wireless communication technologies (Lunetto et al., 2019).

Similar considerations can be also made in relation to specific wireless technologies, such as Radio Frequency Identification and Bluetooth Low Energy (Gnoni et al., 2020).

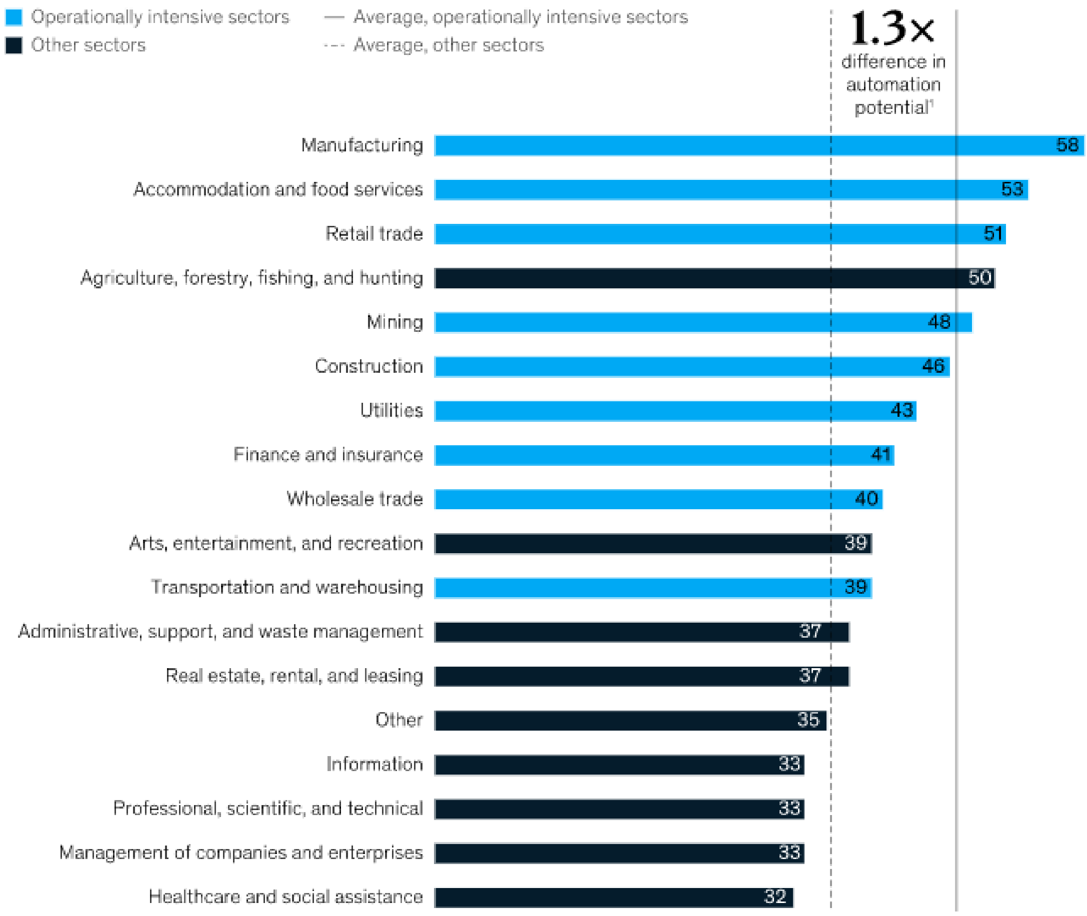
3.3 Preparing for the future of work

"Traditional work models do not provide the agility, scalability, and resilience required by the future enterprise. To drive growth and competitive differentiation, organizations will invest in technologies and services that power automation, human-machine collaboration, new organizational structures and leadership styles, dynamic learning opportunities, a reimagined workplace, and a digital work environment that is not bounded by time or physical place," said Holly Muscolino, research vice president, Content Strategies and the Future of Work (International Data Corporation, 2021).

The rapid changes in technology are unlikely to leave millions of workers without jobs. However, these technological advancements are likely to present more risk of unemployment for some groups. Specifically, low skilled and older employees are at risk of unemployment if companies fail to invest resources in training and job transition programmes. Education, reskilling and upskilling are certainly among the most pressing issues to address when accommodating the digital transition in industries, as qualified human capital is of the maximum importance to make it a reality (Directorate-General for Research and Innovation European Commission et al., 2021). Such efforts will help high-risk employees acquire the necessary skills to find a new role and protect them from the harmful psychological effects of low job security and unemployment (Johnson and Jackson, 2012).

Indeed, the future of work is a fundamental shift in the work model and will require two types of changes across the workforce: *upskilling*, in which staff gain new skills to help in their current roles, and *reskilling*, in which staff need the capabilities to take on different or entirely new roles. In according to McKinsey, the reskilling challenge will be particularly acute in operationally intensive sectors, such as manufacturing, transportation, and retail, and operations-aligned occupations, such as maintenance, claim processing, and warehouse order picking. Those sectors and occupations will experience a magnitude of change greater than the global average because they often employ large numbers of people and because the predictable and repetitive nature of many operational tasks makes them particularly suitable for automation or digitization (McKinsey, 2020). Its analysis suggests that 39 to 58 percent of the worldwide work activities in operationally intensive sectors could be automated using currently demonstrated technologies. That is 1.3 times the automation potential of activities in other sectors (Figure 5).

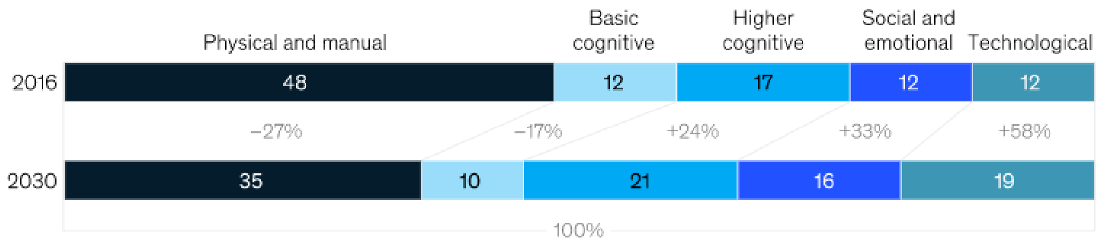
Figure 5: Technologically automatable activities by sector, % of total activities



Source: McKinsey Global Institute Analysis, Building the vital skills for the future of work in operations

Companies will need people with the right skills to develop, manage, and maintain their automated equipment and digital processes and to do the jobs that machines cannot. In Europe and the United States, for example, demand for physical and manual skills in repeatable and predictable tasks is expected to decline by nearly 30 percent over the next decade, while demand for basic literacy and numeracy skills would fall by almost 20 percent. In contrast, the demand for technological skills (both coding and especially interacting with technology) is expected to rise by more than 50 percent, and the need for complex cognitive skills is set to increase by one-third. Demand for high-level social and emotional skills, such as initiative taking, leadership, and entrepreneurship, is also expected to rise by more than 30 percent (Figure 6).

Figure 6: Skill shift in US and Western Europe by category, % of time spent



Source: McKinsey Global Institute Analysis, Building the vital skills for the future of work in operations

The World Manufacturing Forum, a prestigious event during which global policymakers, industry leaders, and eminent academic and research innovators address and discuss the challenges and trends of global manufacturing, has determined the top ten talents required in future manufacturing: "Digital literacy, AI and data analytics", "Working with new technologies", "Cybersecurity" and "Data-mindfulness" are four of them, while the remaining ones are more cross-disciplinary skills in nature, relating to creative, entrepreneurial, flexible, and open-minded thinking.

Companies need to understand which abilities are lacking and since they have knowledge, information, and direct access to best technology, understand what will be needed in the future and consequently educate and train workers in a proper manner (Savoretti & Kitamura, 2022). In addition to money from enterprise and governments, the EU is prioritising investing in people and their skills with the Recovery Plan for Europe proposed by the Commission in May 2020 (European Commission, 2020). The European Skills Agenda sets objectives to be achieved by 2025, based on well-established quantitative indicators (Figure 7).

Figure 7: European Skills Agenda's objectives

Indicators	Objectives for 2025	Current level (latest year available)	Percentage increase
Participation of adults aged 25-64 in learning during the last 12 month (in %)	50%	38% (2016)	+32%
Participation of low-qualified adults 25-64 in learning during the last 12 months (in %)	30%	18% (2016)	+67%
Share of unemployed adults aged 25-64 with a recent learning experience (in %)	20%	11% (2019)	+82%
Share of adults aged 16-74 having at least basic digital skills (in %)	70%	56% (2019)	+25%

Source: European Commission, European Skills Agenda

4. THE PATH TO SOCIETY 5.0

4.1 Society 5.0: concept

The Society 5.0 is the vision of an emerging form of society characterized as “Creative Society” enabled by the digital transformation.

Compared with Society 4.0, Society 5.0 is characterized by problem solving and value creation, diversity, decentralization, resilience, and sustainability and environmental harmony.

The aim is to bring about a society where anyone can create value anytime, anywhere, in security and harmony with nature, and free from various constraints that currently exist:

▪ Liberation from focus on efficiency.

Societies 3.0 and 4.0 pursued scale and efficiency via mass production and consumption to guarantee material wealth to growing populations. In such societies, it was considered important to comply with traditional rules and plans and to follow a plan-do-check-act cycle. Goods and services followed standardized processes to reach efficiency. In Society 5.0, needs become more diversified, and the supply side is ready to meet them with digital technologies. People place emphasis on satisfying individual needs, solving problems, and creating value.

▪ Liberation from disparity.

In Society 4.0, concentration of wealth and information in limited hands increased disparity. In Society 5.0, wealth and information are distributed and decentralized throughout society. Anyone should be able to get opportunities to play a part anytime, anywhere.

▪ Liberation from resource and environmental constraints.

In Societies 3.0 and 4.0, humans depended on models with high environmental impact and mass consumption of resources. In Society 5.0, as data utilization increases energy efficiency and decentralization, there is the option of not depending upon traditional energy networks.

With ambition and ideas, people can conduct activities and business that could profoundly change society. Society 5.0 will require rich imaginations to identify a variety of needs and challenges scattered throughout society and scenarios to solve them, as well as creativity to realize solutions making use of digital technologies and data.

Regarding the manufacturing and service industries, distribution of abilities via AI will provide powerful tools for improving. Until now, a large amount of investment and professional knowledge has been required to analyse data and create useful goods and services. Through digital transformation, these abilities will be distributed and become available as AI modules and services. As described in the previous sections, digital transformation enables anyone to access advanced skills: more people will be able to participate in the manufacturing and provision of services, as part of a digital transformation creating different forms of value.

The combination of digital transformation with the imagination and creativity of diverse people will facilitate not only problem solving, but also value creation that will lead to a brighter future. It is a concept that can contribute to the achievement of the Sustainable Development Goals (SDGs) adopted by the United Nations in 2015, with the resolution of "Transforming Our World: the 2030 Agenda for Sustainable Development" and a promise: it leaves no one backwards (Figure 8). The goals have 169 sub-goals that concern all dimensions of human life, which belong to the world to be admitted by all countries by 2030. They represent a global call to action to which all governments, institutions, NGOs, businesses, and civil society are called to respond by leading the world on a path of sustainability. The goals summarize a strong demand, still largely unfulfilled, towards the creation of a sustainable future on a global scale. In particular, the objectives just described about the manufacturing and service industries aim at achieving the goals number 5, 8 and 9, regarding the gender equality, decent work and economic growth and innovation in the industry and the infrastructure (Keidanren, 2018).

Figure 8: Sustainable Development Goals

Source: United Nations Public Relations Center

4.2 Best in class on Society 5.0

The innovation players are the engine of the process that makes digital transformation the tool for solving the most pressing social problems and present and future challenges, within a collaborative approach that brings together private actors, institutions, and civil society, as conceptualized by the Society 5.0 model. In fact, the involvement of companies represents an integral part of the model, of which they become protagonists by adopting a proactive approach. In the following paragraphs, two case studies about the leading actors of Society 5.0 are illustrated: Hitatchi and Toyota.

Both situated in Japan, Hitachi has become a promoter of sustainable innovation, offering concrete solutions to the various economic, social, and environmental problems that society has faced from time to time. It organises conferences, company sessions, seminars, and presentations through which it shares its vision with customers and stakeholders around the world.

Toyota is recognised as one of the world's most innovative and profitable companies, in addition to its status as the world's biggest car manufacturer. Due to this strong lead, it has seen many of its processes and products copied in one way or another. For example, the Toyota Production System is its main contribution. Designed primarily as a means of eliminating waste, it streamlines manufacturing to maintain high standards of quality and make every process as efficient as possible. It is based on two simple concepts: Jidoka, or "automation with a human touch", the possibility for any operator to halt the entire production line and rectify a defect before it is passed on; and Just-In-Time, a system which ensures that the right part is delivered to the production line at the right time and in the right quantity. Lean manufacturing methods derived from the Toyota Production System have been widely adopted by the entire manufacturing industry.

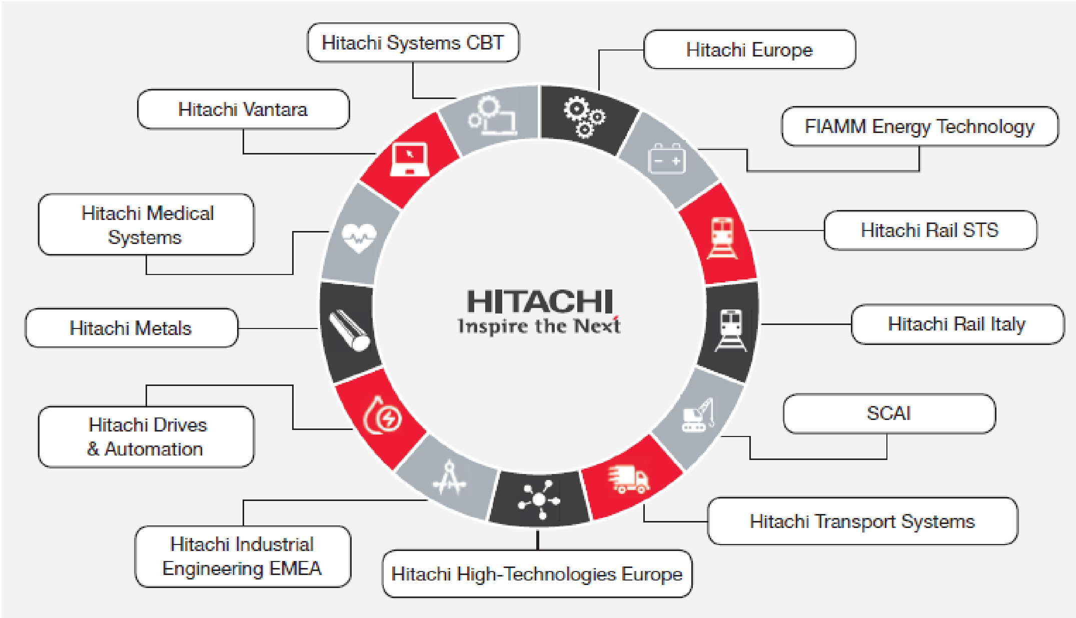
4.2.1 Hitachi

Hitachi's corporate Mission, at the heart of its work since its foundation in 1910, is aligned with that at the core of Society 5.0: the idea of developing a people-centered society through the implementation of cutting-edge technological solutions that respond to real needs of the population, with an approach focused on co-creation.

Thanks to the efficiency of production processes through Operational Technology (OT, the control and automation technologies to support operations) and the development of Information Technology systems (IT, technologies used to create, storing and using information in its many forms) on a large scale to support its infrastructures, Hitachi has established itself not only as a reality universally recognized for quality and reliability, but also as a global player at the

forefront in providing technological solutions that respond to the needs of individuals and society, contributing to the technological pillar of Society 5.0.
In 2016 it developed Lumada, based on the active involvement of its customers. It is an open, shared and highly flexible system that, by integrating machine learning and Artificial Intelligence solutions, transforms data into insights capable of driving digital innovation and the Group's services. After having shared and established a business model that encompasses the objectives and the vision to be adopted jointly with the customer, Lumada collects the data generated by IT and the OT, transforming them into key information for the creation of more effective digital solutions to solve problems previously identified.
In the industry sector for example, data measurement and analysis are used to enhance the skills of workers and increase the quality of the working environment. In addition to this, Hitachi's technology is applied to make it more efficient the supervision process, optimize the activities of the production plants, reduce waste and inefficiencies.
Lumada is a process whose application is not limited only to industry, but which lends itself to a variety of sectors, such as mobility, energy and the health sector. However, this type of transformation, to be effective, must originate from the participation of all public and private actors able to provide a concrete contribution, according to an inclusive and collaborative approach. Considering the private actors, central to the realization of Company 5.0, a progressive take on responsibility by Italian companies emerges, which originates in part from the forward-looking recognition of the interconnection between long-term profitability and the socio-economic-environmental context in which they are placed. The presence of "One Hitachi" in Italy, which is the set of all Hitachi companies and entrepreneurial entities (12 companies in total), is characterized by a wide geographical spread, with a direct presence in 14 Italian regions and multiple sectors of activity. The solutions proposed find application in many business areas, from the railway and metallurgical sector, through information technology and automation, to water and energy management, in addition to the health system (diagnostics), as illustrated in Figure 9.

Figure 9: Main Hitachi Group companies active in Italy



Source: The European House – Ambrosetti, 2019

The European House - Ambrosetti has identified a selection of business cases indicative of Hitachi's contribution to the formation of economic, social or environmental capital in Italy, highlighting the value of innovative technologies and solutions developed by the group to respond to societal challenges.

A paradigmatic case of Society 5.0 is the IoTrain: an example of digi-circularity in manufacturing and mobility developed by Hitachi Rail SpA. On one hand, it created an intelligent factory (the so-called Digital Factory) capable of improving the quality of work, creating added value for the economy and reducing the environmental impact of production thanks to advanced technologies and models. In particular, the factory of the future is built using the technological platforms of the Hitachi Group, Lumada and Pentaho, which enable collaboration between human intelligence (People & Organization) and machine learning (Digital & data platform). On the other hand, it created innovative products, globally competitive, sustainable, capable of putting the needs of customers (co-creation) and users at the center, encouraging sustainable mobility on a systemic scale (the so-called Train of the Future). From the design and engineering phase, the train is designed to guarantee superior standards in terms of duration (expected life, maintenance cost, ...), safety, environmental performance and travel experience. Moreover, the digitalization is intrinsic in the product with the hardware component (for example innovative and recyclable materials, sensors, ...) and on the software side (for example analytics, connectivity, driving assistance, monitoring, obstacle detection, ...).

4.2.2 Best in class on Society 5.0: Toyota

Toyota Production System (TPS) is synonymous with efficiency, productivity and customer satisfaction and in recent years Toyota remains a source of inspiration for continuous improvement in every aspect of an enterprise. It invests significantly in environmental excellence and leads the way in developing greener products as well as reducing its end-to-end environmental footprint. Announced in 2015, the global Environmental Challenge 2050 of Toyota comprises six challenges. They cover every aspect of the business, its exploration of new products and technologies, and its role as an enabler for individuals and communities to learn about and improve the natural world around them. Toyota wants to go beyond zero emissions to a point where products and services only make a positive contribution to society. That means products and initiatives that enhance the communities, societies, and the planet.

The creation of a Hydrogen Society has already begun, in the streamlined shape of the Toyota Mirai. It already goes beyond zero harmful emissions because it emits only pure water. This is only the first part of Toyota’s vision to bring clean hydrogen power to all aspects of society. From buses to boats, from lorries to forklift trucks, sustainable systems are needed to replace fossil fuels which are having a negative effect on our environment. Hydrogen promises to have the biggest impact on decarbonizing, and it is a secure alternative moving the world closer towards a cleaner society.

Japan started to implement Society 5.0 in a large scope as Toyota Motor Corporation (TMC) announced in 2018 it would transform itself from an “automobile company" into a true mobility company that creates well-being for all. In fact, beyond the production of hydrogen vehicles lies Woven City, a fully connected, hydrogen-powered city ecosystem. It’s a prototype for the eco city of the future, where the benefits of clean and plentiful fuel can be experienced and give inspiration to the next generation.

Hence, the next level of the smart factory is the smart city. The United Nations Economic Commission for Europe and the International Telecommunication Union jointly defined a smart city as “an innovative city that uses information and communication technologies (ICTs) and other means to improve quality of life, efficiency of urban operation and services, and competitiveness, while ensuring that it meets the needs of present and future generations with respect to economic, social, environmental as well as cultural aspects" (International Telecommunication Union, 2022).

The Woven City’s plans seemingly align with this definition because the goal is to expand the definition of mobility from simply “moving things,” to adding ease and joy to daily life. Mobility will be seamlessly integrated into essential aspects of society such as healthcare, food and agriculture, energy, finance and education and be used in various ways that inspire daily happiness and amplify human potential.

President of Toyota Motor Corporation, Akio Toyoda believes, “As a global society we need to come together to heal, grow, learn, and create new possibilities for a collective future.” He also stated, “It is only through partnership and collaboration that we will realize the dream of not just mobility for all but a better quality of life for all. In fact, if it were up to me, I would add an 18th goal to the SDG's list - Happiness!” (Woven Planet Holdings, 2021).

Located in Susono City at the site of the former Toyota Motor East Japan, Higashi-Fuji plant, the city is conceived to be completely sustainable, thanks to buildings made mainly of wood to minimize CO2 emissions, combining traditional Japanese carpentry techniques with modern robotic production methods. The roofs will be equipped with photovoltaic panels to generate solar energy that will complement the one generated by hydrogen fuel cells, the residences will be equipped with the latest home automation solutions for everyday life: they will use sensor-based artificial intelligence to control the occupant health, take care of basic needs and improve daily life. Residents will be able to use only completely autonomous and zero-emission vehicles to move around the city. Finally, the autonomous Toyota e-Palettes will be used both for transport and deliveries, and as authentic itinerant shops (Toyota Motors Italia, 2022).

Woven City is how Toyota will integrate automobile manufacturing "Monozukuri" with the latest technologies. Monozukuri is a word that captures the true spirit of Toyota in relation to the concept of sustainability. The literal meaning of Monozukuri is ‘production’. ‘Mono’ is the thing which is made and ‘Zukuri’ means the act of making, but Monozukuri implies more than simply making things. It can be best compared to the word ‘craftsmanship’ in English. In the Japanese tradition of Monozukuri, the craftsman takes great care using resources not to be wasteful or futile. When an item or human effort is taken into use, there needs to be a benefit for the society as a result while, at the same time, the balance between production, resources and the society should be maintained (SA Partners, 2011).

Moreover, in the world of Toyota “Monozokuri is Hitozokuri”, which means that the ability to produce well is linked to the ability to train people. It follows that the factory is normally supported and developed by the people who work in the company. Toyota’s green vehicle technologies and other lean or green initiatives will not work without the full engagement of their people. Mutual trust, authority, empowerment and skills to make quality products are all tenants through which Toyota respects its people.

5. EMPIRICAL ANALYSIS

5.1 Introduction

From Industry 4.0 to Society 5.0, the path described in the previous chapters highlighted both the characteristics and the impact of these new technologies in manufacturing firms.

This chapter focuses in particular on information and communication technologies (ICT), which are technologies used for the treatment and processing of information or for communication functions, including the transmission, reception and display of data.

In the literature, there are many studies related to the impact that the adoption of information and communication technologies can have on innovation processes, on production mechanisms, on the organization of business functions and on the performance of the company and of the entire system. As described in the second Chapter, the high potential of digital technologies can foster new ways of performing economic activities.

However, this positive relationship between the use of ICT and business productivity has not always proved to be right, especially in advanced countries, to the point of developing two currents of thought, “techno-optimists” and “techno-pessimists” (Andrews et al., 2016; Cette et al., 2016). Some papers claim that Italy belongs to the countries in which the use of ICT struggles to become a lever for improving the entire economic system for different reasons:

- the prevalence of small businesses that would not facilitate the spread of new technologies (Accetturo et al., 2013);
- inefficiencies in the selection of management (Pellegrino and Zingales, 2017);
- reduced investment in human capital (Bugamelli and Pagano, 2004);
- low effectiveness of policies in support of innovation (Bronzini and Piselli, 2016).

Companies need to ensure that these changes are embraced by their workforce ensuring success from the outset.

This is a fundamental aspect of the debate about the disruptive potential of new digital technologies since the skills profile of firms filters the penetration of technical change in the economy and lay the foundations for the productivity gains that could be generated in the process (Acemoglu, 2002; Link and Siegel, 2003).

In this contribution, the focus will be on the technology adoption choices made by individual firms in Italy, with the use of firm-level data from the archive of the National Institute of Statistic (Istituto Nazionale di Statistica – Istat). In particular, focus of this study is the survey on information and communication technologies on enterprises (ICT), developed jointly by Eurostat and the National Statistical Institutes of EU countries (in collaboration with the European Commission) in 2018.

The survey provides a wide and articulated set of information relating to the use of information technologies on Italian companies with at least 10 employees.
Furthermore, the OECD started a new project to improve and strengthen the capacity to monitor and define digital transformation policies in European countries through economic statistics capable of making digital transformation visible and understanding its economic effects (OECD, 2019). In fact, the Regulation on European business statistics of 2019 (Regolamento UE 2019/2152, 2019) emphasized the importance of the measurement of the digital economy, given its impact on the competitiveness and growth in the EU, and the need to promote European strategies and policies to achieve a single digital market.
In this broad framework of cognitive needs, the data gathered through this experimental statistic provided new indicators and classifications by integrating the phenomenon of digitization with elements of economic performance; in fact, ICT sample surveys were integrated with the Statistical Register of the main economic variables "Frame SBS" (Structural Business Statistics) of 2019. Its introduction made it possible to consider in the set of known variables used in the ICT survey (the known totals of the variables Number of companies and Number of employees for combinations of ATECO and territorial detail), as well as those relating to the added value, revenues and gross operating margin variables.
The Chapter is organised as follows: the first three sections describe the data sources used and the data preparation method adopted. Section four presents the data relative to technology adoption by the firms considered and provides some descriptive evidence of the phenomenon studied in the Frame SBS. Section five then presents the empirical strategy about the digitization factors and the results of econometric analyses, while section six explores the correlation between the size of the sample firms and their willingness to invest on training.
The objective is to understand the effects of new digital technologies on labour flows. More specifically, it explores: 1) the advantages of the adoption of new technologies; 2) the relative importance of digitalization factors in the process of technology adoption; 3) the share of investment on training of employees, considering the size of the firms and the necessary skills extent.
Particular attention is paid to the role of on-the-job training in the process of technology adoption, in accordance with what has been underlined in the previous chapters.

5.2 Data available and population of interest

The surveys in 2018 were conducted based on criteria and methodologies common to all the countries of the European Union and represent the conceptual and methodological basis for measuring the diffusion of information technologies.

The phenomena observed are those defined by EU Regulation no. 2017/1515 of the Commission, of 31st August 2017. The information specifically concerns: the presence of ICT specialists and IT skills (ICT staff, ICT training and skills research, employees who use PCs and who use PCs connected to the Internet); the type of Internet connection and use (fixed broadband Internet connection for work purposes, mobile Internet connection for work purposes, company website or home page on the Internet, use of social media, use of Internet in relations with the PA); sales and purchases through computer networks (sales via web, app, e-marketplace, other EDI-type networks); electronic invoicing; the use of cloud computing services; the use of 3D printing, robotics and big data analysis; the determinants of the digital transformation of the company (Industry 4.0 investments made in the period 2016-2017, made and expected in the two-year period 2018-2019, importance of the factors enabling the digital transformation in the two-year period 2018-2019).

The survey also collects structural information on the companies thanks to the Statistical Register of the main economic variables Frame SBS, as anticipated in the previous paragraph.

The Frame SBS system contains information on the structural characteristics (size, sector of economic activity, geographical location) and on the main items of the income statement (turnover, added value, gross operating margin, employee costs) of the more than 4.4 million active companies in Italy, which employ over 16 million people.

The output of the project was a series of indicator tables that combine information from Frame SBS and ICT surveys, with a methodology that qualifies the results, in terms of comparability and consistency, according to the standards of the Institute.

The population of interest is made up of companies with at least 10 average annual employees, active in the reference year of the survey and that carry out their main economic activity in one of the following sectors of the Ateco 2007 classification:

- manufacturing (C);
- supply of electricity, gas, steam and air conditioning (D);
- water supply, sewerage, waste management and remediation activities (E);
- buildings (F);
- wholesale and retail trade and repair of motor vehicles and motorcycles (G);
- transport and storage (H);

- accommodation and catering services (I);
- information and communication services (J);
- real estate activities (L);
- professional, scientific and technical activities (M, except for division 75);
- rental, travel agencies and business support services (N);
- repair of computers and communications equipment (group 95.1 of section S).

The archive for the selection of the sample subject of the survey was taken from Asia, the Istat register of companies, relating to the calendar year 2016 (most up-to-date version of the archive at the time of sample selection). The population thus constructed is made up of 22.080 companies.

5.3 Data preparation

Data preparation initially involves extracting, transforming, and loading data, as well as data cleansing. The focus in this thesis is on manufacturing activities. Hence, in the data set available, it is important to select companies with at least 10 average annual employees, which in the reference year of the survey are active and carry out their main economic activity in the manufacturing sector of the Ateco 2007 classification. Table 1 shows the Ateco 2007 classification of the manufacturing activities considered.

The sample thus constructed is made up respectively of 4.682 in 2018.

Table 1: Ateco divisions considered in the sampling plan

C 10-12	Food, beverage and tobacco industries
C 13-15	Textile, clothing, leather goods and similar industries
C 16-18	Wood and paper products industry, printing
C 19-23	Manufacture of coke and petroleum refining products, chemicals, pharmaceuticals, rubber and plastics products and non-metallic mineral processing products
C 24-25	Metallurgy and manufacture of metal products except machinery and equipment
C 26	Manufacture of computer and electronic and optical products, electro-medical equipment, measuring equipment and clocks
C 27-28	Manufacture of electrical equipment and non-electrical household equipment and machinery
C 29-30	Manufacturing of means of transport
C 31-33	Other industries manufacturing, repair and installation of machinery and equipment

Source: ISTAT, Survey on information and communication technologies in companies: Methodological aspects of the survey, 2018

In the process of data preparation, the second step includes selecting which columns of information are relevant to provide an assessment of the nexus between technology and human capital. The purpose is to describe the aggregate patterns of adoption of the new technologies and then to perform an econometric analysis of the role of training in the acceptance of these new changes by the workforce. This is linked to the Chapter 3.

The data set consists of many informative columns, so this step involves sifting through the information and finding the data relevant to the predefined metrics.

Two main sets of variables are important for these analyses.

The first one includes the investments in new enabling technologies made by manufacturing firms.

Starting from the data provided by the ICT survey, the key question to take into consideration concerns investments over the period 2018-2019. It states: “Indicate whether the company has made or plans to make the purchase of tangible or intangible assets (such as software, systems, and applications) or services to be used for its activities, related to these technological areas”.

Firms could choose among the following answers:

a. Internet of things (IoT);
b. 3D printing;
c. Robotics (industrial robots, interconnected and programmable collaborative robots);
d. Other capital goods, computerized machinery or machinery managed through sensors and interconnected with other company systems;
e. Cloud computing (set of IT services that can be used via Internet, which allow access to software, computing power, memory capacity, etc.);
f. Web applications or apps (applications accessible via Internet, including management software);
g. Online sales;
h. Big data analytics;
i. Augmented and virtual reality;
j. Cybersecurity;
k. Other.

A single answer was allowed for each technology, that is equal to 1 if firms have invested in over the period 2018-2019, 0 otherwise. The information contained in these columns allows to indicate the technological intensity adopted by each company.

Since data is at enterprise level, other relevant information for the analysis are the values of revenues, the employee class and the geographical areas.

Instead, the data provided by the Frame SBS underlines the advantages brought by the investments in new technologies through two important variables, labour productivity per employee and revenues per employee.

The second set of variables considered is related both to the ICT survey and the Frame SBS and it concerns workplace training practices. The activation of training at the firm level is linked to the size of the firm and is differentiated between specialized and non-specialized skills.

Hence, a customized view of the data was created by considering the variables just mentioned and by hiding columns that were irrelevant to the purpose of the analysis.

During this phase of the data preparation process, the quality of the data was also simultaneously examined. In particular, missing values have been entered in some records for one or more variables and the changes below have been made to the data set.

The recoding of categorical and discrete quantitative variables concerns:

- The geographical areas have been replaced by Rip, identifying with a number the five territorial divisions: the division number one is the north-west, the division number two is the north-east, the division number three is the middle of Italy, the division number four is the south, and the division number five identify the islands.
- Economic activity 5-digit Ateco code has been replaced by Ateco_1, identifying only the letter of the Ateco 2007 classification. In this case, only the letter C has been selected, as illustrated in Table 1.
- The average number of employees has been recoded to clad3, because it has been aggregated into classes: the class identified with number one has 10-49 employees, the class number two 50-249 employees and the class number three has more than 250 employees. The exact average number of employees has been deleted as protection measure.

The recoding of continuous quantitative variables:

- Two manufacturing companies didn’t answer the questions about the investments in new technologies made in 2018 and 2019. For this reason, it is assumed that they didn’t invest at all. This leads to the adoption of a continuous measure of Industry 4.0 investment and the creation of a new variable “I4.0”, that is equal to a number from 1 to 11 if firms have invested in one or more I4.0 technologies, 0 otherwise. It is essentially the sum of all the dichotomous variables which identify the columns of new technologies.
- The total value of revenues from the sale of goods and services has been recoded to revenues_cl: revenues have been aggregated according to the classes specified in Table 2.

Table 2: Revenue classes

Label	Description
0	[0, 20.000)
20.000	[20.000, 50.000)
50.000	[50.000, 100.000)
100.000	[100.000, 200.000)
200.000	[200.000, 500.000)
500.000	[500.000, 1.000.000)
1.000.000	[1.000.000, 2.000.000)
2.000.000	[2.000.000, 4.000.000)
4.000.000	[4.000.000, 5.000.000)
5.000.000	[5.000.000, 10.000.000)
10.000.000	[10.000.000, 20.000.000)
20.000.000	[20.000.000, 50.000.000)
50.000.000	[50.000.000, 200.000.000)
200.000.000	[200.000.000, ∞)

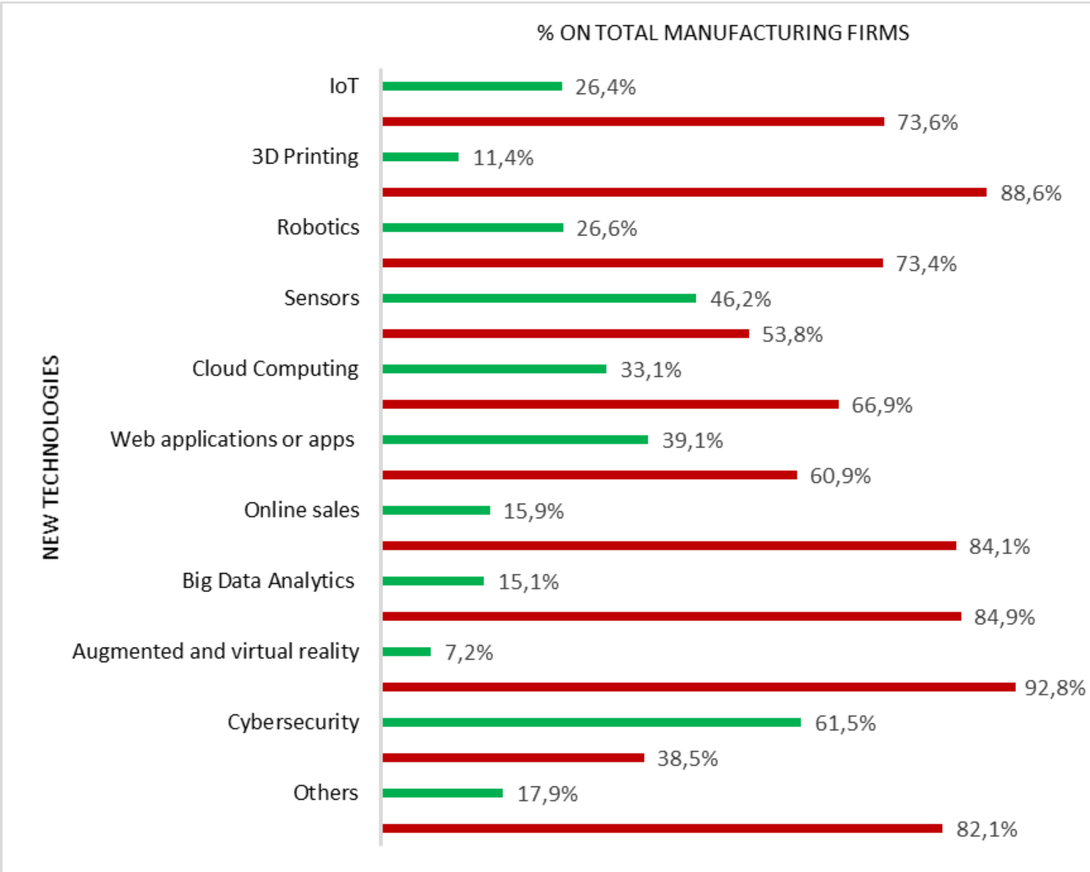
Source: ISTAT, Survey on information and communication technologies in companies: File Description, 2018

Data were created and processed in another Excel file. Each objective has a page on the Excel file with the necessary columns, which is very important for information extraction and provides a general overview.

5.4 Data analysis: Descriptive statistics

Table 1 distinguishes I4.0 investments into specific types of technologies, showing the percentage of manufacturing firms which decided to invest or not over the period 2018-2019.

Figure 10: Share of firms investing in I4.0 2018-2019 with legend



2018-2019	***Investment***		***NO investment***	
	Numbers	**%**	**Numbers**	**%**
IoT	1.238	26,4%	3.444	73,6%
3D Printing	534	11,4%	4.148	88,6%
Robotics	1.246	26,6%	3.436	73,4%
Sensors	2.163	46,2%	2.519	53,8%
Cloud Computing	1.548	33,1%	3.134	66,9%
Web applications, apps	1.833	39,1%	2.849	60,9%
Online sales	744	15,9%	3.938	84,1%
Big Data Analytics	708	15,1%	3.974	84,9%
AR/VR	338	7,2%	4.344	92,8%
Cybersecurity	2.881	61,5%	1.801	38,5%
Others	837	17,9%	3.845	82,1%

Source: elaboration of the author

The majority of I4.0 investments are concentrated in cybersecurity (61,5%), whereas 3D printing (11,4%) and AR/VR (7,2%) cover only a marginal share of adopters. In fact, most companies use a limited number of technologies, giving priority to infrastructure investments (cloud solutions, mobile connectivity, management software and cyber-security) while leaving the adoption of application technologies such as IoT, automation, robotics, and big data analysis to a later stage (Istat 2020).

However, it is important to highlight that already in the years 2018 and 2019, 26,6% of the manufacturing firms were investing in robotics and 26,4% in IoT to improve their processes.

Especially in 2020, the country discovered the importance of digital technologies but, recorded by the Anitec-Assinform Report on “Digital in Italy”, the pandemic has played against an increase in investments, especially for those sectors most affected by the collapse in demand, such as transport, tourism and various industrial sectors.

In 2021, the launch of the National Recovery and Resilience Plan (PNRR) overturned the scenario, with digital innovation becoming the strategic axis of all modernization programs and the revival of growth (Anitec-Assinform, 2021).

Despite these considerations, about 25% of Italian manufacturing firms declared not to invest in any of the technologies related to the Industry 4.0 plan over 2018-2019. This leads to the conclusion that about 75% of them invest in at least one of the technologies. It must be noted that the decision not to invest is limited to the years 2018 and 2019, it does not mean that these manufacturing firms did not invest at all in the previous or following years.

In this way, it is possible to identify a so-called treated group composed by I4.0 adopters, about 75%, against a control group of non-adopting companies. It is worth recalling that it was created a continuous variables of Industry 4.0 investment, that is equal to a number from 1 to 11 if firms have invested in one or more I4.0 technologies, 0 otherwise. It is essentially the sum of all the dichotomous variables which identify the columns of new technologies, that is equal to 1 if firms have invested in that specific technology, 0 otherwise.

In recent years, Istat has launched an intense research activity for the enhancement of administrative sources and statistical registers and for the integration of the latter with sample surveys. The integrated analysis of the digital profiles of companies deriving from the direct survey on the use of ICT and the economic performance indicators that can be deduced from the extended register Frame SBS allows to grasp some interesting phenomena.

The attached tables show, for companies with at least 10 employees, the structural characteristics (propensity to export, belonging to groups), the productivity and efficiency indicators (labour productivity, turnover per employee, added value on turnover) and competitiveness (labour cost per unit of product, labour cost per employee) in relation to the indicators that measure the degree of use of ICT.

They refer to the year 2017 by macro-sector, size class and by level of the composite indicators of use of ICT relating to 2018. In this contribution, the indicator considered is the Digital intensity index, which evaluates the level of digitalization with respect to 12 specific characteristics of the companies, measured by intensity. In fact, the economic indicators are studied based on “low”, “very low”, “high” and “very high” intensity of digitalization.

The analysis of the specific characteristics that contribute to the definition of the composite digitization indicator are useful to identify the technologies that come implemented first until at least a “basic” level is reached.

In the business class 10-49 employees, the most frequent situation corresponds to the use of the broadband connection at speeds of at least 30 Mbit/s. In case of large companies, a more complex combination of at least nine technologies is widespread: Internet connection, cloud, management software (ERP and CRM), use of social media and smart devices (Iot).

It is only among companies with at least 50 employees that the adoption of management software is also included among the top four most used technological models.

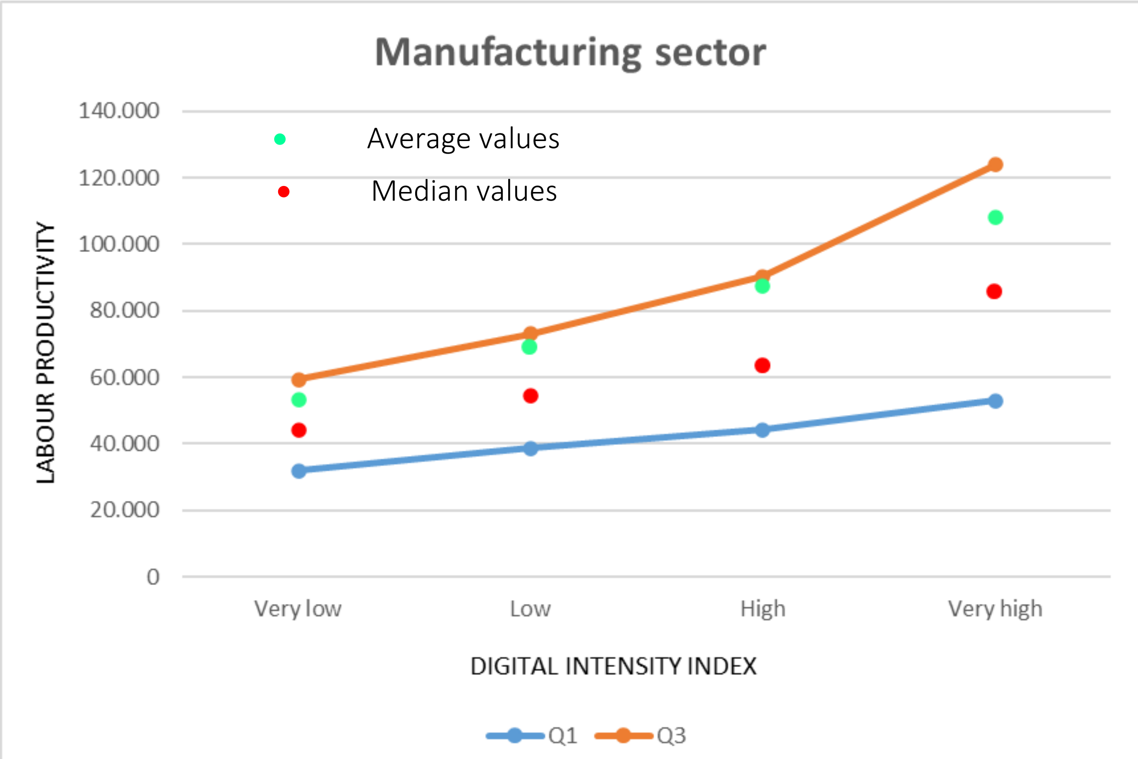
The medium-high level cloud is also an activity chosen by small businesses, confirming the great diffusion of this type of services recorded in recent years.

Finally, activities relating to the most advanced technological innovations, such as the Internet of Things and Artificial intelligence, they position themselves among the first four combinations only among companies that already have adopted other basic activities and are therefore mainly connected to high and very high degrees of digitization of larger companies. (ISTAT, 2022).

Focusing on the Digital Intensity Index, a preliminary analysis illustrated on the Figure 12 has been made between the adoption of new technologies and labour productivity, measured in terms of added value per employee. The table of the Frame SBS already provides the data divided by quartile, with values of labour productivity expressed in euros. There is a strong positive correlation between the two variables, in fact the more intense the digitalization, the more added value per employee. This is especially true in manufacturing companies already in a position of high productivity compared to the others (third quartile).

Another observation is that the interquartile gap seems to mostly increase with the growth of the technological indicator, highlighting a greater dispersion around the average of the indicators and therefore a greater differentiation between those who get the most benefits and those who fall further behind (ISTAT, 2020).

Figure 11: Labour productivity by level of ICT use



	MANUFACTURING SECTOR				TOTAL			
Digital Intensity Index	Q1	Q3	Median	Average	Q1	Q3	Median	Average
Very low	31.883	59.310	43.954	53.291	22.475	51.250	35.401	42.093
Low	38.622	72.930	54.582	69.145	33.730	66.079	46.850	55.620
High	44.216	90.341	63.493	87.434	36.534	76.519	52.114	79.709
Very high	53.063	123.854	85.750	108.194	36.536	80.099	52.912	92.277

Source: elaboration of the author

Productivity is commonly defined as the ratio between the volume of output and the inputs that contribute to its realization. It measures the efficiency of the use in the production process of primary factors, labour and capital, and it is considered a key indicator of economic growth and competitiveness, also for the purpose of evaluating economic performance in international comparisons. The approach used by Istat to estimate it allows to break down the dynamics of the output into the contributions deriving from primary production factors (labour and capital) and total factor productivity. Other factors that explain the changes in productivity could be the improvement in the quality of capital goods, the trend of the economic cycle, economies of scale, externalities, the reallocation of production factors, as well as any errors in measuring output and production factors.

According to Istat, labour productivity is given by the relationship between added value and hours worked (ISTAT, 2021). In the manufacturing sector, the labour productivity doubles with the growth of digital intensity.

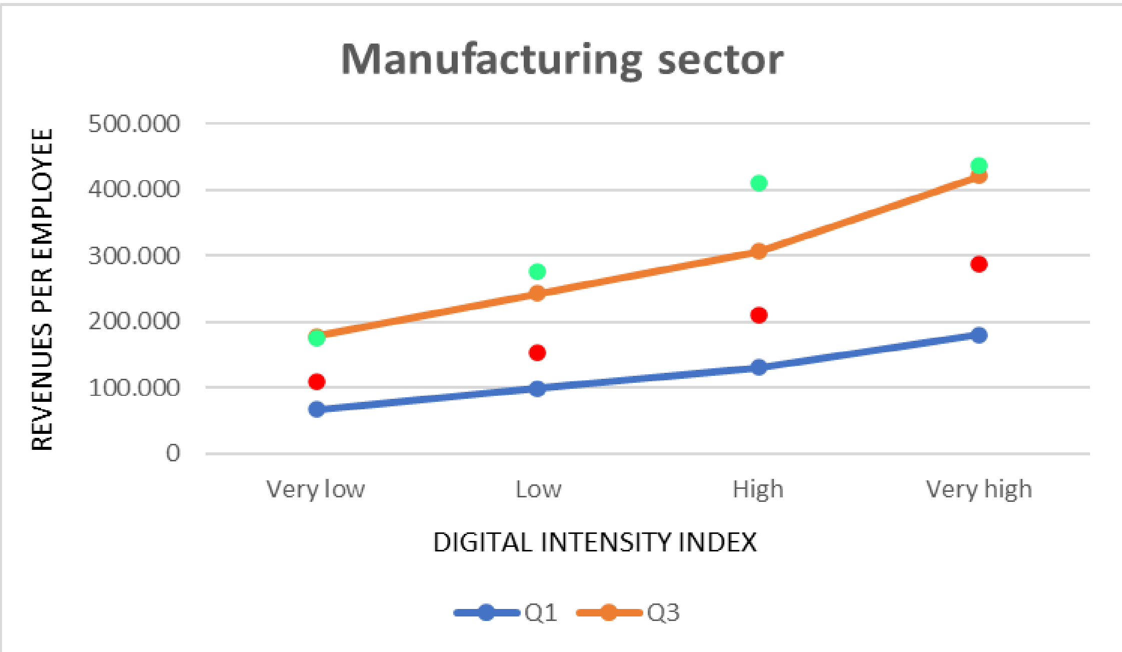
Going through the definition of added value, it is important also to assess the variables "Revenues per employee" and "Cost per employee" that are included in the formula.

An increase on both the variables is expected because digitalization has both benefits and costs: for example, it is difficult to realize a great increase on revenues if firms don't invest in the employees and provide them adequate training.

The focus now is on the relation between Digital Intensity Index and the revenues realized per employee. Figure 12 shows a positive correlation between the adoption of technologies and revenues per employee. This is especially true in manufacturing companies already with high revenues (third quartile) and in a position of high or very high level of ICT use compared to the others. The manufacturing sector is quite similar to the behaviour of the other sectors.

For this reason, the net effect of new technologies is likely to exert a positive effect on productivity.

Figure 12: Revenues per employee by level of ICT use



	MANUFACTURING SECTOR				TOTAL			
Digital Intensity Index	Q1	Q3	Median	Average	Q1	Q3	Median	Average
Very low	67.303	177.761	108.481	175.061	49.434	152.648	87.259	137.701
Low	98.614	242.620	154.404	276.025	78.051	241.064	136.742	237.518
High	130.791	307.347	209.854	410.918	85.957	304.642	168.646	365.766
Very high	180.582	421.521	287.872	437.242	99.435	416.775	190.154	419.748

Source: elaboration of the author

5.5 Data analysis: Empirical strategy

In the previous section, it has been ascertained that the adoption of new technologies is beneficial for the competition and the growth of Italian firms. In particular, the manufacturing sector is experiencing a large increase in the productivity.

In this section, the focus will be more specific in the role of workers among companies that adopt new technologies.

First, the analysis starts with a question of the survey about ICT of 2018: “Which digitization factors could most positively affect the competitiveness and development of the company?”

Multiple answers have been selected, including infrastructure and ultra-broadband connection, benefits, financing, tax incentives to support digitization, ability to network by implementing collaboration models with other companies and research centers for digitization, insertion and development of new digital skills through the recruitment of new staff, development and consolidation of skills of existing staff, development of a business digitization strategy.

Infrastructure and ultra-broadband connection, benefits, collaboration models and a business digitalization strategy are expected to be the most important elements that support the adoption of new technologies.

However, in this thesis it has been underlined how people are central in Industry 5.0.

Furthermore, skills upgrading through training is beneficial to the adoption of new technologies because technical change can only generate productivity gains it is successfully integrated in contextual production processes (Boothby et al., 2010). Whenever skills requirements are firm-specific, or in a context with stronger labour market frictions, training is the most efficient solution (Ramachandran, 1993; Hamermesh and Pfann, 1996). Moreover, in the complex cognitive process of adaptation to radical new technologies (Raffaelli et al., 2019), training can shape workers' perception of a new technology and influence their attitude to change (Ouadahi, 2008). It is interesting to notice that there are contrasting results in the literature on ICT adoption and training: for example, Arvanitis in 2005 found evidence of complementary between investment in information technology and training, whereas Giuri et al. in 2008 did not (Cirillo et al., 2021). The most plausible hypothesis that can be made for new digital technologies follows the expectation that firms planning changes in production are more likely to prepare their workers by updating or upgrading their skill sets to fully capture the benefits of new technologies. Even though technical change always entails an element of uncertainty also in diffusion processes, it can be argued that firms expect technologies to require contextual adjustments and may benefit from having training programmes in place. For this reason, we posit that:

Hypothesis: The training of workers has a positive effect on the adoption of new digital technologies by manufacturing firms.

Hence, the central research question of this thesis focuses on the role of skills and training as determinants of technology adoption. Since the data is at firm level, more controls are added in the equation, such as the revenues class (Table 2), the employee class and the geographical area. To understand the difference with the other digitalization factors, we estimate the following equation, taking into consideration also the other variables:

$$Y_{i,t} = \alpha + \beta_1 \mathrm{Infr}_{i,t-1} + \beta_2 \mathrm{Benefits}_{i,t-1} + \beta_3 \mathrm{Network}_{i,t-1} + \beta_4 \mathrm{Newhiring}_{i,t-1} + \beta_5 \mathrm{Training}_{i,t-1} + \beta_6 \mathrm{Strategy}_{i,t-1} + \beta_7 \mathrm{Revenues}_{i,t-1} + \beta_7 \mathrm{Employee}_{i,t-1} + \beta_8 \mathrm{Rip}_{i,t-1} + u_{i,t} \quad t = [2018,2019]$$

where the dependent variable of equation ($Y_{i,t}$) represents a continuous indicator of the Industry 4.0 investment (I4.0) taking values from 1 to 11 if firms have invested in one or more I4.0 technologies over the period 2018-2019, 0 otherwise. It is essentially the sum of all the dichotomous variables which identify the columns of new technologies, that is equal to 1 if firms have invested in that specific technology, 0 otherwise.
As for our key explanatory variables, Infr_i , $\mathrm{Benefits}_i$, $\mathrm{Network}_i$, $\mathrm{Newhiring}_i$, $\mathrm{Training}_i$ and $\mathrm{Strategy}_i$ indicate, respectively, the share of infrastructure and ultra-broadband connection adopted, the share of benefits, financing and tax incentives received, the share of collaboration models adopted, the share of new hiring, the share of training offered to existing workers and the adoption of a business digitization strategy. They are all dichotomous measures, that are equal to 1 if the firm i believes that the digitalization factor affects the competitiveness and the development of the company, 0 otherwise.
The other variables are included to add some controls at firm level.
The variable $\mathrm{Revenues}_i$ indicates the revenues aggregated in classes. They are identified with a discrete number that refers to the specific class of revenues: the labels of the classes are described in Table 2.
The variable $\mathrm{Employee}_i$ refers to the class of employees. It could be discrete number from 1 to 3: the class identified with number one has 10-49 employees, the class number two 50-249 employees and the class number three has more than 250 employees.
The variable Rip_i refers to the territorial division of each company: the division number one is the north-west, the division number two is the north-east, the division number three is the middle of Italy, the division number four is the south, and the division number five identify the islands.

The parameter $u_{i,t}$ indicates an idiosyncratic error term.

The following table shows the Excel output relating to the model taken into consideration (Table 3).

From the output the obtained expression for the estimated model with the estimated coefficients is:

$Y_{i,t}$ = -0,26 + 0,77$\text{Infr}_{i,t-1}$ + 0,61$\text{Benefits}_{i,t-1}$ + 1,12$\text{Network}_{i,t-1}$ + 1,01$\text{Newhiring}_{i,t-1}$ + 0,65$\text{Training}_{i,t-1}$ + 1,09$\text{Strategy}_{i,t-1}$ + 0,00$\text{Revenues}_{i,t-1}$ + 0,92$\text{Employee}_{i,t-1}$ – 0,07$\text{Rip}_{i,t-1}$ t= [2018,2019]

Table 3: Summary of the regression model results

Regression Statistics	
Multiple R	0,631653364
R Square	0,398985972
Adjusted R Square	0,397828197
Standard Error	2,081179459
Observations	4682

ANOVA					
	gdl	*SS*	*MS*	*F*	*Significance F*
Regression	9	13433,677	1492,631	344,61434	0
Residual	4672	20235,871	4,331308		
Total	4681	33669,548			

	Coefficients	*Standard Error*	*t Stat*	*P-Value*
Intercept	-0,2613971	0,1090111	-2,3979	0,0165286
Infrastructure and ultra-broadband	0,775532224	0,0647593	11,97561	1,424E-32
Benefits, financing, tax incentives to support digitization	0,615588574	0,0628698	9,791482	2,01E-22
Collaboration models with other companies and research centers for digitization	1,119513249	0,1082661	10,34039	8,548E-25
Recruitment of new staff	1,00646935	0,0805877	12,48911	3,11E-35
Training of existing staff	0,653532673	0,0663706	9,846715	1,175E-22
Business digitization strategy	1,058659314	0,0704839	15,01986	7,797E-50
Revenues	8,77238E-09	7,487E-10	11,71713	2,841E-31
Employee class	0,919142276	0,0510673	17,99865	4,43E-70
Geographical areas	-0,06540565	0,0283634	-2,30599	0,0211549

Source: elaboration of the author

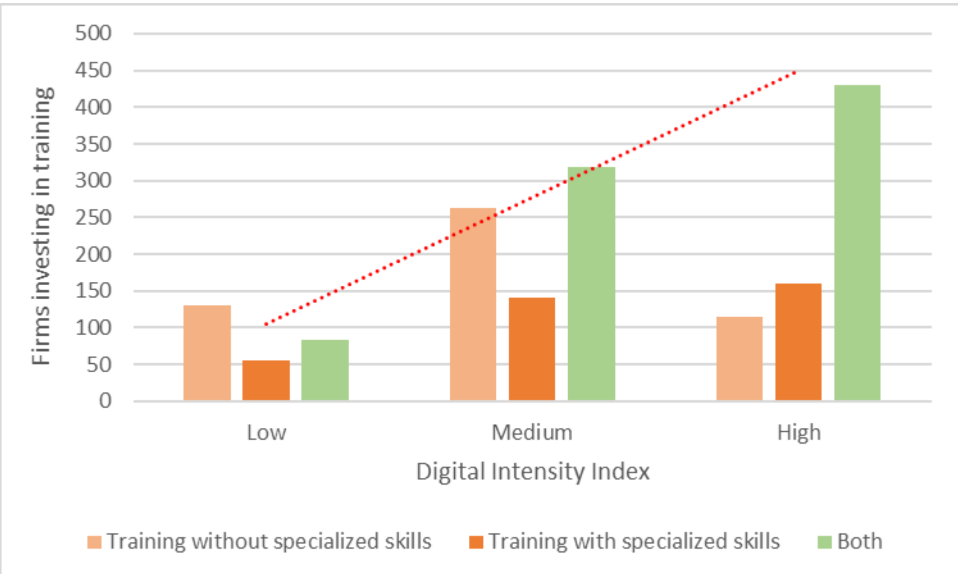
A first observation that can be made is regarding the Adjusted R^2 for the regressions. The Adjusted R^2 is a measure of goodness of fit, that ranges from 0 to 1, and describes how much of the variability in the dependent variables can be explained by the variability in the independent variables employed in the model (Hanke & Wichern, 2009). In the case of these regressions, the Adjusted R^2 is 0,398, suggesting that while some of the variability can be explained by the variables considered, there are also other factors impacting the adoption of new technologies that were not included in the model.

The corresponding p-values are all very small and less than 0.05. Therefore, we can conclude that all the nine variables make a significant contribution to the regression model.

The most impacting variables are the adoption of collaboration models and a business digitalization strategy. But the interesting result is that the presence of adequate infrastructure is as important as the recruitment of new staff and the training of existing staff.

Hence, firms characterized by a higher share of educated workforce invest more in new technologies because of the increased awareness and acceptance and the reduction of any possible work-related disease. This result is represented in the Figure 13, which assesses the relation between the digital intensity (low, medium, high) and the investment in training (training without specialized skills, with specialized skills and both). We consider the investment in both the types of training as a high level of intensity of training supported by the firm. The firms which provide a high intensity of training are associated with a high adoption of digital technologies, as the red line in the Figure shows.

Figure 13: Relation between Training and Digital Technologies



Source: elaboration of the author

The last three variables included in the regression are useful to differentiate the enterprises in terms of size (with the variables Revenues and Employee class) and geographical area. It seems that even if the total value of revenues doesn't impact the adoption of new technologies, the average number of employees does. These two variables are always considered together to define the size of a company, so we can conclude that the net effect is positive on the adoption of new technology.

Looking at the location of each company, the regression suggests that the more you move to the south the less is the adoption of new technologies.

These last results open a discussion that will be addressed in the next paragraph.

Since the equation contains multiple dummy variables, it's important to verify the non-collinearity of the regression. The perfect collinearity arises when one of the independent variables is a perfect linear combination of the other independent variables. The multiple regression of this empirical analysis could include a situation called "the trap of the dummy variables", which brings to perfect collinearity. Issues in particular arise when two independent variables are highly correlated, with a value closer to 1.

With our equation, we calculate the correlation between all the independent variables to check every relation. The following table shows the results (Table 4).

Table 4: Check for collinearity

	I4.0	*Infr and connection*	*Benefits and incentives*	*Collab models*	*New staff*	*Training*	*Business digit strategy*	*Revenues*	*Employee class*	*Geograph areas*
I4.0	1,000									
Infrastructure and connection	0,224	1,000								
Benefits and incentives	0,188	0,204	1,000							
Collaboration models	0,156	-0,020	0,028	1,000						
New staff	0,238	-0,012	0,008	-0,005	1,000					
Training	0,187	-0,024	0,089	-0,025	0,093	1,000				
Business digitization strategy	0,284	-0,020	0,044	0,026	0,035	0,057	1,000			
Revenues	0,448	0,109	0,025	0,065	0,167	0,079	0,184	1,000		
Employee class	0,511	0,181	0,068	0,089	0,172	0,115	0,213	0,646	1,000	
Geographical areas	-0,093	-0,003	0,030	-0,011	-0,053	-0,025	-0,032	-0,116	-0,114	1,000

Source: elaboration of the author

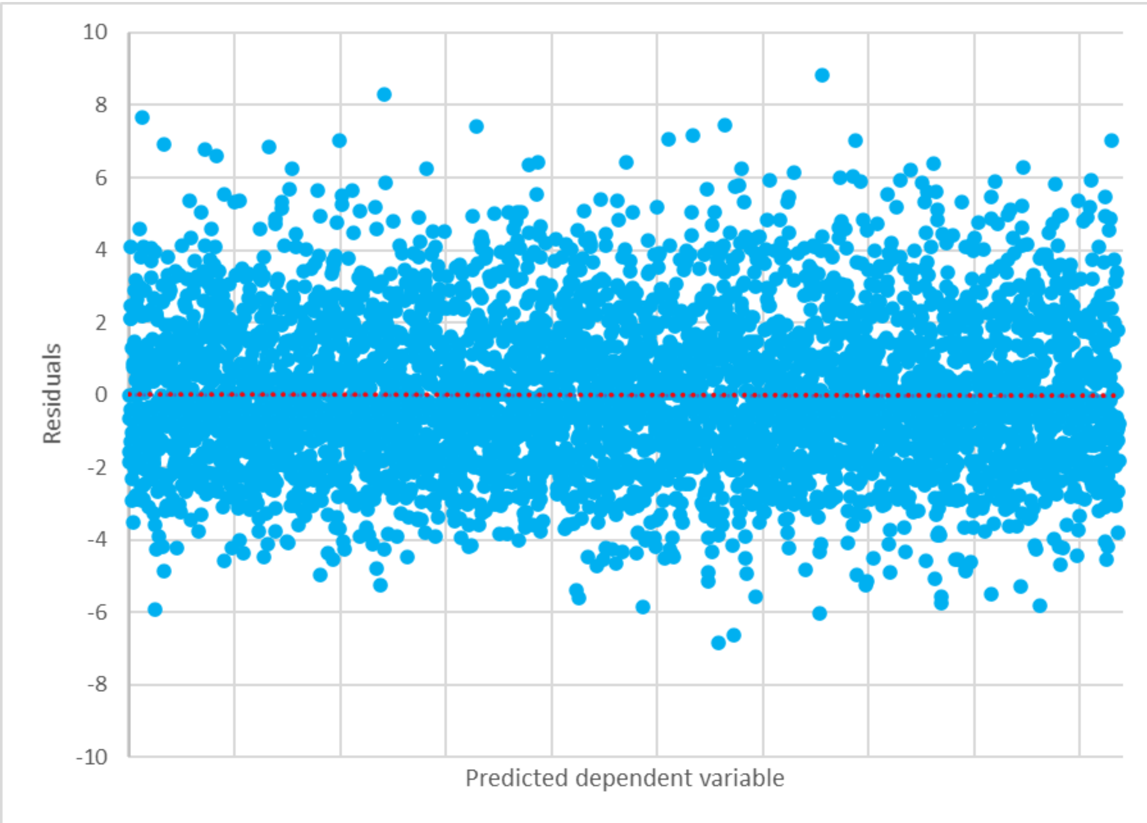
It seems not to be any problem of collinearity in the regression. Only the correlation between the class of revenues and the class of employees is quite high. In fact, these two variables are usually considered together to define the size of a company.

The second important control to make is to assess the heteroscedasticity. Heteroscedasticity may be due to an omission from the specification of relevant variables or a real variability in the variance of errors.

After running the model with the output reported in Table 3, we test for it through a graph first and then through the Breusch-Pagan test.

First, the residuals are calculated. We build a scatter plot of the residuals against the predicted values. If there is no heteroskedasticity, the dispersion of the residuals will be similar with different values to the predicted values. The graph is reported in the Figure 13.

Figure 14: Check for heteroscedasticity



Source: elaboration of the author

It is evident that the variability of residuals around the mean is constant, because there is not an increase or decrease in the values of residuals as the dependent variable gets larger. Thus, the graph suggests that there is no problem of heteroscedasticity.

However, the Breusch-Pagan test is run to provide a formal test that confirm the results.

The method used is the regression of the squared residuals $\hat{u}^2$, the predicted values $\hat{y}$ and their squares $\hat{y}^2$. The null hypothesis is the presence of homoscedasticity against the alternative hypothesis of heteroscedasticity.

The significance F of the coefficients results too small in this case, so the null hypothesis is rejected.

The reason is for sure the presence of dummies variables in the regression. To solve the problem of heteroscedasticity, robust standard errors should be used.

5.6 The investment in workers by Italian companies

Expectations about new technologies are rightly enormous, but in addressing the new perspectives it's important to underline that the country does not start from an homogeneous situation. It has strong territorial and organizational imbalances, that can be attributed to two structural criticalities: the backwardness of development processes in the southern regions and the fragmentation of the Italian manufacturing base.

In fact, the implementation of digital technologies is very different between large companies and SMEs, and between the regions of the Center-North and the South.

Going further in the descriptive analysis, it is interesting to discover more specifically which companies are more willing to invest in people: small, medium or large companies?

Taking into consideration the two variables "average number of employees" and "total value of revenues", the European Commission defines the micro, small and medium-sized firms.

The category of micro, small and medium-sized enterprises (SMEs) is made up of enterprises that employ less than 250 people, whose annual turnover does not exceed €50 million or whose annual balance sheet total does not exceed €43 million.

In the SME category, a small business is defined as a company that employs less than 50 people and achieves an annual turnover or annual balance sheet total not exceeding 10 million euros.

In the SME category, a micro-enterprise is defined as a company that employs less than 10 people and achieves an annual turnover or an annual balance sheet total of no more than 2 million euros (Directorate-General for the Internal Market, Industry, Entrepreneurship and SMEs European Commission, 2017).

By exclusion, the large enterprise is defined as a company that employs more than 250 people, whose annual turnover does exceed €50 million or whose annual balance sheet total does exceed €43 million.

The questionnaire provided to the manufacturing enterprises in 2018 contains a question related to the decision about training. In particular it asked if the companies have provided (directly or through external companies) any type of training aimed at developing or updating the ICT skills of their employees, both specialized and not specialized. By ICT specialist it means a worker for whom information and communication technologies constitute the main job, a figure with advanced computer knowledge including for example the ability to define, design, develop, install, operate, support, maintain, manage, analyse information technologies (hardware and software) and corporate information systems. The others are workers who have to deal with new technologies, but ICT does not constitute the main job.

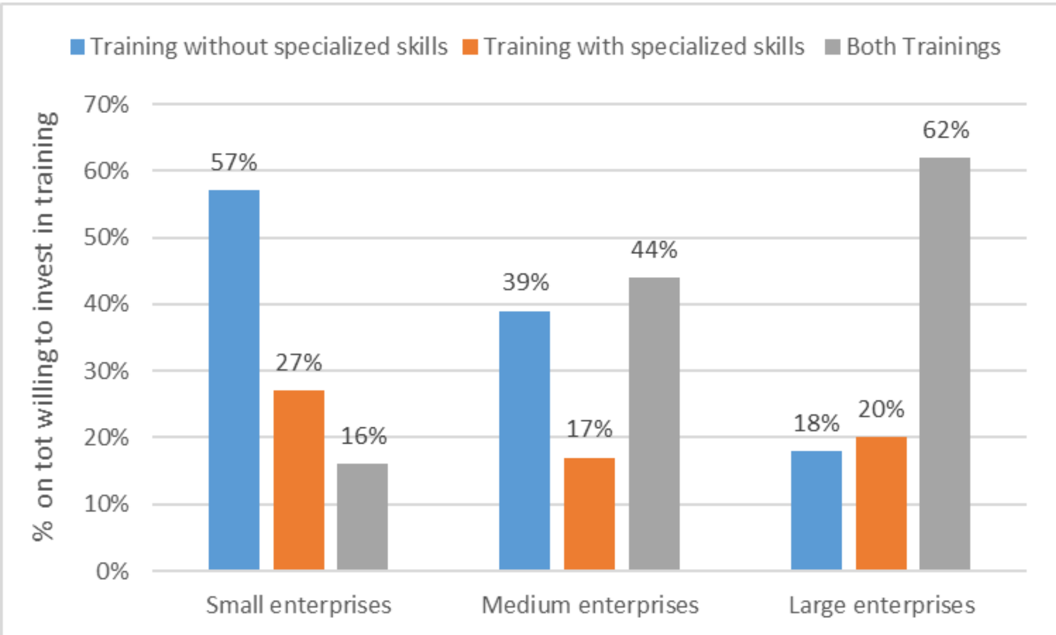
The possible answers are only two (yes or no), thus it comes up two dichotomous variables that are equal to 1 if firms have invested in specialized training (or not specialized training), 0 otherwise.

Selecting the manufacturing enterprises that have adopted new technologies (I4.0 equal at least to 1), Figure 14 underlines the percentage of firms that invested in the workforce by providing training to the current employees.

In general, firms prefer to invest in training without specialized skills and hire in the market workers with specialized skills already generated through the education system.

However, the numbers highlight that the bigger the enterprise the higher the willingness to invest in both the types of skills. In fact, the share of investment in low- and high-skilled job starts from a 16% in small enterprises up to a 62% of the total number of firms investing in the case of large firms.

Figure 15: Share of firms investing in training divided by size and skills



Source: elaboration of the author

However, the numbers didn't confirm the fact that large enterprises are more willing to invest in general. A more general overview of the data is needed, simply comparing the number of firms investing in training with the number of firms considered in the sample.

The first total has been calculated summing the number of firms investing in training with specialized skills, in training without specialized skills and in both trainings.

The Figure 14 shows the results.

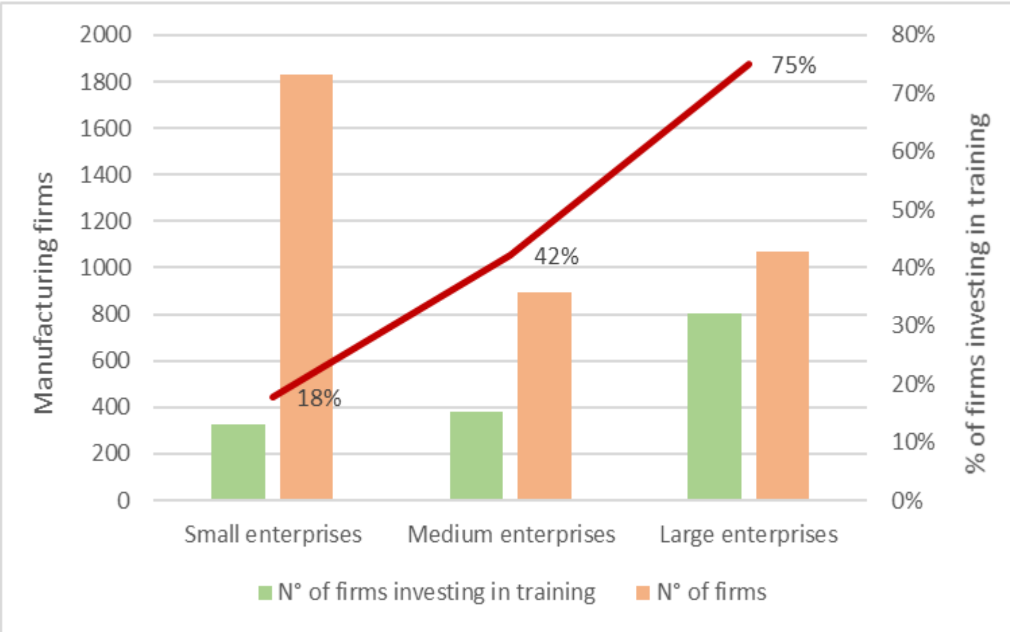
The share of small enterprises investing in the workforce is only 18% compared to the total number of small enterprises.

The share of medium enterprises investing in the workforce is 42% compared to the total number of medium enterprises.

The share of large enterprises investing in the workforce is 75% compared to the total number of large enterprises.

As expected, large enterprises are more willing to invest.

Figure 16: Share of firms investing in training divided by size



Source: elaboration of the author

6. CONCLUSIONS

In the new scenario, we think of digitized territorial ecosystems as ecosystems in which the driving forces of innovation coexist and collaborate; ecosystems in which companies, regardless of their size and geographical location, can reach the benefits of the interaction between emerging technologies.

While the average firm is still very far from this archetypal model of production, at least in the Italian context, the process of diffusion of new enabling technologies is on its way and it is already possible to identify some defining characteristics of adopters, even in a context that is lagging in terms of digitalisation compared to similar economies.

This thesis investigated the path from Industry 4.0 to Society 5.0 with a focus on the impact and the change new technologies have brought in the manufacturing firms, first in general, then more specifically in workers.

It has been described the cutting-edge technologies which characterized the Industry 4.0, such as Internet of Things, Artificial Intelligence, cloud infrastructure, and big data/analytics. Furthermore, it has been analysed in detail the enabling technologies of the Industry 5.0: a set of complex systems, such as smart materials, with embedded, bio-inspired sensors, that combine technologies of the Industry 4.0 to unfold their potential.

All these technologies were introduced within industrial assembly lines to improve productivity and support workers through an interactive process. However, changing roles and increased reliance on complex technologies require new skills. Indeed, people will tend to feel frustrated, neglected, and overpowered by the technology (Kinzel, 2017).

All these aspects lead to psychological stress, which includes conditions such as anxiety, mental fatigue, the possible feeling of frustration or isolation, and, generally, excessive cognitive workload. Excessive cognitive load, linked to the use of technology, can reduce the levels of attention with respect to the main task to be performed, generate physical fatigue, have negative effects on long-term memory and decrease mental acuity.

In general, a negative attitude toward technology could prevent its acceptance and adoption, although it is intended to help workers in specific tasks (Faccio et al., 2022).

The future of work is indeed a necessary shift in the work model, and it requires an important investment in the role of workers. This allows to reach the idea of Society 5.0, an emerging form of society characterized as "Creative Society" enabled by the digital transformation: with their ambition and ideas, people can conduct activities and business that could profoundly change society.

In the last chapter, it has been analysed the manufacturing sector in Italy regarding the technology adoption choices made by firms, looking at a large dataset provided by Istat.
The vast majority of adopters opt for infrastructure investments, such as cloud solutions, mobile connectivity, management software and cyber-security, while leaving the adoption of application technologies such as IoT, automation, robotics, and big data analysis to a later stage (Istat 2020).
It has been investigated the effects of digitization on firm productivity and growth, showing the positive effect of increasing technology adoption on added value and revenues per employee.
Furthermore, the econometric evidence has underlined strong complementarities between skills and new technology. The empirical analysis in fact confirmed the hypothesis made about the investment in the workforce: human capital measured both by education attainment levels (hiring of new staff) and on-the-job training are positively associated with the adoption of digital technologies.
The conclusions we can derive from the analysis made is that all the stress and work-related diseases that a digital transformation can conduct (described in the first chapters), could dramatically decrease if the firm demonstrates to recognize the value of its workforce.
It is from this progressive dynamic that the vigorous push can be born, necessary to get the whole country out of the shallows of non-growth and embark on the path of digital economic development that is inclusive and sustainable (Anitec-Assinform, 2021).
The thesis is characterized by some limitations. Unfortunately, the data available about Industry 5.0 is very limited, because surveys and projects on the topic are still under a detection phase or the data is yet be processed. The most recent questionnaires about new emerging technologies were conducted in 2018 or 2019 and they have been exploited for the analysis. However, it would have been more interesting studying more recent data.
In general, the data set served its purpose and provided an initial overview of different qualitative and quantitative variables, but some of the information provided was not relevant and did not allow for a more in-depth analysis. Changes had to be made to make data reasonable and relevant. Furthermore, the variables available were most of all dummy variables, creating problems to the goodness of the regression.
For these reasons, new microeconomic evidence on adoption behaviours could be useful to shape strategy and policy decisions. Moreover, the analysis could be expanded in a variety of contexts of application, assessing the impact of emerging technologies in other industries for example. Finally, it could be interesting a point of view of workers, by asking them their degree of satisfaction of the digital strategy adopted by the firm.

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