NOVA SCHOOL OF SCIENCE & TECHNOLOGY

DEPARTAMENT OF
APPLIED SOCIAL SCIENCES

# Impact assessment of AI-enabled automation on the workplace and employment

## The case of Portugal

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Master in Biological Engineering

DOCTORATE IN TECHNOLOGY ASSESSMENT

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“L’étude du facteur humain et de ses limites nous laisse entrevoir comment serait susceptible de s’opérer, dans une société d’où auraient disparu les obstacles fondamentaux du profit privé, cette valorisation du travail: valorisation triple, qui devrait être à la fois intellectuelle, morale et sociale. (…) Il faut que l’ouvrier comprenne la valeur sociale de son travail. Il faut qu’ily ait, de lui à ses camarades, de lui à l’entreprise, coopération et même adhésion. S’il se sent coparticipante t responsable (à um degré quelconque) dans la vie et la direction de son entreprise, s’il éprouve que son travail s’intègre dans une collectivité, usine, société, nation, à laquelle il n’est pas étranger et dont il épouse les tendances et les aspirations. (...) Ainsi, même dans les conditions particulièrement difficiles de l’étape actuelle du travail industriel, transition vers l’automatisme, pourraient apparaître de nouvelles forms de ‘joie au travail’” (Friedmann, Georges, *Problèmes humains du machinisme industriel*, Paris, Gallimard, 1946, pp. 392-393)

English version:

“The study of the human factor and its limits gives us a glimpse of how, in a society from which the fundamental obstacles to private profit would have disappeared, this valorization of work would be likely to operate: triple valorization, which should be both intellectual, moral, and social. (…) The worker must understand the social value of his work. There must be, from him to his comrades, from him to the company, cooperation and even adhesion. If he feels co-participating and responsible (to any degree) in the life and direction of his business, if he feels that his work fits into a community, factory, society, nation, to which he is not no stranger and whose tendencies and aspirations he espouses. (...) Thus, even in the particularly difficult conditions of the current stage of industrial work, transition towards automation, could appear new forms of 'joy at work'” (G. Friedmann, 1946)


The Economist, 20th April 2023

# ABSTRACT

Artificial intelligence (AI) has the potential to lead to a wave of innovation in organizational design, changes in the workplace and create disruptive effects in the employment systems across the world. Moreover, the future deployment of broad-spectrum algorithms capable of being used in wide areas of application (e.g., industrial robotics, software and data analysis, decision-making) can lead to considerable changes in current work patterns, swiftly render many unemployed across the globe and profoundly destabilize labour relations. The impacts of AI are estimated to lead to a reduction of millions of workplaces. But qualitative research about AI and its governance is scarce. An emergent technology requires a technology assessment (TA) approach to understand the implications of AI in firms. Mechanisms of industrial democracy can help to adopt AI by ensuring adequate arrangements for employees and avoiding conflicts (mitigating negative effects, promoting reskilling, etc.).

In this research work, the probable penetration of AI in the manufacturing sector is identified to study its effects in work organization and employment in Portugal. Is the employment changing alongside recent AI trends in Portugal? What are the expectable changes in work organisation due to AI-enabled automation? Are there signs of work qualification to go with AI systems implementation? Are there visions on the role of humans on the interaction with the features of industry 4.0? Does that imply new forms of human interaction with AI? These are the questions this research work will try to answer. A TA approach using mixed methods was applied to conduct statistical analyses of relevant databases, interviews with academic, industrial and social actors and exploratory scenarios of AI-based automation systems, on work organization and employment. The manufacturing industry was the chosen sector since it is the sector where most cases of AI-based automation systems are in place.

Findings suggest that, until now, it seems AI is still not able to replace most of the human skills and cognitive capacities but can replace humans on simple tasks. In the future, four different possible states may occur, according to the various initial conditions, the company's motivation, their business strategy, the public policies in place and main social actors involved: Re-organisation of work; Substitution of the workforce; People at the centre and Focus on Efficiency. These were the basis for our scenario outcomes.

**Keywords:** Artificial intelligence, Manufacturing industry, Industry 4.0, Employment, Work organization, Technology assessment, Social implications, Portugal

# RESUMO

A inteligência artificial (IA) tem o potencial de levar a uma onda de inovação no desenho das organizações, nas mudanças no local de trabalho e em criar efeitos disruptivos nos sistemas de emprego em todo o mundo. Além disso, a futura implementação de algoritmos de amplo espectro, capazes de serem usados em muitas áreas de aplicação (por exemplo, robótica industrial, software e análise de dados, tomada de decisão), pode levar a mudanças consideráveis nos padrões de trabalho atuais, e rapidamente, levar ao desemprego em todo o mundo e à desestabilização profunda das relações laborais. Estima-se que os impactos da IA levem a uma redução de milhões de locais de trabalho. Mas a investigação qualitativa sobre IA é escassa. Uma tecnologia emergente requer uma abordagem de avaliação de tecnologia (AT) para entender as suas implicações. Mecanismos de democracia industrial podem ajudar a adotar a IA, garantindo condições adequadas para os trabalhadores e evitando conflitos (mitigando efeitos negativos, promovendo requalificação, etc.).

Neste trabalho de investigação identifica-se a provável penetração da IA no setor da indústria transformadora para estudar os seus efeitos na organização do trabalho e emprego em Portugal. O emprego está a mudar a par das tendências recentes da IA em Portugal? Quais são as mudanças na organização do trabalho devido à automação baseada em IA? Há indícios de qualificação do trabalho para acompanhar a implementação dos sistemas de IA? Existem visões sobre o papel do ser humano na interação com os recursos da indústria 4.0? Isso implica novas formas de interação humana com a IA? Estas são as perguntas que este trabalho de investigação tentará responder. Na abordagem de AT, foram usados métodos mistos para realizar análises estatísticas de bases de dados, entrevistas com atores do ecossistema académico, industrial e social e cenários exploratórios sobre os efeitos da adoção de sistemas de automação baseados em IA, na organização do trabalho e emprego. A indústria transformadora foi escolhida por ser onde existem a maioria de casos de aplicação de sistemas de automação baseados em IA.

Os resultados sugerem que, até ao momento, que a IA não tem a capacidade de substituir a maioria das competências e raciocínio humanos, mas apenas tarefas simples. No futuro, poderão ocorrer quatro situações, dependendo das condições iniciais, motivação e estratégia da empresa, das políticas e incentivos públicos existentes e do envolvimento de atores sociais: Re-organização do trabalho; Substituição da mão-de-obra; Pessoas no centro da transformação e foco na Eficiência.  Estas foram a base para os nossos cenários de referência.

**Palavras chave**: Inteligência artificial, Indústria transformadora, Indústria 4.0, Emprego, Organização do trabalho, Avaliação tecnológica, Implicações sociais, Portugal

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# CHAPTER 1. INTRODUCTION

The 1st Industrial Revolution occurred from around 1760 when the first machines were used to replace the human strength. They were based on steam, coal, and iron. The 2nd Industrial Revolution started around 1860, with the increasing use of electricity as main energy source. Most products were steel and chemicals. From 1970 onwards the 3rd Industrial Revolution took place, with the development of information technology and automation. Currently, we are going through the 4th Industrial Revolution where digital technologies are embedded in the production processes resulting in cyber-physical systems, with the incorporation of intelligent agents in the production processes result in a Human-Machine collaboration (OECD, 2017). This tends to be a deterministic narrative. In doing a technology assessment of these processes it will be possible to understand that other elements and dimensions also contribute to the construction of such recent changes in the production process.

The assessment of these transition processes (or "industrial revolutions") requires clear definitions of some concepts, as manufacturing and organisation of work, as basic ones. The emerging concepts of artificial intelligence, complex manufacturing process and hybrid workplace, will also be considered. Thus, as Chryssolouris propose, "manufacturing is defined as the transformation of materials and information into goods for the fulfilment of human needs and it is one of the primary wealth creation activities for any nation and contributes significantly to employment" (Chryssolouris, 2006). However, if in terms of formal classification for statistical purposes the definition is usually clear, the sector structure has known a recent change. In a recent *OECD Science, Technology and Industry Policy Papers* is mentioned that "manufacturing industries increasingly sell and buy services, while services industries have become very similar to manufacturing industries. Several firms that are classified as services firms are in reality manufacturing firms that have re-organised their activities on an international scale within GVCs [global value chains]. The competitiveness of manufacturing firms in OECD countries is increasingly linked to 'intangible' services activities like design, R&D, sales, logistics, etc. The blurring boundaries between manufacturing and services make them that effective targeting of manufacturing has become increasingly difficult" (De Backer, Desnoyers-James & Moussiegt, 2015).

With the globalisation processes the goods production became segmented, not inside a same company but among different companies with own specialization, creating a value chain. This process was meant to increase competencies, lower product prices through the economies of scale, and, therefore, increase competition. To find lower component costs (with lower labour and material costs), these value chains became established at a global level. The process was made easier with information and communication technologies (ICT). Thus, the whole value chains were not including only just manufacturing companies, but also service companies. If in most 20$^{th}$ century service and industry were completely different sectors, the last decades revealed a more integrated connection where technology played a role of providing the tools to increase competitiveness.

In fact, the models of industrial production have changed over the various industrial revolutions which have had implications for the organisation of work, the organisation of products and for the way of producing and last, but not least, for the organisation of society. Taylorism, where the employee only carries out his simple, repetitive tasks as quickly as possible, without the need to know anything more about the production process, leaving knowledge of the production process exclusively to the managers. Or Fordism, which is the mechanised variant of Taylorism, where, to the characteristics of the previous model, the adjustment of the workers to the machines is added. And finally, Toyotism or (Just-In-Time), where only what is necessary is produced and stocks are reduced (Moniz, 2018). Therefore, it is expected that the current industrial revolution will also have implications on the organization of work, products, production models and society.

There are important scientific and public debates which assume that automation - as the general processes of substitution of labor by machines or software - is one single phenomenon that homogeneously impacts work and employment. Autor (2015), Frey and Osborne (2017), or Brynjolfsson and McAfee (2014) are among the main contributors, who strongly defend the hypothesis of technologies as enabler of changing work environments. However, automation is a process that encompasses different technologies, and each one will impact labor in different ways (Eurofound, 2019; Pfeiffer, 2017). For example, an industrial robot may be complex and expensive to implement and might replace a few workplaces, whereas a software algorithm is relatively simple and inexpensive to implement and can swiftly generate unemployment by displacing several workers.

Furthermore, the effects of technological change can be differently distributed, depending on the institutional framework that each society sets for its working conditions (Eurofound, 2018).

According to Geels et al. (2016) the impacts on work and employment of each technology or each technological system will vary depending on the national innovation institutions. But they can be based on the industrial relations system (Freeman, 1995), and even type of capitalism (Hall & Soskice, 2001). Additionally, a much-debated form of automation is artificial intelligence (AI) which will be in the focus of this dissertation.

## 1.1 What is artificial intelligence?

Artificial intelligence (AI) is the most relevant emergent technology system to understand the development of automation in areas related to information technologies, robotics, and data communications in Europe (Moniz, 2018). Moreover, according to Chryssolouris, Alexopoulos and Arkouli (2023) "AI has been studied since the 1940s, but it seems that only recently are scientists getting closer to effectively exploiting its potential. In particular, within the 80 years of AI research, there have been periods of upsurge and downturn, according to the restrictions of the contemporary technology".

In 1956, John McCarthy defined AI very shortly as "the science and engineering of making intelligent machines". This "intelligence" is provided by the capacity of programming machines, and to enable the capacity of communicating with them. By humans and by other machines. This communicating network of humans and machines has been evolving quickly in recent years. The main elements that enable this "intelligence" to work are the machine learning (ML) systems, cloud computing and big data.

According to Russel and Norvig (1995), there are different definitions of AI which vary along two main dimensions: thought processes and reasoning, and behavior. This means, the definitions can measure success in terms of human performance or measures against an ideal concept of intelligence, which is called rationality. This gives us four possible goals to pursue in artificial intelligence: systems that think like humans; systems that think rationally; systems that act like humans, systems that act rationally. Historically, all four approaches have been followed. As one might expect, a tension exists between approaches centered around humans and approaches centered around rationality since they translate the focus on the social dimension vs efficiency at all costs.

This type of autonomous rationality has been pursued by technology firms, basically to demonstrate their capacity to innovate and to sell their products. Applications can vary from car production (autonomous driving) to domotics (service robotics, domestic smart devices), to health care (companion robots). In fact, AI is a general-purpose technology (GPT), that can be applied to a large variety of situations. However, the similitude of thinking and action can also raise controversies and irrational attempts to develop technology. As Noam Chomsky, a well-known linguist at the Massachusetts Institute of Technology (MIT), was correct when opined that a computer beating a grandmaster at chess is about as interesting as a bulldozer winning an Olympic weightlifting competition. For him, thinking is a human feature.

Overall, AI involves the system's ability to interpret external data correctly, to learn from such data, and to use those learnings to achieve specific goals and tasks through flexible adaptation. A more operational concept of industrial AI is a "systematic discipline focusing on the development, validation, deployment and maintenance of AI solutions (in their varied forms) for industrial applications with sustainable performance" (Peres et al., 2020: 220122). As already mentioned, AI is not one monolithic term but instead needs to be seen in a more nuanced way: It can be observed through the lens of evolutionary stages (artificial narrow intelligence, artificial general intelligence, and artificial super intelligence), or by focusing on different types of AI systems (analytical AI, human-inspired AI, and humanized AI). translating into an aggregating term of several technologies of the referred discipline, such as recommendation systems, automatic translation, facial-speech-text recognition, planning and transport systems, production automation with machine learning, CPS and IoT, autonomous driving, cleaning robots, trading agents or virtual assistants (Boavida & Candeias, 2021: 2/17). The fields of application cover all fields of our daily lives.

## 1.2 AI in the manufacturing process

AI (in a Narrow perspective) has already been employed to support decision-making and optimization in manufacturing systems since the 1970s. Focusing on the applications of the AI methods that were presented in manufacturing, in the period from 1970 to 1990, researchers focused on expert systems that were used to support the decision making of people without expertise in a field and helped them decide as though they were experts (Fox, 1996). Also, AI was frequently used for Manufacturing System Simulators to assign production tasks to the system resources, according to certain dispatching rules (Chryssolouris et al., 1988). AI and the operations research approach to modeling flexible manufacturing systems, have been investigated in several use case scenarios, like by Heragu and Kusiak (1988) where they have included machine layout and task scheduling. Although AI was used in industry, there were no industrial booms, so the interest in AI started decreasing. This changed after 1990 thanks to the Artificial Neural Networks (ANN), the emergence of intelligent agents, and the availability of very large datasets, but mostly thanks to deep learning, which put AI in the spotlight again (Chryssolouris, Alexopoulos & Arkouli, 2023). In general, we can conclude that many applications of AI systems have been implemented in manufacturing industry. First, to enable the communication between humans and machines, and between machines, and then to upgrade the capacity of the networks involving shop floor and design and control units. The post-Fordist developments (that will be explained in the following chapters) led to the concepts of flexible production systems (FMS) and computer integrated manufacturing (CIM), where programming, simulation and planning capacities were developed. AI systems in the manufacturing can be understood as new steps further from those stages (flexibility and integration).

As artificial intelligence technologies have become more mature and affordable, new applications have been introduced into production systems, in support of the manufacturers, on complex decision making and in their business processes. For instance, the potential of ML has been thoroughly investigated for quality inspection.

Programs such as "smart manufacturing" (United States) and "Industrie 4.0" (Germany) have been established in several countries with the aim to reinforce domestic industry over the worldwide competition. At the same time, efforts have been made in defining architectures that will enable the necessary information flows by linking the operational technology and information technology domains, where heterogenous data from several sources e.g. machines, factory automation, supply chain management, etc. while enabling end-to-end communication among all production-relevant assets and fulfilling time and batch size constraints. Additional challenges include interoperability, compatibility with legacy industrial systems, as well as security, trust, and privacy that remain open research topics (Chryssolouris, Alexopoulos & Arkouli, 2023 and Boavida & Candeias, 2021)). As mentioned above, flexible systems and integrated manufacturing brought new industrial concepts already by the end of 20 century. The novel Industry 4.0/smart manufacturing concept increased the problems that the application of AI face today.

Today's factories envision levels of automation, where industrial robots mimic the movements and, seemingly, the intentionality of human workers. Robots nowadays, not only do they work faster and more reliably than their human counterparts do, but also perform tasks, such as the microscopically precise assemblies, which are beyond the human capability altogether. But, again, this capacity has limitations related to the security and reliability of systems, trust between humans and these towards machines, and privacy of information.

In literature, the real benefit from AI in manufacturing, is described not to be just through the automation of tasks but through the provision of new levels of autonomy that will make entirely new applications possible and introduce new business processes in manufacturing (Handy, 1999; Makó et al, 2003; Frey, 2019). Predictive maintenance, energy management optimization, involvement of customers in the design phase, plant-wide control is some of the AI-enhanced capabilities. Moreover, automated processes, autonomous vehicles, robotics, Human–Robot collaboration and the combination of all may contribute to achieve the optimum dynamic exploitation of the resources, if integrated into combination with smart planning and scheduling systems (Chryssolouris, Alexopoulos & Arkouli, 2023: 11). There is, in fact the ability of AI to take decisions in many manufacturing processes, also as a general-purpose technology, or GPT. This means it can raise many social, organizational and ethical questions as mentioned by Frey and Osborne (2017), Brynjolfsson and McAfee (2014), Acemoglu and Restrepo (2018), Autor (2015), among many others.

## 1.3 Why the focus on workplace?

Since the arrival of the first steam-driven machines in factories in the late 18th and early 19th century, waves of passionate and polarized discussions about the future of work have started. There are arguments in favor of the belief that technology will continuously be improved and will lead to an end-of-duly-work scenario. There are also arguments against this scenario, while it may reveal the feasibility of job losses just focusing on the substitution of humans by machines effect. One of the main arguments today is that we are now facing an unprecedented level of interaction between humans and machines, due to a combination of technological breakthroughs in artificial intelligence, miniaturization, the internet, and social media (Eurofound, 2018 and 2019; Degryse, 2019).

These developments are leading to a wave of innovation in organizational design and changes to institutionalized norms of the workplace. This was well analysed by Larry Hirschhorn on “Beyond mechanization” in 1984, and Ann Majchrzak on “The human side of factory automation” in 1988. Hirschhorn said that we are looking at a transition where the post-industrial work become defined as a labour in the frontier of physical systems and realities. The worker becomes no longer a controlled element in the production process, but the one that manipulates control devices to control the control devices...” (p. 116). Majchrzak focuses on the changes at the organizational level: “many organizations may find that if they do not assign the responsibility for implementation to the automation project team, implementation activities occur in an unplanned, haphazard fashion” (p. 263).

More recently, Schildt (2017) presented an overview on this recent development of algorithmic management and its impact on the organizational design. Advanced algorithms that can have a broad range of applications and be applied to many situations can generate more concern, as they may produce significant technical, economic, and social effects in firms.

Techno-optimists named this present phase the “second machine age,” arguing that it now involves the substitution of the human brain. On the other hand, the present level of human–machine interaction can also be described as not more than the natural prolongation of the previous ICT macro-trajectories. There are many non-automatable tasks that make jobs less vulnerable than suggested by, for example, the study by Frey and Osborne, as was already pointed out in Boavida & Candeias (2021).

According to Arnold et al. (2018), within the same occupation, the automation potential can vary greatly from job to job; threats in occupations vary significantly by qualifications and, importantly, by countries; thus, complementarity instead of substitution might prevail in many workplaces, as Autor have mentioned in his work on the paradox of economic growth (Autor, 2014). Therefore, despite the resurgence of the debate and social angst about the future of work, there is not a clear consensus on whether we are on the verge of a quantum leap in human–machine interaction or seeing a continuation of previous trends. Current approaches use mainly quantitative models with drawbacks associated with occupations and tasks (see Boavida & Candeias, 2021).

Due to the ability of a machine to perform cognitive actions is normally associated with humans (reasoning skills, learning, recognizing patterns and inference), several implications have been described in the literature at the level of work organization that can be observed by changes in the worker and job profiles, number of workers needed, human-machine collaboration, physical presence vs. virtual presence and employment relationships, among others.

Generally, it is expected that to the rise of Big Data and improvements in computing power, the development of large spectrum algorithms of AI will have a significant technical, economic, and social impact. In fact, it is expected that the introduction of AI will meaningfully transform the organization of work in firms, the tasks being developed at workplaces, and the skills and qualifications necessary to cope with its challenges (Boavida & Candeias, 2021).

## 1.4 Problem and Research Objective

Despite AI existing already since the mid of last century, its development has accelerated exponentially in the last decade due to 3 factors: increased computing capacity; access to large amounts of data and advances in the field of machine learning (namely in neural networks and deep learning), as referred by Brynjolfsson and McAfee (2014). Such development has focused, in particular, on face recognition, natural language understanding and computer vision, allowing intelligent machines to significantly increase their ability to perform non-repetitive and relatively high-profile tasks. Besides to the repetitive, non-cognitive tasks that existing automation technologies were already performing.

In addition, the generic reduction of costs associated with digital technologies in different aspects, it is considered that AI will be one of the technology systems that will have greater weight in the digital transformation (4th Industrial Revolution) in the near future (Cetrulo & Nuvolari, 2019). In previous Industrial Revolutions productivity, employment and organization of work have been affected so it is expected that the adoption of AI-based systems will also have implications around the world and also in Portugal. In those technology transitions the implications for economy and society had effects on substitution of duly and hazardous jobs, with impact on employment and qualification structures. However, although there are debates around the world about this issue, in Portugal only impacts at the level of productivity have been given more attention. It can be expected that further impacts on models of work organization, on employment, on qualification strategies can become more central.

For this reason, the object of this research study is the impact assessment of the social effects of artificial intelligence, in Portugal, until 2035, in the manufacturing industry. To perform this exercise a Technology Assessment approach was used. It will provide methodological contributions to this approach and to demonstrate the pertinence of this assessment to fully understand the diversity of dimensions related to the recent technology transition in the Portuguese industry.

Just with such understanding it can be possible to tackle the potential negative impacts and to integrate the different perspectives around the focus of debate. There are not many technology assessment exercises around the implementation of AI-driven industry transitions, neither case studies on manufacturing sectors. Even less there are studies on the impacts over social dimensions, as employment structures, organizational models, job contents, qualifications for work, human-machine interaction processes. This research study aims to address this exercise to know about the multi-dimension characteristics of the present transition in industry in modern economies, including, Portugal.

The major question for this research then will be: **what are the organisational, and social effects of AI-enabled automation in the manufacturing industry, in Portugal, by 2035, on the workplace and employment?**

## 1.5 Outline of the Research Thesis

The thesis is organised into 6 chapters. The present Chapter 1 shows the general context and research objective: evaluation of the social and economic effects of artificial intelligence, in Portugal, until 2035, in the manufacturing industry. The Chapter 2 presents the literature review including conceptual foundation for the thesis on the evolution of automation, organisation of the production processes with increasing automation, debates around implications on employment and workplace. On Chapter 3, Towards a TA approach, the research questions, hypotheses, and research gaps, around three dimensions: Adoption of AI-enabled systems, Organisation of the digital transformation process and Prospects of human-machine interaction in the workplace are provided. It also includes the methodology and methods used: Literature Review, Documental Analysis, Secondary Statistical Analysis, Interviews, Group Discussion and Scenarios.

Chapter 4 and 5 are about results and discussion. Whereas Chapter 4 presents the contextual situation of AI-based systems in Portugal and the choice of sectors to focus the research study further, Chapter 5 discusses existing studies about the Manufacturing Industry in Portugal complemented with the discussion around the empiric evidence collected and proposes possible future scenarios with the adoption of AI-enabled systems.

At last, Chapter 8 includes main conclusions, recommendations, limitations to the research work and further research needs. A summary of the presented outline can be found in Figure 1.

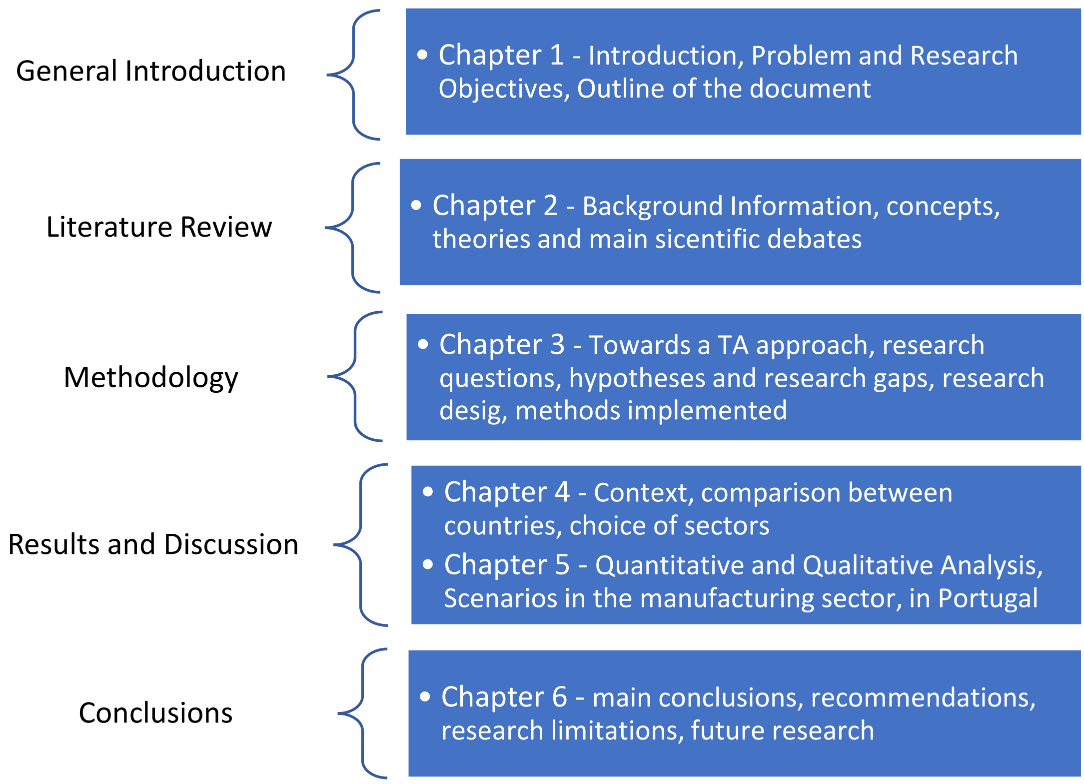


Figure 1: Thesis Outline

# CHAPTER 2. BACKGROUND INFORMATION AND SCIENTIFIC DEBATES

This chapter presents the theoretical concepts that served as framework for the research work of the thesis. It starts by introducing the notions of **socio-technical transitions** in industrial manufacturing and, afterwards, the evolution of **industrial transformations** (industrialisation, production rationalisation and automation) is presented. Next, another building block, on the recent developments of AI-enabled automation gives an overview of the evolution of the different technologies at the machine and process level and how this can be disrupted by AI, including the concepts and definitions of **AI-enabled automation systems** and the debates around its impact on employment and in the workplace. It continues presenting the visions of Industry 4.0, around efficiency, models of organisation of work and the new vision for Industry 5.0. At last, based in the literature review the main **research gaps** around impact assessment of AI-enabled automation in employment and in the workplace are presented.

The timeframe towards 2035 is related with the fact that most public policies, strategies, and action plans are valid until 2030. Therefore, current policy options are also taken in consideration in the design of future scenarios with the adoption of AI-enabled automation systems.

In order to answer the guiding question on the organisational and social effects of AI-enabled automation on the workplace and employment, the following three dimensions were defined:

- Adoption process of AI technology systems by the manufacturing industry
- Organization of the digital transformation process in companies from the manufacturing industry

- Prospects of human interaction forms with AI in the work environment (substitution or complementarity effects)

## 2.1. Socio-Technical Transitions on Manufacturing

Larry Hirschhorn starts the introduction to his seminal book *Beyond mechanization: Work and technology in a postindustrial age* (1984), that "robots cannot run factories. The common notion that computers eliminate the need for human skill and judgement is wrong" (p.1). He also concludes that "technology alone cannot determine work and organizational design, which are also shaped by social and political interests. But technology can set the limits within which design are made. The new technology presents new opportunities and problems for work design" (Hirschhorn, 1984: 2). This means that AI cannot replace human skills and thinking but can replace humans operating simple tasks. It also means that the design of technology already integrates the limitations for human-machine interaction and for the organizational options. These findings establish a new framework about the transitions on society, in general, and on manufacturing.

Such transitions were made at the end of 20th century with both social and technological dimensions. And now, almost the same words from Hirschhorn can be used to make the same statements about the transition towards industry 4.0 with regards to the developments of AI in manufacturing settings. In other words, **AI-enabled automation brings socio-technical dimensions. It is not just a technical or engineering problem or solution.**

"The underlying premise of socio-technical thinking – according to Baxter and Sommerville - is that systems design should be a process that considers both social and technical factors that influence the functionality and usage of computer-based systems. The rationale for adopting socio-technical approaches to systems design is that failure to do so can increase the risks that systems will not make their expected contribution to the goals of the organization" (Baxter & Sommerville, 2011: 4). These ideas show that still today, the same problem on the importance of the human factor in complex technical environments remain as by the end of 20th century. In other words, explicit human factors in computer-based systems are approachable when socio-technical dimensions are considered. If those systems are only analysed from a technical approach (engineering, or computer sciences), the human factor is marginalized or even non-existent.

In the same direction, a frequent quoted conclusion from the Office of Technology Assessment of the US Congress said that "the main stumbling blocks in the near future for implementation of programmable automation technology are not technical, but rather are barriers of cost, organization of the factory, availability of appropriate skills, and social effects of these technologies" (OTA, 1984: 94). This means AI-driven transitions in manufacturing should integrate the social dimension as well. This also proved that the socio-technical considerations on the automation processes are not present just now. They have been analysed since the so-called 3rd industrial revolution. **The present transition towards industry 4.0 should also consider the main outcomes of the research on organizational innovation and on the centrality of human factors, that have been done since then.**

## 2.2. Industrialisation, rationalisation and automation: three steps in the same production process

The concept of automation has been approached as a production process that enables industrialisation into further levels. The issue is not only the quantities of products manufactured, but the way they are transformed and the new possibilities to create new markets. John Diebold, who published the book *Automation: The advent of the Automatic Factory* in 1952, referred to the concept of automation to designate the methods of automatic command of the means of production. The meaning would be suggested above all by the contraction of the concepts of "automatization" and "organization".

Later on, the Italian sociologist Federico Butera published his definition of automation in the *International Encyclopedia of the Social and Behavioral Sciences* where he states that "automation is a stage in the process for integrated systems of processes, technology, organization, roles and values, where technology plays a wide variety of roles, existing and new tasks, and where interaction is conceived between human beings and technical systems with the aim of achieving optimal products and services" (Butera, 2015: 296). This author thus underlines the relationship between human work tasks, mechanical automatism and the integration of technological, organizational and social dimensions. He also refers to the optimization aim, which is an element of a new rationale of the production processes.

Another approach to the analysis of production process is done by Braverman's book entitled *Labor and Monopoly Capital* (1974), who initiated the so-called (by Braverman) labor process debate, where he examines his own experience from a Marxist perspective, as he was an industrial worker. He drew attention to processes at work that were not considered by the vast majority of scientists at the time. That is, that capitalist management models will be the main cause of the decrease in qualifications in organizations. This principle can as well justify the substitution effect caused by recent development strategies of AI-enabled automation if they are twined with such management models.

These models integrate increasing investment in technology and increasing automation. This author represents, in fact, an important change in the perspective of knowledge of automation processes. He analyzed in detail the characteristics of the most modern equipment that were being introduced since the 1960s. He referred, for example, to the transfer machines that began to characterize the production lines of engines for the automotive industry. Braverman also noted that "when such a system includes arrangements for machine actuation per workpiece, so that the need for direct labor is further diminished, the production line becomes 'automatic'" (Braverman, 1974: 192). **Therefore, automation implies the action of interconnected machines, independent of human intervention, which successively transform the workpieces and transport them from one workstation to the next according to a pre-defined and rational production process.**

As Pardi et al. (2020) refers, "since the introduction of mass production in the 1910s the stamping, welding, and painting of the car have been progressively mechanized paving the way in the 1970s and 1980s to the automation of most of these assembly operations. By contrast final assembly where most of the variety and complexity of the assembly process converged was still manually intensive and concentrated over 60% of the total employment in the factories (MacDuffie and Pil 1997, 247). The most important efforts in terms of automation focused in the 1980s on breaking the final assembly bottleneck to move towards the engineers' dream of an almost unmanned factory. These efforts came in particular from carmakers that suffered in the 1970s from productivity and quality problems and saw the automation of the whole assembly process as the ultimate solution to these issues. GM and Fiat were amongst the most engaged in this process (Camuffo and Volpato 1997)" (Pardi, Krzywdzinski, Luethje, 2020).

The Uddevalla case raised many debates. This Volvo factory manufactured trucks and had an atypical organisation of work model. At that time, the dominant production model was lean production model and in the Uddevalla factory production was performed in workstations disposed in islands which the car had to go through to be assembled. Moreover, the team of workers of each workstation had autonomy of decision regarding quality and execution time. Lean production supporters argued that Uddevalla required twice as many hours of work to assemble a car than the average lean factory (Womack, Roos, and Jones, 1990). Uddevalla supporters showed that it had better productivity and quality results than the other standard mass production factories of Volvo and argued that this was the right term of comparison to judge its performances (Berggren 1994; Freyssenet 1995), and therefore, it could be presented as a new rationalized model of production. Eventually the debate came to a sudden end when Uddevalla was closed in 1992 following the 1991 economic crisis and a sharp decline in the sales of Volvo, even though the concept survived on a very ad-hoc basis in some Japanese factories, including some Toyota ones (Nohara, 1998: 8). Although it was not a matter of which production model was used but rather due to market conditions and lack of demand for Volvo products which led to the Uddevalla shut down, the automation of production processes followed a more intensified transition after that debate on the lean production which became a new industrial rationale. Optimization with less waste and costs became the production objective in manufacturing industries. Nevertheless, is also worth taking in consideration Boyer's statements, when he states that "the management model of a firm is the outcomes of a process, often long and contradictory, of making the different technical, organizational, and economic systems internally coherent and externally relevant" (Boyer, 1998: 25).

The emergence of the "lean production" model, based on the Toyota production system (Womack, Roos, and Jones, 1990), appeared as the new "one best way" proposed in former times by Ford. But this model was, as Freyssenet presents, "an amalgam of profit strategies and industrial models which are different and incompatible, [and] cannot be the industrial model of the twenty-first century" (Freyssenet, 1998: 45). However, companies that adopted this rationality principles were those that integrated first the AI-enable automation processes. That was also the case for the automotive industries.

As the initial GERPISA program has designed their hypotheses in the late 90s (Freyssenet et al., 1998), it seems to be still true that "the evolution of industrial models has two drivers. First, there are 'trajectory effects' within a geographical space, often via major crisis, either in production or more generally. Secondly, there is the impact of efforts to internationalize, which give rise to the enrichment through hybridization of the initial principles of production" (Boyer, 1998: 41).

## 2.3. Recent developments of AI-enabled automation

### 2.3.1. From numerical control of machinery to "smart factory"

Although numerical control (NC) systems were developed shortly after World War II, we only find major steps towards automation from the 60s of the last century (Alique, 1986; Berting et al. 1980; Gettelman, 1982; ILO, 1985; Kaplinski, 1987; Moniz, 1986, 1987; OCDE, 1983). The emergence of Computerized Numerical Command (CNC) machine tools is (relatively) recent and is due to an invention made in 1942 to overcome a practical difficulty in manufacturing a part for a bomber engine. Thus, coded perforated cards were used that automatically guided (without manual operation) the machine tools. This new system was then developed at M.I.T. by order of the U.S. Air Force. in 1949.

As Braverman points out, "with the NC, the mechanical process is susceptible to control by a separate unit, which receives instructions from two sources: in numerical form from an external source, and in the form of signals from controlling devices that confer the ongoing process at the point of contact between tool and workpiece. Using that information, the control unit emits signals that activate the energy that controls the part, tool, coolant, etc. (...). The coding of a work is quickly completed when separated from the mechanical execution, and once codified it never needs to be analyzed again" (Braverman, 1977: 172).

It is, therefore, a technique that provides pre-recorded information in a symbolic (digital) way. This information represents all the instructions necessary for the operation of a machine, in particular:

a) location of the tool in relation to the workpiece;
b) tool locations in the machine's own coordinate system;
c) distances and types of movements required;

d) auxiliary operations (tool change), for example.

The movement of the tool, the part to be machined, or just the location of the different central elements is usually represented using a Cartesian coordinate system.

But this idea introduced a totally new concept in the working of machine tools. And the development of this concept has been progressively changing the machine-making system itself and the "philosophy" underlying industrial activity. Despite this, the introduction of NC systems does not by itself profoundly change the classical Taylorist conception of work organization. At least we can consider the NC system as one of the particularly important elements in the work rationalization process, but which can, due to the characteristics of its development, jeopardize this same process (Elgozy, 1968; Braverman, 1977).

Indeed, Elgozy already mentioned in the late 60s that "the Numerical Control system is nothing more than an application of information technology to industry, where calculators are necessary whenever the parameters of a process become too numerous" (Elgozy, 1968: 108). Thus, the introduction of numerical programming commands not only in machining systems, allowed its generalization to other means of manufacturing. Now, the application of commands by calculator allowed the reduction of adjustment times, and also allowed the transformation of the machine into a universal means of production. The flexible shop floors are based, in technological terms, on this type of electronic application to industrial production.

Therefore, the effects of NC on the work organization system can be revealed, in the fact, that "the unity of this process in the hands of the specialized mechanic is perfectly plausible, and in fact has much to recommend it, since the knowledge of metallurgy practices required for programming is already mastered by the mechanic. There is no doubt - says Harry Braverman in his work *Labor and Monopoly Capital* - that, from a practical point of view, there is nothing to prevent the manufacturing process under numerical control from remaining a total responsibility of the professional" (Braverman, 1977: 172).

In fact, NC machine tools rapidly evolved, in particular from the beginning of the 70's of the last centuries. It was also from that time that microcomputers appeared in manufacturing industry. Consequently, these information processors are applied to these machines: the CNC (computer numerical command, or computerized) and the DNC (direct numerical command) appear. This rapid diffusion is also because working times and production costs tend to be lower (DeGarmo, 1969: 916-917).

But other aspects have substantially altered the capacity for technological development in the industry. One of them has to do with the fact that before the introduction of NC it was unthinkable to use multiple tools simultaneously. Only very complex, specialized machines could be capable of performing more than one operation per workpiece.

Any one of these systems adapts in particular to small and medium series, automating them. The CNC uses a dedicated computer inserted in a numerical control unit. This computer is capable of working with parameters that are introduced locally. The CNC can be part of a DNC system. This system uses a computer to distribute data programmed in parts to several remote NC machine tools. Thus, CNC systems can then be compared with other technical systems, in particular the conventional system, the DNC, and robotics. In this way, it will be possible to understand under what circumstances it is necessary to use one system or another.

The difference between CNC and DNC resides in the following: CNC machines are autonomous since they have their own computer system, while DNC machines correspond to a centralized system, where a more powerful computer directs and governs “directly” the different factory or workshop NC machines. However, due to the growing capacity of microprocessors, and due to the debate between ”centralizers” and “decentralizers”, the CNC system has, in the last decades, demonstrated its greater versatility and adaptability, particularly in SMEs (Cortés: 1986; Scott, 1985).

The first DNC system appeared in Japan in the mid-60s, and first appears in Europe - in Hungary - in 1973. On the other hand, the abandonment of DNC development was due to several factors: the high cost of computers and their poor reliability when applied to this system. “Later - the Catalan engineer Sanfeliu Cortés tells us -, in the light of the results observed with the direct control, it was possible to prove that for complex cases this system was not appropriate, since the performance of the computer was drastically reduced and, on the other hand, the control was enormously complicated” (Cortés, 1986: 37).

The development from the numerical control of machinery towards robotics represented an important step in terms of digitalisation of the production process. A robot can be considered a machine but is used to replace humans for feeding machine tools or other production operations.

In fact, in the 1970s, industrial robotics began to be considered as part of Computer Aided Manufacturing's (CAM) own "philosophy", not only due to rising labor costs, but also to the pressure to move workers away from jobs with poor working conditions. However, the introduction of robots in CAM systems in the industry is still due to the consumer market's insistence for a greater variety of product styles (Scott, 1985: 35). Industrial robots are part of what is considered manipulation mechanisms (along with manually controlled manipulators and sequential manipulators).

It is easier to distinguish a robot from a manually controlled manipulator or a sequential manipulator, as these are "consisting of articulated mechanical arms controlled by a pneumatic, hydraulic or rudimentary electrical logic system, with simple and repetitive movements" (Cugy: 1983).

Industrial robots have a poly-articulated or mobile type architecture (AGV's, that is, auto-guided vehicles), and can have a fixed or metamorphic nature. Its structural systems can be divided as follows: a) body; b) arms; c) locomotion system; d) terminal elements.

The arms of **industrial robots** may have the following configuration: (i) Cartesian, (ii) polar, (iii) cylindrical, (iv) angular, or (v) mixed. Its constituent elements may be bars, joints (simple, composite and/or distributed), and a base.

Figure 2 – industrial robot
https://i.pinimg.com/originals/87/bd/cc/87bdcc2d596f17ca7e308137ffbce931.jpg

With regard to **AGVs**, their locomotion system is based on rolling elements, and may be filo-guided by magnetic means, through vision sensors or by ultrasound. The other structural subsystem is related to terminal elements.

Figure 3 – auto-guided vehicle (AGV)
https://www.flexqube.com/uploads/brix/51451/agv-pw6g1i-1024x0.jpg

It is precisely the terminal elements of industrial robots that serve to manipulate or support the tool necessary for automated work.

In the **welding robot**, the welding point must be on the axis of the robot's arm in order to facilitate the programming of the arm's trajectories. Usually, this type of robot has a poly-articulated architecture, and its base is fixed and the configuration of its arms is angular.

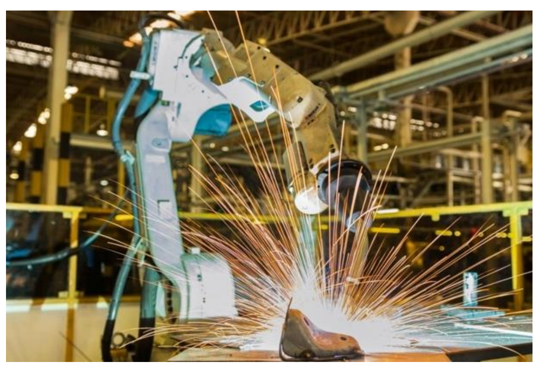

Figure 4 – welding robot
https://diverseco.com.au/wp-content/uploads/2018/09/Robot-Technologies-Australia-Welding-Stock-1024x683.jpg

The “**scara” type handling robot** is mainly applied to assembly tasks. The configuration of its arms is usually cylindrical. If the base - which is normally fixed - is based on a mobile one, its configuration becomes Cartesian. However, its architecture, as in the previous case, is also multi-articulated.


Figure 5 – scara robot
https://www.shgongboshi.com/photo/pl33400164-scara_robot_sr_3ia_4_axis_payload_3kg_reach_400mm_assembly_robot.jpg

**Painting robots** also have a poly-articulated architecture, and their base is usually fixed. A pneumatically driven sprayer is attached to the tool holder. They require, however, less precision in the programming because the ink particles can be attracted by the plate with electrostatic charge.

Figure 6 – painting robot
https://paultan.org/image/2013/08/vw-paint-shop-robots.jpg

These new types of programmable machinery were disseminated in a wide range of factories around the industrialised world. They have established the infrastructure and the ground for the possibility of more advanced artificial intelligence devices to be aggregated. The need to coordinate the robotic systems with the numerical control machinery, and these with buffers and warehouses, raised the need to develop the AGVs and **logistics concepts at the shop floor.**

The steps from **the intelligent automation** towards a more advanced concept of "smart factory" was established. The technical conditions were provided already in the decades of 80s and 90s of the last centuries, and then emergent organizational concepts should encompass these new steps.

## 2.3.2. From FMS to CIM and from production cells to Industry 4.0

The flexible manufacturing systems, or FMS, were designed to produce in medium series and with a medium level of variety. They emerged in the last decades of 20$^{th}$ century and was presented as a step forward in terms of integration of different emerging production technologies. It can be said that this system is at the midpoint of production techniques, having the advantages of large-scale and small-scale production. And it is precisely this middle point that normally causes the deficits of industrial companies. But also, flexible automation is "revolutionary" because its automation system is based fundamentally on logical systems ("software") and not on the equipment itself ("hardware") of the machines.

The FMS systems are associated with production management activities, the management of all engineering project information and, finally, the databases relating to the different dimensions necessary for their operation. Associated with the engineering project information is its most important element, that is, the CAD-Computer Aided Design system. Production programming and planning have been an activity associated with production management and, therefore, was necessarily to be linked to flexible production systems.

FMS's appeared in the mid-70s with the development of factory automation, as they controlled the transport (or flow) of materials between the various machine tools or machining phases, using different "cells". These cells typically contain CNC machine tools, assembly cells, industrial robots, inspection machines, and conveyor systems. According to the French sociologist, Benjamin Coriat, the FMS "has as its main mission the optimization of circulation times between machine tools. These procedures (...) have, above all, the advantage of setting in motion flexible forms of organization of production" (Coriat, 1985: 103).

It can therefore be said that FMS cells tend to always include CNC machines, autonomous robots (which incorporate self-diagnosis systems and powerful controllers, that is, without human assistance), flexible warehouses, and connections with other sub -systems (CAD, CAM and management) so that they can re-program production. Each cell is thus a small block of the FMS which generally consists of a machine[1] controlled (i.e., reprogrammable) by a computer. This type of machine must be able to perform a single operation or a series of operations on automatically loaded and unloaded parts of the machine, using tools that also change automatically (Ranky, 1985: 208; Bonetto, 1985; Vilrokx et al., 1986).

The **concept of flexibility** was a condition for industrial infrastructure at the global level. The possibility to program machine-tools and production systems enabled the market to provide smaller series of similar products, greater differentiation among the same type of product, and a closer linkage with the consumers. Globalization of economies also brought the so-called "customization" of production. This process become the antithesis of the Fordist model based on scaled economies. In other words, when the Fordist model included the concept of production systems to provide very large batch similar products to the market to decrease the unit price, make those products more affordable, and with higher levels of productivity and profits, the flexible market was based on differentiated demands.

This differentiation was pushed by strong cultural changes and societal needs that shaped markets. To provide products for this new market structure, the technological developments enabled companies to cope with those challenges. Achieved the technical flexibility with intelligent systems organised in FMS, a new criterion emerged: the need for technical integration. Advances in machine programming were focused on the outcomes of each machine. These new steps needed coordination and integration.

**Computer Integrated Manufacturing systems**, better known as CIM represent a fundamental change in the recent evolution of production technologies and work organization systems. They also represent a new paradigm shift. This productive system constituted, until recently, the most advanced stage of two of the fundamental tendencies of technological development (and of industrial modernization in its most advanced aspects), such as: a) the integration, global and systematic control by computer of the manufacturing processes; b) the extent of automation at all levels and areas.

As mentioned by J. Child, this system integrates two dimensions. One will be "the physical dimension in which the transformation and transfer of material and components can approach the

[1] Not necessarily a machine tool, but other types of machines can also be considered.

concept of continuous flow. The second, the informational or management dimension, in which marketing, design, engineering, production and accounting activities achieve a high level of coordination in the interest of achieving a flexible and cost-effective response to market opportunities" (Child, 1987: 117).

According to Jones and Webb, "What is different about CIM is that it represents not only the automation of the manufacturing processes themselves, but also the information and control systems through which work is planned, organized and carried out" (Jones & Webb, 1987: 61).

One speaks of CIM ("Computer Integrated Manufacturing") when referring to computer-integrated manufacturing, that is, when CAD and CAM functions (and even FMS) are integrated. In this way, we are witnessing high levels of integrated automation linking several automated "islands" in a distributed processing system. According to Ranky, "the technology applied in CIM makes intensive use of distributed computer networks and data processing techniques, Artificial Intelligence and Database Management Systems" (Ranky, 1985: 205).

In this open system concept, product needs and product design (creativity) are the inputs of the system, while the outputs are, logically, the finished products. It is through product design specifications and project preparation that the process of designing the work teams and equipment that will be allocated in the various production stages arises. In the design phase of the project, the entire structure of the project is assumed. From there, the structure of the product is articulated with the Planning and Product Programming area, and this requires the specification of the needs coming from the Team and Facilities Design area.

The more interaction there is between the various sectors of activity in a company, the greater its technical efficiency. Hence, all the figurative elements of CIM concepts or of the integral elements of the system can never present domains of clear specialization and self-sufficiency. Precisely, in a CIM system there will be ever greater dependence of all sectors on each other. One of the reasons for this trend is that, in an integrated CAD/CAM system, all equipment shares a common database of information, for example, engineering specifications, part and sub-assembly numbers, and instructions that turn computer data into concrete guidelines for specialized tools. In this way, it is possible for this integrated production process to have high levels of productivity and efficiency with low production costs (Dratch, 1986; Kochan, 1985).

However, the concept of a CIM system has mainly been associated with a "technocentric" approach, that is, production systems are conceived as a concatenation of technical tools and equipment. In this way, production problems are analysed only in terms of technical engineering. In addition, the sole purpose of introducing new technological systems is to strengthen integrated production processes, increase productivity, or reduce labor costs.

### 2.3.3. AI-enabled automation: current systems and future developments

The manufacturing process integrates physical mechanisms to transform the shape or the form and properties of a material. Thus, the high-level classification divides manufacturing processes into discrete parts processes (where single items are processed) and continuous processes (where the material that is processed is continuous matter). For instance, the metalworking industry involves the production of several single items thus, it utilizes discrete component manufacturing (as in the electronic industry or the automotive sector), whereas chemical processing, which is also involved in the fiber-making industries, uses continuous processes.

In parallel, the role of AI in supporting key activities, at the manufacturing process level, includes (i) process monitoring and data processing, (ii) process modeling, optimization and control, (iii) fault diagnosis, tool wear prediction and remaining useful life estimation and (iv) process quality assessment and prediction. AI-based tools can inflate the advancements in manufacturing processes in all production sectors, either in the continuous process industry, or in the discrete production industry.

The harsh environmental conditions (especially in the process's production) sometimes restrict the use of specific control sensors. In this case, there are potentially critical data that can be limited for the deployment of AI based data. "Additionally, the existence of legacy systems along with equipment, engineering, recurring, and training costs have prevented the integration of new sensors in industrial environments, in many cases" (Chryssolouris, Alexopoulos & Arkouli, 2023: 31).

With increasing automation, more and more human inspection activities are allocated to **intelligent sensors**, which have sensing and processing capabilities at the same or a superior level. By way of illustration, **machine vision** has been used to watch for product surface changes and tool breakage and detect the excessive vibrations between tools and parts or even enable the anticipation of tool failure, which was previously achieved by the hearing sense of operators.

Machine vision is widely adopted for workpiece monitoring, as it is deemed to significantly improve defect detection in terms of efficiency, reliability, and quality. The large amounts of data acquired at high speed (e.g. videos), in combination with the networking possibilities of I4.0 has inflated the adoption of big data perspectives (Chryssolouris, Alexopoulos & Arkouli, 2023: 19).

Besides data processing and control, AI has attracted the attention of many researchers and seems promising in **fault recognition applications**. The recognition of the experienced faults can be regarded as a pattern recognition problem, where the power of AI algorithms has been frequently tested, proving their robustness and adaptation capabilities (Liu et al., 2018). The reduction of impact on product quality, and the reduction or even the elimination of unexpected machine downtime are the main motives for fault diagnosis. In particular, the aim is to enable the diagnose and repair problems without human intervention. Typically, tool condition monitoring and tool wear prediction are necessary to prevent problems due to physical phenomena that induce performance degradation in machine tools.

AI algorithms have the potential to detect patterns accurately, reliably, and quickly, which together with the advent of **advanced inspection methodologies** enables the detection of the effects of process deviations and tolerances exceedance. The equipping of manufacturing systems with hundreds of sensors, though, has favored the collection of quality-related big data and the automation of analyses with the use of methods such as neural networks. Hence, the Zero-Defect Manufacturing concept, which aims at decreasing and mitigating failures within manufacturing processes has been provided (Psarommatis et al., 2020).

Online programming and offline programming are the two main categories of **robot programming**. As Chryssolouris, Alexopoulos & Arkouli refer, the traditional methods for robot programming typically require either using the robot teach pendant or simulating the robot task inside a programming environment. The first case necessitates the training of the operators in properly using the teach pendant, and the inherent point-to-point programming style is efficient only for simple movements. In the second case which falls under offline programming, the process is based on models of the workstation and simulation of the robot, and hence requires financial investments for additional personnel and equipment. Also, knowledge of the platform-specific programming language (or of a 3D CAD program) is necessary. Human is in the loop in this case, as it is frequently necessary to link activity-specific paths with each other to create the complete robot action sequence, but also to correct inaccuracies and errors that emanate from uncertainties (Chryssolouris, Alexopoulos & Arkouli, 2023: 52).

One potential application for AI systems in manufacturing is the need to decrease the demand on programming time, as well as system integration. This can be provided to the human operator to support decision-making by enabling the automatic plan of robot motion given the initial and target status avoiding collisions, and visualizing the context relevant information.

**Motion planning** involves searching for paths through the robot's configuration space to achieve moving a robot from an initial state to a target configuration while avoiding collision with objects in the surroundings. Even though several robotized applications have been deployed in industry e.g. assembly, welding, painting, etc. their broader adoption is currently restricted due to the high engineering time required for the optimization and/or reconfiguration of robot trajectories (Kaltsoukalas, Makris & Chryssolouris, 2015). When using conventional programming methods, robot path programming is performed by experienced robot programmers or even operators who need to spend considerable time programming them.

Additional planning problems that are relevant in **automation and robotics** include navigation among movable obstacles, pick-and-place planning, manipulation planning, and rearrangement planning, as well. The **navigation of mobile robots** includes modeling of their surroundings, localization of their position, motion control, obstacle detection, and avoidance, whereas the most critical function of navigational techniques is safe path planning. Mobile robot navigation has been categorized into global and local navigation, wherein the first case information about the environment, the goal position, and the position of the obstacles are required in contrast with the second that can deal with unknown environments (Chryssolouris, Alexopoulos & Arkouli, 2023: 55).

In the paradigm of hybrid workstations, safe **human–robot collaboration** has been ensured through appropriate monitoring systems, tracking the human position or detecting collisions and triggering appropriate control strategies. AI can promote the accuracy of the alarm generation and the smart adjustment of the robot's behavior for collision prevention or impact minimization.

Another approach taking advantage of the virtual space was used to enable the adaptation of the robots' behavior for flexible and reconfigurable systems. This work is based on the **Digital Twin** concept, where mobile dual arm cobots autonomously navigate inside the shop floor undertaking multiple assembly operations, while acting as assistants to human operators (El-Haouzi et al., 2021;

Kousi et al., 2019). This assembly paradigm requires high autonomy and flexible behavior from the robot side, which in turn necessitates organizing efficiently all production entities and reason over the perceived environment using real-time data from the shop floor.

Since the implementation of human–robot interaction has been affected by the user's expectations, the design of the collaborative tasks should facilitate the monitoring of the robots' operations (Moniz, 2018). The tools that have been developed to support humans usually involve indirect or direct human–robot interaction (HRI).

With the developments of **advanced automation**, with the integration of production technologies, and the increasing implementation of AI in the shop floor environment, the complexity of manufacturing systems revealed the importance of the human interaction with technology. Some studies focused on the interfaces of those systems with the operators, and others with the need to complement further experiments at the organizational level.

The notion of "social" dimensions derives from the worker–robot interaction (WRI) with regard to industry safety, control systems and interface ergonomics. To a certain extent, these specifics are increasingly turning into decisive aspects of **human–robot interaction** (HRI) in general. HRI can be applied to developments and standards in the field of service robotics and also to all sectors in manufacturing processes (De Santis et al., 2008).

HRI, in this context, is understood as a generic field where one can include "classical" human–machine interaction (HMI) elements like communication with machines, intermediation between humans and objects, need for anticipation, simulation, etc. (Moniz and Krings, 2016: 2/21)

"It seems that working with robots became reality at least in selected branches like automotive, electronics, metal engineering or plastics already in the last decades of the last century. In these branches, larger companies have developed automation processes to improve their productivity" (Moniz and Krings, 2016: 7/21).

The large sized companies are better placed to focus on human involvement in technology processes with new organizational schemes, as indicated, e.g., by Anderson and Gartner (1985), Bernstein et al. (2007), Brödner and Latniak (2003), and OECD (2001). The more robots are introduced in work environments, the more human interaction with those systems becomes crucial. Thus, a management strategy for human involvement in the production activity becomes decisive for developing and implementing the organizational policy towards productivity or the quality standards adopted. Evaluating the increase in the number of automated systems in industry without considering its economic impact does not seem adequate. The increase in productivity seems to be the driver for working with robots in many branches (Moniz and Krings, 2016: 7/21).

The introduction of CIM systems in the 1980s had fundamental effects on the organizational level of work (Jones & Webb, 1987). On the one side, digitization of work processes created a vision about the complete automation of factories without personnel (Majchrzak, 1988). Yet, on the other side, the high level of technical standards created a discourse about the rising and dependent scope of human actions within working processes (Pfeiffer, 2017).

The conventional systems imply "a strict human-machine interaction in a delimited workspace, dependent on technical parameters and on rational production lines. This organization disappears while considering the support of qualified and responsible employees, which should be actively involved in the production processes" (El-Haouzi et al., 2021: 3/15), as in the case of implementation of Industry 4.0 concept in industry. The development of CIM concept, and the application of **production cells** brought new experiments towards the operator autonomy in the decision process, in parallel with the need for increased flexibility and distributed production units (those cells or their components).

It must be noted that such flexible work organization – continue El-Haouzi and colleagues (2021) - is more complex to design than ones restricted to the mechanistic and hierarchical principles of management. The participation of the employees into these processes should imply the introduction of tacit knowledge, planning and operation, group work, as well as decision-making processes (3/15). In the same direction, Bryn Jones has studied the importance of the tacit knowledge in these processes of automation (Jones, 1983 and 1986).

Tacit knowledge or implicit knowledge — as opposed to formal, codified or explicit knowledge — is knowledge that is difficult to express or extract. It can be defined as skills, ideas and experiences that are possessed by people but are not codified and may not necessarily be easily expressed. This kind of knowledge can only be revealed through practice in a particular context and transmitted through social networks (Schimdt, F. and Hunter, J., 1993). To some extent it is "captured" when the knowledge holder joins a network or a community of practice (Goffin, K and Kopers, U, 2011). They also have concluded that there were empirical results that have shown the fact "that these distributed internet-based systems bring path dependencies that may restrict the possibilities for alternative work organization models by automation. If human factors are not included simultaneously with technological factors in the design process, there is little space for 're-automation' regarding human interference into the work processes" (El-Haouzi et al., 2021: 3/15 [2]).

### 2.3.4. Industry 4.0 - visions and strategies

The challenges and opportunities of the application of Industry 4.0 vision in each European country presents a variety of available literature and national debate and policies. However, there are dissimilarities among these countries. Those different approaches may have been strongly connected with the scientific and cultural tradition of each country. For example, if this debate is quite intense in UK, in Germany, in Sweden or France, it seems to be less expressive in other less industrialized economies.

New policies towards industry 4.0 are a great step forward in comparison with the policies focused on wide purpose investment incentives. They are as well the result of, not only, advances in specific technologies but of the convergence of all of them for the same purpose (investments under a coherent concept of industry 4.0). The emphasis on the range of hardware technologies, such as sensors, actuators, communication networks, microprocessors, mechatronics and robotics, will make possible "to deploy the equivalent of the nervous and neuromuscular system of production plants", as some experts explains. On the other hand, the variety of software technologies, such as Artificial Intelligence, data science and knowledge engineering, allows the developers to provide a "brain" to the whole manufacturing environment. It is like a centralised brain, as is the case of cloud computing, and a multitude of distributed brains, in the case of ubiquitous computing. The difficulty remains when all of this has to be provided, with a robust immune system, which would be the task of cyber-security systems. Information system security also becomes a component of the concept of industry 4.0, and a challenge for the companies that will get involved with such strategy.

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2 with references to Schirner, G.; Erdogmus, D.; Chowdhury, K.; Padir, T. (2013) The Future of Human-in-the-Loop Cyber-Physical Systems. *Computer*, 46, 36–45.

Some investments that the manufacturing companies will make in the coming years will mark their future evolution. According to the International Federation of Robotics (IFR), more than 50% of manufacturers will include IoT technology in their products' design phase. Manufacturing is one of the sectors that were most impacted by IoT. Using the same biology references, IoT can be understood as the nervous system of a production process. This technology will grow from capturing external signals to becoming the brain of the product itself, sending, receiving, growing, and collecting information constantly, from the core of the product and throughout its lifecycle.

## 2.4. The debate around the impact of automation on employment

Many debates assume that automation - as the general processes of substitution of labor by software or machines (Autor, 2015) - is one single phenomenon that homogeneously impacts work and employment. However, automation is a process that encompasses different technologies, and each one will impact labor in different ways (Eurofound, 2019, Pfeiffer, S., 2017). For example, an industrial robot may be complex and expensive to implement and might replace a few workplaces, whereas a software algorithm is relatively simple and inexpensive to implement and can swiftly generate unemployment displacing several workers at a time. Furthermore, the effects of technological change can be differently distributed, depending on the institutional framework that each society sets for itself (Eurofound 2018).

Importantly, due to the rise of Big Data and improvements in computing power, the development of large spectrum algorithms of AI will have a significant technical, economic, and social impact (Degrysse, 2019). In fact, it is expected that the introduction of AI will meaningfully transform the organization of work in firms, the tasks being developed at workplaces, and the skills and qualifications necessary to cope with its challenges (Boavida & Candeias, 2021: 2/17)

The impact of computerisation on labour market outcomes is well-established in the literature, documenting the decline of employment in routine intensive occupations – i.e. occupations mainly consisting of tasks following well-defined procedures that can easily be performed by sophisticated algorithms. Autor, Levy and Murnane (2003), distinguishes between cognitive and manual tasks on the one hand, and routine and non-routine tasks on the other. They argue that computer technology substitutes for workers in performing routine tasks that can be readily described with programmed rules, while complementing workers in executing non-routine tasks demanding flexibility, creativity, generalized problem-solving capabilities, and complex communications (Autor, Levy, Murnane, 2003) leading to two different consequences according to job activities.

Following on this argument, Acemoglu and Autor (2011) argue that a systematic understanding of recent labor market trends, and more generally of the impact of technology on employment, requires a framework that factors in such changes in the allocation of skills to tasks. In particular, they suggest that "recent technological developments have enabled information and communication technologies to either directly perform or permit the offshoring of a subset of the core job tasks previously performed by middle skill workers, thus causing a substantial change in the returns to certain types of skills and a measurable shift in the assignment of skills to tasks". The distinction between skills and tasks becomes particularly relevant when workers of a given skill level can perform a variety of tasks and change the set of tasks that they perform in response to changes in labor market conditions and technology.

In their proposed framework they assume three types of skills - low, medium and high, that each worker is endowed with one of these types of skills and that technical change can alter both the productivity of different types of workers in all tasks (factor-augmenting technical change), in specific tasks (comparative advantage) and allow for new technologies that may directly replace workers in certain tasks: "More generally, it treats skills (embodied in labor), technologies (embodied in capital), and trade or offshoring as offering competing inputs for accomplishing various tasks. Thus, which input (labor, capital, or foreign inputs supplied via trade) is applied in equilibrium to accomplish which tasks depends in a rich but intuitive manner on cost and comparative advantage" (Acemoglu & Autor, 2011). This will lead to consequences at the level of qualifications.

In addition, as Frey and Osborne (2017) mention, the studies by Charles, et al. (2013) and Jaimovich and Siu (2012) were emphasizing the ongoing decline in manufacturing employment and the disappearance of other routine jobs. It seemed to cause low rates of employment. In addition to the computerisation of routine manufacturing tasks, Autor and Dorn (2013) document a structural shift in the labour market, with workers reallocating their labour supply from middle-income manufacturing to low-income service occupations. According to Frey and Osborne (2017), this is because the manual tasks of service occupations are less susceptible to computerisation, as they require a higher degree of flexibility and physical adaptability (Autor, Levy & Murnane, 2003; Goos & Manning, 2007; Autor & Dorn, 2013).

Although three useful frameworks for examining the impact of computers on the occupational employment composition, existed, in Frey and Osborne's (2013) view, they seemed inadequate in explaining the impact of technological trends going beyond the computerisation of routine tasks. They argued that, while the computer substitution for both cognitive and manual routine tasks was evident, non-routine tasks involved everything from legal writing, truck driving and medical diagnoses, to persuading and selling. Therefore, in their study, they argued that legal writing and truck driving would soon be automated, while persuading, for instance, would not. Their approach was based on determining which problems engineers needed to solve, from a technological point of view, for specific occupations to be automated.

By highlighting these problems, their difficulty and to which occupations they relate, jobs were categorized according to their susceptibility to computerisation, allowing them to examine the future direction of technological change in terms of its impact on the occupational composition of the labour market, but also the number of jobs at risk should these technologies materialise.

While computerisation has been historically confined to routine tasks involving explicit rule-based activities (Autor, Levy & Murnane, 2003; Goos, Manning & Salomons, 2009; Autor & Dorn, 2013), algorithms for big data were rapidly entering domains reliant upon pattern recognition and would be available to readily substitute for labour in a wide range of non-routine cognitive tasks (Brynjolfsson & McAfee, 2011; MGI, 2013). In addition, advanced robots were gaining enhanced senses and dexterity, allowing them to perform a broader scope of manual tasks (IFR, 2012b; Robotics-VO, 2013; MGI, 2013) what, in the opinion of Frey & Osborne (2017), was likely to change the nature of work across industries and occupations. In their framework they distinguished between high, medium and low risk occupations, depending on their probability of computerisation and focused on the potential job automatability over some unspecified number of years. According to their estimates around 47 percent of total US employment was in the high-risk category - jobs at risk – i.e. jobs that could be automated relatively soon, perhaps over the following decade or two. Their model predicted that most workers in transportation and logistics occupations, together with the bulk of office and administrative support workers, and labour in production occupations, were at risk. They also found that a substantial share of employment in service occupations, where most US job growth has occurred over the past decades (Autor and Dorn 2013), was highly susceptible to computerisation.

While nineteenth century manufacturing technologies largely substituted for skilled labour through the simplification of tasks (Braverman, 1974; Hounshell, 1985; James and Skinner, 1985; Goldin and Katz, 1998), the Computer Revolution of the twentieth century caused a hollowing-out of middle-income jobs (Goos, et al., 2009; Autor and Dorn, 2015).

Frey and Osborne's model predicted a truncation in the trend towards labour market polarisation, with computerisation being principally confined to low-skill and low-wage occupations, thus implying that as technology races ahead, low-skill workers would be reallocated to tasks that were non-susceptible to computerisation – i.e., tasks requiring creative and social intelligence. But for this to happen, however, workers would have to acquire creative and social skills.

Literature addressing the consequences to labour patterns of Industry 4.0 is almost exclusively concentrated on German forecasts (Pfeiffer, 2016; Hirsch-Kreinsen, 2016; Krzywdzinski 2017; Moniz, Krings & Frey, 2021). Currently, contradictory development scenarios are being discussed for two main reasons: the volume of potential job losses caused by new technologies is highly controversial; and the recognition of diverging consequences for job activities and qualifications.

Most reports estimating the impact of AI are based on quantitative modelling of employment by occupations or tasks, such as the ones described beforehand. In Europe, the impacts of AI were estimated to lead to a reduction of millions of workplaces by 2030. In Finland, AI will destroy some 15% of jobs by 2030 and change the nature of work in a considerably larger proportion of tasks, and the country should be prepared to retrain one million Finnish workers. In Portugal, a study reported that AI can reduce 1.1 million workplaces and suppress 50% of the workhours by 2030 (Nova SBE/CIP, 2019: 36). In Hungary, 49% of work hours can be automated based on existing technologies, which is equivalent to the work of about 2.2 million people (Fine et al., 2018).

In the McKinsey report entitled "A future that works: Automation, employment, and productivity" (McKinsey Global Institute, 2017), states that "automation could accelerate the productivity of the global economy by between 0.8 and 1.4% of global GDP annually, assuming that human labor replaced through automation joins the workforce and is so productive as in 2014" (p. 15). Automation itself will not be enough to achieve the aspirations of economic growth in the long term around the world.

According to the above-mentioned McKinsey report, this will require additional measures to increase productivity, including the reformulation of business processes or the development of new products and services. This interesting report also states that the reallocation of the work of those excluded by technology to new jobs will be one of the most important social challenges. "Governments are generally not particularly capable to anticipate the types of jobs that might be created, or new industries will develop. However, they could initiate and promote dialogues about what work needs to do and about the big societal challenges that require more attention and effort" (McKinsey Global Institute, 2017: 18).

The concrete changes in labour patterns seems to depend on the influence of numerous factors, in particular of the concept of automation realized in each case and its implementation process (Wolter et al. 2016, Moniz & Krings 2016, Pfeiffer 2016, Krzywdzinski 2017).

Smart production systems, for example, face important barriers: one, is related to the technical problems of data migration, the integration and security problems across the production system; other, is the skepticism towards automation and efficiency from many management and practitioners; and, finally, other is a defensive stance from technical experts towards loss of competence and autonomy, as well as the surveillance potential of digital systems (Hirsch-Kreinsen 2016).

The study of Pardi et al. (2020) continues, mentioning that "the second part of the 1990s saw the abandon by all the carmakers of both the "high technology" and the radical "human motivating" automation strategies and a general convergence towards the "low cost" and moderate "human fitting and motivating" automation strategies associated with lean production. As a result, at the end of the decade the rate of automation in assembly had not progressed significantly by comparison with the late 1980s, even though more flexible robots had been introduced in the body and paint shops (MacDuffie & Pil 1997)" (Pardi, Krzywdzinski & Luethje, 2020: 8).

Artificial Intelligence is set to influence every aspect of our lives, not least the way production is organized with AI-enabled automation systems. AI, as a technology platform, can automate tasks previously performed by labor or create new tasks and activities in which humans can be productively employed as argued by Acemoglu and Restrepo (2019). They argue that recent technological change has been biased towards automation ("the wrong kind of AI"), with insufficient focus on creating new tasks ("the right kind of AI") where labor can be productively employed. The consequences of this choice have been stagnating labor demand, declining labor share in national income, rising inequality and lower productivity growth. In their view, the current tendency is to develop AI in the direction of further automation, but this might mean missing out on the promise of the "right" kind of AI with better economic and social outcomes.

They draw the attention to the fact that many new technologies, those called automation technologies, do not increase labour productivity, but are explicitly aimed at replacing it, by substituting cheaper capital (machines) in a range of tasks performed by humans. "The productivity effect is complemented by additional capital accumulation and the deepening of automation (improvements of existing machinery), both of which further increase the demand for labor. These countervailing effects are incomplete. Even when they are strong, automation increases output per worker more than wages and reduce the share of labor in national income. The more powerful countervailing force against automation is the creation of new labor-intensive tasks, which reinstates labor in new activities and tends to increase the labor share to counterbalance the impact of automation." (Acemoglu & Restrepo, 2018).

At the center of Acemoglu and Restrepo's (2018) framework is a task-based approach, where automation is conceptualized as replacing labor in tasks that it used to perform. This type of replacement causes a direct displacement effect, reducing labor demand. If this displacement effect is not counterbalanced by other economic forces, it will reduce labor demand, wages and employment. But their framework also emphasizes that there are several countervailing forces, including, the fact that automation will reduce the costs of production. At the same time, that will create a productivity effect, an induced capital accumulation, and the deepening of automation. In other words, technological advances that increase the productivity of machines in the tasks that have already been automated.

These first-order countervailing forces are generally insufficient to totally balance out the implications of automation. In particular, even if these forces are strong, the substitution effect of automation tends to cause a decline in the share of labor in national income, according to the same study of Acemoglu and Restrepo. They also demonstrate that history of technology and industrial development has shown that despite several waves of rapid automation, and the growth process has been more or less balanced, with no secular downward trend in the share of labor in national income. Therefore, they argue this is because another powerful force is balancing the implications of automation: the creation of new tasks in which labor has a comparative advantage, which fosters a countervailing reinstatement effect for labor. These tasks increase the demand for labor and tend to raise the labor share. When they go hand-in-hand with automation, the growth process is balanced, and it need not imply a dismissal scenario for labour. Nevertheless, according to these authors, the adjustment process is likely to be slower and more painful than this account of balance between automation and new tasks at first suggests. This is because the reallocation of labor from its existing jobs and tasks to new ones is a slow process, in part owing to time-consuming search and other labor market imperfections.

Even more ominously, new tasks require new skills, and especially when the education sector does not keep up with the demand for new skills, a mismatch between skills and technologies is bound to complicate the adjustment process. In sum, they have emphasized the role of the productivity effect in partially counterbalancing the displacement effect created by automation; highlighted the negative consequences of a shortage of skills for realizing the productivity gains from automation and for inequality and finally, government policies and labor market institutions may impact not just the speed of automation (and thus whether there is excessive automation), but what types of automation technologies will receive more investments. To the extent that some uses of AI may complement labour more or generate opportunities for more rapid creation of new tasks, an understanding of the impact of various policies, including support for academic and applied research, and social factors on the path of development of AI is critical (Acemoglu & Restrepo, 2018).

### 2.4.1. Speeding up and efficiency

Braverman was referring to examples of new technologies, such as “multiple function machines” that approached numerically controlled machines (Braverman, 1974). He then spoke of a new characteristic of the machinery: the pattern of its operation is fixed in the mechanism and is not linked to external controls or to the work results. He mentioned the automatic or predetermined movements of machinery (Braverman, 1974: 189). In this sense, we can then speak of a deterministic relationship of technology on society, that is, the automated systems of machinery made their operators dependent on the instruments of the production process.

With the supply of conveyor belts for the production lines, it was then possible to associate different machines producing sequences of automatic operations, as was the case at that time with the transfer machines applied mainly in the automotive industry. This technology has created a dependency of jobs and tasks on a predetermined sequential relationship. In addition, conveyor belts or parts transport systems made task execution dependent on the speed of these equipment. Likewise, when automated machines are introduced into these production lines, the tasks performed by humans also remain dependent on that speed (Moniz, 2018: 68-69).

From those developments, that have started with the implementation at Ford Motor factories in early 20 century, human work has been dependent of the production system speed and pace. Thus, if speed and sequencing can be changed by external information that induces autonomous control, then there may be greater autonomy of human work. “Can” is an important term because that autonomy then depends on the possibility of influencing the control system. Therefore, in work systems where the sequence of operations is predetermined, even if we are dealing with robots and numerically controlled machines, the determination remains. Thus, in this case, the determinism resides not in the technology associated with the machines, but in the concept that defines the production system that requires the predetermined sequencing of operations (Moniz, 2018: 69).

Besides this relation between speeding up and technology determinism, efficiency is related to the capacity of achieve defined or negotiated aims, objectives, or targets. Thus, efficiency can be achieved when the indicators of those targets are accomplished as expected. This approach to efficiency is related to new capacities to develop organisational models that enable the achievement of higher levels of productivity. Such achievement is reached through the implementation of AI feature on the production structures.  Therefore, most literature in the field points out difficulties on the empirical analysis stream (Dhondt, Kraan & van Sloten, 2002).

### 2.4.2. Models of Organization of Work

According to the National Institute for Occupational Safety and Health (NIOSH) organization of work refers to the work process (the way jobs are designed and performed) and to the organizational practices (management and production methods and accompanying human resource policies) that influence job design. Also included in this concept of organization of work are external factors, such as the legal and economic environment and technological factors that encourage or enable new organizational practices (2003).

As Ennals and Gustavsen underline, "work organization has a linking and switchboard function in the workplace: it is a web that links all elements. A noisy machine is, for instance, not a work environment problem unless someone has to remain in its vicinity, and who has to stay there, and for how long, is decided by the work organization" (Ennals & Gustavsen, 1999: 53). This description presents clearly how the work organizational is linked to the human dimension and not to the technical one. These experts on organizational innovation refer even that " in performing just this linking function, work organization becomes, literally speaking, linked to everything else: to the demands emanating out of technological development, materials development, development in information technology and, above all, to all the notions, concepts and drivers that continuously put pressures on working life such as productivity, quality, zero stocks logistics, customization of products, and so on" (Ennals & Gustavsen, 1999: 53). This being said, we must understand however that the organization of work follows, nevertheless, different models. Not just a single one. According to Henry Mintzberg there are five organizational structures. He suggests that companies adopt one of these structures to carry out business operations successfully, though the type that will work best for the enterprise will likely depend on the type of industry, how long it is in business, leadership goals and other factors. The five structures are: adhocracy, **machine organization**, professional organization, entrepreneurial organization and divisional organization.[3]

There are also several alternative comprehensive schools of thought on work organization: the mechanicist school, the socio-technical school, the human relations school, the labor process school, the various stress and pressures schools [ergonomics].

The basic and old one can be defined as **mechanicist.** For this approach, the organizations should be like machines. The first theory inputs start from Adam Smith, where in his work *An Inquiry Into The Nature and Causes of the Wealth of Nations* (1776), the Scottish economist described the principles of division of labour and the mechanic design of the assembly line. From this perspective it was possible to consider the standardization need as criteria for the functioning of such production lines. The US engineer Frederick Taylor studied the human body movements in order to improve the production capacities. That meant the need to segment and simplify the design of tasks, so the organization of work could even be more similar to the components of a perfect machine. Even under the theoretical approach, we can mention the proposal of Henry Ford to achieve higher levels of

[3] The Management Theory of Henry Mintzberg (https://www.business.com/articles/management-theory-of-henry-mintzberg-basics/)

production outcomes. In his factories he introduced the conveyor belt to improve the capacity of assembly lines using the principles of Smith and later Taylor. Under this "school" the Taylorist and Fordist approached are the main contributions.

In a machine organization, workers operate as parts of a standardized system. Each department is responsible for its own tasks, and decision-making is centralized. These departments are incredibly formalized, and specific parameters define employees and their work. In a larger company, these departments could be accounting, marketing, human resources or other standardized teams.

Having clearly defined roles gives workers clarity on their responsibilities. But if these departments differ in workflow and are inconsistent with the business's goals, then conflicts and incompatible work may result.

These are the characteristics of a machine organization:

- Standardized work processes
- Centralized decision-making
- Formal departments
- Clearly defined roles
- High degrees of specialization

This mechanicist thinking for organizing work in the shop floor became itself like a standard in almost all modern manufacturing industries. Just later, already after the World War II, different ideas and experiments took place. Most of them more focused on the human factor. From those, the **socio-technical approach** that emerged from the seminal work of Emery and Trist (1960) and the work of the Tavistock Institute in London are here mentioned. "Socio-technical systems design methods are an approach to design that consider human, social and organisational factors, as well as technical factors in the design of organisational systems", as Baxter and Sommerville define in their article (2011).

Another approach that criticized the Taylorist and Fordist models, was the **human relations theory of management**. In the early 1920's, productivity was the focus of business, and Elton Mayo began his experiments at the Western Electric Hawthorne plant, to prove the importance of people for productivity – not machines. He discovered that job satisfaction increased through employee participation in decisions rather than through short-term incentives (Mayo, 1946).

The **labour process theory** highlights all the steps of the organisation of work in society. Their approach is that to ensure that profits are made, managers control all the steps of the labour process, in other words, the way work is organised, as well as the pace and duration of work is controlled by managers. Braverman (1977) and Knights and Willmott (1990), are some of the reference authors.

Finally, the **ergonomics approaches** still consider the human factor, but in a functionalist way, representing a more modern development of the Taylorist principles, but integrating measurements as well on human stress and mental load effort in the working process.

### 2.4.3. Towards Industry 5.0?

However, by the end of the 20th century, another type of CIM approach emerged. This second approach presupposes advanced information technologies as a communication tool, not an objective in itself. This therefore implies "not only a redesign of technology but also an integrated combination of technologies, worker skills and organizational factors, i.e. an **'anthropocentric' approach**. An 'anthropocentric' approach is understood to mean the development of systems centered on the individual based on the balance between human resources, skills, technologies and adaptive organization" (Cooley, 1989: 90). The same type of concept is very closed to the one more recently mentioned as Industry 5.0.

In the last years, this concept of **Industry 5.0** has been widely based on technology pushed experiments, enabling important steps in the fields of machine learning, CPS, IoT device developments and integration at the industrial shop floor level. However, new organizational concepts and innovation processes have been secondaries. Some production efficiencies, cost reductions, and business model adaptations have been achieved with Industry 4.0.

When the implementation of this wide-known concept happens in most advanced economies, these manufacturing experiences are accompanied with social, economic, and organizational challenges. In most cases that means increased income inequalities, a public perception for de-qualification and job losses, and data security and privacy problems. It seems, nevertheless, that a solid human-centric concept of Industry 4.0 still misses the ethical sciences, sustainability, social sciences and humanities perspective and experience. The idea of "Industry 5.0" (I5.0) is centred on such a concept of an anthropocentric technology and it implies that technology, organisations, and working places must be adapted to human and societal needs.

The transition from Industry 4.0 to Industry 5.0 would have to be done by assessing the nature of jobs transformation, future occupations and reduce the skills' gaps, to cope with possible unemployment effects (especially those derived from technology unemployment), and to foster industrial competitiveness and innovation while enhancing inclusiveness.

The most recent commitment toward I5.0 also includes, however, an interest on "responsible innovation", meaning that it is "not only or primarily aimed at increasing cost-efficiency or maximising profit, but also at increasing prosperity for all involved: investors, workers, consumers, society, and the environment." (Breque, De Nul & Petridis, 2021).

## 2.5. Research Gaps

Through the literature review, it was possible to identify the main research gaps and limitations in the impact assessment of AI-enabled automation systems in employment and in the workplace.

Likewise, the literature pointed out knowledge gaps concerning the three above dimensions identified with the adoption of AI enabled automation which are summarized next.

In the case of the manufacturing industry, in Portugal, research gaps consist in the **scarce knowledge about the mechanisms behind the adoption process of AI in the manufacturing industry; main motivation for technology investment in AI-based systems in industrial sectors, and about the involvement of the stakeholders in the process, in particular, the workforce**. Moreover, when undergoing changes at the factory level usually there are pilot projects and studies conducted to anticipate possible effects, barriers and limitations. However**, knowledge about the level of preparation of firms previously to the adoption process of AI, if there is strategy behind it and, according to the type of strategy, what are the effects it may have at the level of employment, work organization and workforce qualifications, is missing.**

Finally, with the features of AI increasing the ability of machines to perform cognitive, non-routine and non-manual tasks, there is a **need to search for knowledge about forms of interaction**

**between humans and AI-based systems**. Are these interactions made in a conventional way as with conventional machinery? Are new forms being experimented? Which are they? What possible futures and visions might exist regarding the year 2035 based on these types of interaction? Research on these topics was not found; thus, it seems there is a knowledge gap on this. Scientific knowledge about that is important to make sure current policy options are still valid or if additional initiatives (and on what dimensions) they are needed to improve working conditions and the human-machine interaction in emerging complex AI-enabled automation manufacture system.

# CHAPTER 3. TOWARDS A TECHNOLOGY ASSESSMENT OF AI-BASED AUTOMATION SYSTEMS

While technological changes can be positive, they can also be disruptive, as we have seen with the current debates about the implications of digital transformation. With the fast development pace of AI in recent years, automation may be accelerated either in one (efficiency) or the other direction (organisation of work) or even open new possibilities (industry 5.0). Therefore, it is critical for policy-makers, civil society and industry to be able to understand and evaluate these changes, to ensure, for example, national security, wealthy economy, a fair and inclusive society and global competitiveness.

Thus, to enhance knowledge and awareness to assist decision making the methodology approach of this research work consisted of a Technology Assessment of AI-based automation systems. It was divided in the following three phases: **Description of the context and object of the research study**; **Research Design** and **Implementation.**

On the first stage the research questions and research hypotheses are defined linked with the methods used and research gaps. The second stage presents the design of the methodological approach explaining why methods used were chosen and what was the evidence collected through them. Finally, the last stage presents conditions and how the methods were implemented.

## 3.1. Description of the context and object of the study

To have an initial understanding of the technology, such as the state of the technology, potential effects and limitations; the context of the technology, such as social, political and economic factors, a Literature Review (Chapter 2) and documental analysis and statistical analysis (Chapter 4) was conducted.

Based on this knowledge, the research gaps were identified and the following goals, research questions and hypotheses were defined. Studies already performed, stakeholders' groups, main sectors to be addressed and relevant policies were also identified and discussion of its findings is presented in Chapter 4.

## 3.2. Research hypotheses

The goal of this research activity, to understand the effects of AI-enabled automation on the workplace and employment of the Manufacturing Industry, in Portugal, by 2035, have been divided in three dimensions:

a. Adoption of AI-enabled automation;
b. Organization of the digital transformation process; and
c. Prospects of human-machine interaction in the workplace.

Hereinafter, the research hypotheses are presented along with the related research questions and research methods that were designed and implemented to address the research gaps (Chapter 2) identified.

### 3.2.1. Research questions and hypotheses on the adoption of AI technologies

The main **research questions** elaborated based on the literature review, are the following:

a. What motivates the investment and adoption/development process of AI-enabled automation technologies in industrial companies?
b. Is the workforce involved in the adoption process of AI-enabled automation technologies?

There is a need to analyse in further detail the main **driving forces** in this transition. They are presented for the analysis of the different scenarios and for the assessment of the research hypotheses.

For the above-mentioned research questions, several research hypotheses have been issued.

All of them can be verified through a qualitative analysis of empiric evidence from specific methods and research techniques and will contribute to fill in some knowledge of the identified research gaps. The first three hypotheses related to questions on adoption of AI technologies are the following:

H1 – Motivation for investment in AI-enabled automation is due to the association of these technologies with cost reduction, increased product quality, increased productivity, increased exports to the global markets

H2 – Motivation for investment in AI-enabled automation is due to the availability of financial incentives, from public policies, for digital transformation

H3 – There is no involvement of the workforce in the AI-enabled automation adoption process led by its employers.

**Research methods:**

While qualitative data analysis from semi-structured interviews was valuable to collect empiric information on motivations from the manufacturing industry (H1) and if the workforce has been involved in the AI-enabled automation adoption process led by its employers (H3), potential futures from the Scenarios also contribute to confirm or contradict H1 and H3. Document Analysis was used to get knowledge on the public policies for digital transformation, and respective financial incentives (H2).

**Research Gaps**:

Knowledge about the mechanisms behind the adoption process of AI in the manufacturing industry; main motivation for technology investment in AI-based systems in the industrial sector identified, and about the involvement of the stakeholders in the process, in particular, the workforce.

### 3.2.2. Research questions and hypotheses on the organization of the digital transformation process

The main **research questions** elaborated based on the literature review, are the following:

a. In the case of AI-enabled automation adoption, was an implementation/development strategy previously planned?
b. Is the employment changing alongside recent AI trends in Portugal?
c. What are the expected changes in work organization due to the AI-enabled automation adoption?
d. Are there signs of work qualification to go with AI-enabled automation systems implementation?

There is a need to analyse in further detail **the effects** of this transition. For the above-mentioned research question, several research hypotheses have been issued.

All of them can be verified through quantitative and qualitative analysis of evidence from specific methods and research techniques, and will contribute to fill in some knowledge of the identified research gaps. The three **research hypotheses** related to questions on the organization of the digital transformation process are the following:

H4 – The implementation of AI-enabled automation technologies in the manufacturing industry results in an immediate productivity increase which, in turn, increases the company's competitiveness generating additional business opportunities and thus, increasing employment. However, since there are no changes in the work organization, the employment growth is not sustainable

H5 – There are no changes on the work organization due to the AI-enabled automation adoption

H6 – The implementation of AI-enabled automation technologies, in the manufacturing industry, does not increase the qualifications of the workforce working directly with these AI-enabled automation systems.

**Research Methods:**

Statistical Secondary Analysis was used to assess the investment in AI adoption and the impact of AI-enabled automation on productivity and employment (H4).

Complementary to this, deductive analysis of qualitative evidence from semi-structured interviews was performed, to understand if changes to the organisation of work are happening, and to testimonial evidence from a group discussion between workers' representatives, on the concerns and attitudes of the workers to the implementation of AI-based automation (H4).

Interviews were also used to collect evidence on the perceptions on what might occur to the organisation of work with the AI-enabled automation adoption (H5) and on the level of qualifications of the workforce directly or indirectly working with AI-enabled automation systems (H6). Potential futures from the Scenarios also contribute to confirm or contradict H5 and H6.

**Research Gaps:**

Knowledge about the level of preparation of firms previously to the adoption process of AI in the manufacturing industry and what was the strategy behind; knowledge about if there is an influence of AI adoption at the level of employment, at the level of work organization and on workforce qualifications.

### 3.2.3. Research questions and hypotheses on the prospects of human interaction with AI in work environment

The main **research questions** elaborated based on the literature review, are the following:

a. Are there visions on the role of humans on the interaction with the features of industry 4.0?
b. Does this imply new forms of human interaction with AI?

There is a need to analyse in further detail **the future** of this transition. For the above-mentioned research question, one research hypothesis has been issued.
It can be verified through scenario analysis and will contribute to fill the knowledge of the identified research gaps. The **research hypothesis** related to questions on human interaction with AI is the following:

| |
|---|
| H7 – There are multiple visions about the role of humans on the interaction with AI-enabled automation. |

**Research Methods:**

Documental Analysis was used to understand if there are already studies and reports about the role of humans on the interaction with industry 4.0 technologies and was complemented with, evidence from semi-structured Interviews for insights on this issue, Observation to understand better the different roles and Scenarios to identify potential futures (H7).

**Research Gaps:**

Knowledge about forms of interaction between humans and AI-based systems; about possible futures and visions from this interaction.

| Research Gaps | Research Questions | Hypotheses | Methods | Outcomes |
|---|---|---|---|---|
| Mechanisms behind the adoption process of AI in the manufacturing industry;<br>Main motivations for technology investment in AI-based systems in this industrial sector;<br>Involvement of the stakeholders in the process, in particular, the workforce. | a. What motivates the investment and adoption/development process of AI-enabled automation technologies in industrial companies?<br><br>**b**. Is the workforce involved in the adoption process of AI-enabled automation technologies? | **H1.** Motivation for investment in AI-enabled automation is due to the association of these technologies with cost reduction, increased product quality, increased productivity, increased exports to the global markets;<br>**H2.** Motivation for investment in AI-enabled automation is due to the availability of financial incentives, from public policies, for digital transformation;<br>**H3.** There is no involvement of the workforce in the AI-enabled automation adoption process led by its employers. | Documental Analysis: Literature and grey literature review<br><br>Qualitative data analysis:<br>Semi-structured interviews<br><br>Scenarios | Knowledge on the public policies for digital transformation and respective financial incentives (H2).<br><br>Empiric evidence on motivations from the manufacturing industry (H1)<br><br>Empiric evidence on the workforce engagement in the AI-enabled automation adoption process led by its employers (H3),<br>Possible futures (H1 and H3) |

| | | | | |
|---|---|---|---|---|
| Level of preparation of firms previously to the adoption process of AI in the manufacturing industry;<br>Strategy for Industry 4.0, if any;<br>Effects of AI adoption at the level of employment;<br>Effects of AI adoption at the level of work organization and,<br>Effects of AI adoption at the level of workforce qualifications. | c. In the case of AI-enabled automation adoption, was an implementation/development strategy previously planned?<br>d. Is the employment changing alongside recent AI trends in Portugal?<br>e. What are the expected changes in work organization due to the AI-enabled automation adoption?<br>f. Are there signs of work qualification to go with AI-enabled automation systems implementation? | H4. The implementation of AI-enabled automation technologies in the manufacturing industry results in an immediate productivity increase which, in turn, increases the company's competitiveness generating additional business opportunities and thus, increasing employment. However, since there are no changes in the work organization, the employment growth is not sustainable;<br>H5. There are no changes on the work organization due to the AI-enabled automation adoption;<br>H6. The implementation of AI-enabled automation technologies, in the manufacturing industry, does not increase the qualifications of the workforce working directly with these AI-enabled automation systems. | Statistical Secondary Analysis<br>Deductive Analysis: Semi-structured interviews<br>Testimonial group discussion<br>Inductive Analysis: Semi-structured interviews<br>Scenarios | Investment in AI adoption and the impact of AI-enabled automation on productivity and employment (H4).<br>Knowledge about changes to the organisation of work,<br>Level of qualifications of the workforce directly or indirectly working with AI-enabled automation systems (H6).<br>Evidence on the concerns and attitudes of the workers to the implementation of AI-based automation (H4).<br>Evidence on the perceptions on what might occur to the organisation of work with the AI-enabled automation adoption (H5)<br>Possible futures (H5 and H6). |

Figure 7 – Overview of the Research Design including Research gaps, research questions, methods and main outcomes

| Research Gaps | Research Questions | Hypotheses | Methods | Outcomes |
|---|---|---|---|---|
| Forms of interaction between humans and AI-based systems; Possible futures and visions for human machine interaction. | g. Are there visions on the role of humans on the interaction with the features of industry 4.0?<br>h. Does this imply new forms of human interaction with AI? | H7. There are multiple visions about the role of humans on the interaction with AI-enabled automation. | Documental Analysis:<br>Grey literature review<br>Qualitative Inductive Analysis:<br>Semi-structured Interviews<br><br>Observation<br>Video visioning<br>Scenarios | The role of humans on the interaction with industry 4.0 technologies<br>Knowledge on different roles of the human when interacting with AI systems<br><br>Potential futures (H7). |

Figure 7 (continuation) – Overview of the Research Design including Research gaps, research questions, methods and main outcomes

## 3.3. Research design

The research work started with desk research including **literature review** (Chapter 2) and **grey literature review** (reports, official documents, newspapers, studies) - Chapter 4. An in-depth knowledge of the concepts, theories, debates and studies was gained through literature review. Based on this, research gaps around the implications of AI-enabled automation on employment and in the workplace were identified and research questions and hypotheses were designed to address them. Next, to have insights about the current situation in Portugal, documental analysis, statistical analysis and **exploratory interviews** with three experts in industrial productivity and employment, were performed and the socio-economic context and object of study was defined, namely, in regard to the manufacturing sectors and stakeholders' groups to be addressed (Chapter 4).

Due to the nature of evidence needed to confirm or contradict the research hypotheses, **mixed methods for quantitative and qualitative analysis were selected. This approach is innovative and allows for a closer examination at the company level of ways in which work is being redefined, what the future expectations are, and on understanding of the extension of complementarity that might prevail between machines and humans.**

The goal of a company is to have revenues, profit and sustained economic growth over time. To continue growing, the company must remain competitive, either through higher productivity or greater capacity for innovation. Thus, for a manager to decide whether to incorporate AI in his production processes, or not, he/she has to assess whether this technology makes the company more competitive. To evaluate the incorporation of AI-enabled automation in production processes it will be necessary to observe changes at the level of products/ services/ processes (productivity, efficiency, quality, innovation) (Sreelekha, 2018).

However, given that different countries, have different industrial structures, to validate the relationship of innovation by AI and the effects at the level of productivity and employment, and be comparable between countries, it is necessary to ensure that indicators are used for the same industrial sector (meso level) (Smith, 2006). On the other hand, within the same industrial sector there can be differences at company level, according to its profile, its positioning in the value chain, according to its products, so it is necessary to make an analysis at micro level, at company level. In the sample of end-users, different profiles of companies were studied to address differences at micro level.

Quantitative data analysis consisted on **secondary statistical analysis** of international and Portuguese databases for the assessment of some indicators, namely, gross fixed capital formation (GFCF), productivity (P), employment (I), research funding (R&D), to understand what is the current situation at the **macro** (Portugal), **meso** (Manufacturing Industry) and **micro** (firms) level (H4), and identify possible tendencies (H4).

The uncertainty of the regulatory framework and the ethical concerns of products or services that use emerging technologies may translate into a flow of products to the market that are out of line with the company's expectations. Unlike the indicators to assess business competitiveness resulting from the adoption of AI in the company's production process, which are all quantitative, in this case not only quantitative indicators but also qualitative indicators (qualifications, organisation of work, motivations, human-machine collaboration, receptivity and motivation of the workforce to work with AI) will be anlaysed, because research on AI, in these dimensions, is scarce. Most probably because it is an emergent technology.

Although there are some reports based on qualitative data analysis of the impact of AI significant difficulties of social partners to deal with the broad effects of automation phenomena were identified (Naumann, 2017). Nevertheless, this difficulty can be bypassed by conducting interviews with the different profiles of industrial stakeholders and with experts on organizational change and labor processes which can also provide details about the effects on work organization, skills, and qualifications required.

**For this reason, fieldwork was driven through 16 semi-structured interviews, two factory visits, four shop floor videos and one group discussion were performed**

**Semi-structured interviews** are pre-defined standardized interviews to cover topics and questions that need to be covered by all of the interviewee's categories. Through this method is possible to collect detailed information on a topic and to understand thoroughly the answers provided. They were conducted to collect qualitative data on unmeasurable dimensions, such as **organisation of work** (H3, H4), **qualifications** (H5), **motivations** (H1, H2), which influence the implications of AI-enabled automation on the workplace. The manufacturing industry includes distinct sectors with different features at the level of technology intensity, production process, type of products, type of flow. There are also companies with different positions in the value chain.

Therefore, the interview sample should also include a **mix of the different profiles**. Two of the interviews (ceramics sector) were followed by **site visits** from which it was possible to

**observe different behaviours and attitudes, and forms of organisation of work.** More visits were planned (two OEMs and a part supplier from the automotive sector) but due to the pandemics, followed by the war in Ukraine and all the consequences it represented to the automotive sector (semicondutor shortage, negotiations with the workers) they were not performed. Instead, **video visioning** (4) helped to understand better what is already implemented at the factory floor and how it works. Next, a **group discussion**, with one of the most affected stakeholders' group (workers) by the digital transformation, was conducted to get testimonial evidence about examples and different concerns and expectations of workers (H7) from the automotive industry on AI-enabled automation systems.

Finally, the **scenarios**, based on all the evidence collected, was used to define possible futures of interaction between humans and the features of industry 4.0 (H7, H1, H3, H4, H5). Scenarios are a description of possible future states taking into consideration various characteristics or variables.

The construction of scenarios is particularly useful in situations where it is unlikely that the past and the present are a guide to the future, especially when dealing with complex situations, high probability of significant changes, the dominant trend is not favourable and an analysis is necessary, or when the time horizon is relatively long. Therefore, the scenarios can be important to situate possible relationships between variables and evaluate their development trends, therefore allowing the establishment of possibilities of realization with the various impacts known before they occur. Their construction then allows support to the decision-making process about investments to be made, or about organizational models that take the best advantage of what the technology has to offer.

## 3.4. Implementation

### 3.4.1. Research Methods

To implement this research process, we have used several methods and techniques that will be explained in further detail in the next pages, as the documental analysis, the secondary statistical analysis, the semi-structured interviews, the testimonial evidence, the observation and the scenario design and analysis.

#### 3.4.1.1. Documental analysis

Documental analysis is important to gather information about Manufacturing Industry, in Portugal and external trends. For that purpose, during 2022 and 2023 evidence from documents like reports, official documents, newspapers, studies, companies' websites and public policies were analysed. This information will be useful to define the conditions upon which the scenarios will be built, the factors of change that may affect the trends and the various categories of relevant actors. In addition to this, an analysis of statistical data was also carried out to identify critical trends.

| TYPE OF DOCUMENT | RELEVANCE | SOURCE |
|---|---|---|
| **REPORTS** | Number of robots and NC machine tools in Portugal | IFR (World Robotics annual statistics)<br>Moniz (2018)<br>Master Thesis (2022)<br>CECIMO (2023)<br>ILO (Internacional Labour Organisation) |
| **STUDIES** | Impact assessment of AI in productivity and employment | McKINSEY reports<br>OECD (STI databases, Industrial innovation)<br>CIP/NOVA SBE (2019) |
| **OFFICIAL DOCUMENTS** | Public policies; National strategy for Industry 4.0; for Digital Transition, Industry 4.0; Action Plans for Digital Transition, industry 4.0, skills; funding programmes | COTEC<br>Missão Recuperar Portugal<br>IAPMEI<br>Estrutura de Missão Portugal Digital |
| **MEDIA** | Public opinion, initiatives, visions, | Expresso, Jornal de Negócios,<br>RTP<br>Fundação Francisco Manuel dos Santos |
| **COMPANY'S WEBSITE** | Features of firms | |

Figure 8 – Type of documents analysed

Sources:

**International Federation of Robotics (IFR)** – The IFR was established as a non-profit organization in 1987. Its institutional members are from the robotics industry, national or international industry associations and research & development institutes representing, directly, over 90 members from more than 20 countries. Besides many things, they provide worldwide market data for surveys, studies, and statistic. The IFR Statistical Department provides data for two annual robotics studies: World Robotics - Industrial Robots and World Robotics - Service Robots. The reports provide global statistics on industrial robots and service robots, respectively. The global statistics on industrial robots are presented in standardized tables and enables national comparisons to be made. It presents statistical data for around 40 countries broken down into areas of application, customer industries, types of robots and other technical and economic aspects. Production, export and import data is listed for selected countries. It also offers robot density, i.e. the number of robots per 10,000 employees, as a measure for the degree of automation. (International Federation of Robotics (ifr.org))

**CECIMO** – represents globally the common position of European Machine Tool Industries and related Manufacturing Technologies and promotes co-operation with other organisations worldwide. CECIMO is the European data hub for the machine tool (MT) sector, as there is no other complete source openly available on the European MT industry and its competitive position in the global market. Anyone, who wants to learn about Europe's position in manufacturing and trade of machine tools and related technologies, can find up-to-date figures and key statistics on the CECIMO website. (https://www.cecimo.eu/about-us/what-we-do/)

#### 3.4.1.2. Statistical Analysis

Secondary statistical Analysis was performed to:

- compare economies, (macro level) using, databases from OECD, Eurostat, ILO and IFR ;
- compare sectors, (meso level), using databases from PorData, INE and MTSSS.
- Analyse Manufacturing Industry, using databases from PorData, INE and MTSSS

OECD – Organisation for Economic Cooperation and Development

- ICT employment data (https://data.oecd.org/ict/ict-employment.htm)
- Science, Technology and R&D Statistics (https://www.oecd-ilibrary.org/science-and-technology/data/oecd-science-technology-and-r-d-statistics_strd-data-en)
- Employment and Labour Market Statistics database (https://www.oecd-ilibrary.org/employment/data/oecd-employment-and-labour-market-statistics_lfs-data-en)

Eurostat – statistical office of the European Union

- Data browser (https://ec.europa.eu/eurostat/databrowser/explore/all/all_themes?lang=en,en&display=list&sort=category)
- Labour market statistics (https://ec.europa.eu/eurostat/web/labour-market/overview)
- Digital economy and society (https://ec.europa.eu/eurostat/web/digital-economy-and-society/overview)
- Structural business statistics (https://ec.europa.eu/eurostat/web/structural-business-statistics/overview)

International Labour Organisation (ILO) – tripartite U.N. agency

- Statistics on employment (https://ilostat.ilo.org/topics/employment/)
- Labour force survey (LFS) resources (https://ilostat.ilo.org/resources/lfs-resources/)
- ILO modelled estimates (ILOEST) https://ilostat.ilo.org/topics/labour-productivity/

PorData – the Database of Contemporary Portugal, organized and developed by the Francisco Manuel dos Santos Foundation

Statistical data on: (https://www.pordata.pt/)

- Employment and Labour Market
- Enterprises and Personnel
- Economic Activities
- Macroeconomics
- Science, Technology and Information Society

Instituto Nacional de Estatística (INE) - Statistics Portugal is the national statistical authority

- Labour market database (https://www.ine.pt/xportal/xmain?xpid=INE&xpgid=ine_base_dados)

Relevant indicators analysed were:

- **Investment for the adoption of automation technologies and AI**

As there is no direct measure for this variable we used as proxy the **Gross Fixed Capital Formation indicator as it represents the investment in tangible and intangible assets (e.g. machinery, equipment, software, etc.).**

- **Apparent Labour Productivity**

Another indicator that translates the adoption and effect of automation and AI technologies is the Apparent Labour Productivity, defined as the wealth obtained in the production of goods or services (Gross Value Added - GVA) per worker (Employment) and can be synonymous with efficiency, quantifying the appropriate use of productive resources in the company's activities, measuring product quality and waste and downtime for maintenance or breakdown.

- **Employment**

Employment is a variable defined by the number of active populations employed.

- **Worktime Week**

Working time per week refers to the number of hours worked in a week. The regulation of working time is one of the oldest concerns of labour legislation. Already in the early 19th century it was recognized that working excessive hours posed a danger to workers' health and to their families. The very first ILO Convention, adopted in 1919, limited hours of work and provided for adequate rest periods for workers. Today, ILO standards on working time provide the framework for regulated hours of work, daily and weekly rest periods, and annual holidays. These instruments ensure high productivity while safeguarding workers' physical and mental health.[4]

[4] https://www.ilo.org/dyn/normlex/en/f?p=NORMLEXPUB:12100:0::NO::P12100_ILO_CODE:C001

- **Qualifications**

Qualifications refers to the level of qualifications acquired in the workplace for which there is no definition. According to the Portuguese statistics database of Ministry of Labour (MTSSS, Quadros de Pessoal) the levels of qualification in an occupational context are distributed among several levels, from unskilled professionals to senior management, however, it is an abstract concept that has no direct statistical basis since workers are classified as "semi-skilled" become "qualified" based on years of professional activity experience. Therefore, the analysis statistical analysis will be done only to the "non-skilled" and "semi-skilled" workers.

- **Gross Value Added - GVA**

Gross value added is the wealth generated in production, discounting the value of goods and services consumed to obtain it, such as raw materials.

- **Technological Intensity**

Technology intensity is a classification based both on direct R&D intensity and R&D embodied in intermediate and investment goods proposed in Hatzichronoglou (1997). Four categories were introduced: high-, medium-high, medium-low and low technology. Technological effort is a critical determinant of productivity growth and international competitiveness. However, since it is not spread evenly across the economy, analyses of industry performance and structural change attach much importance to technological criteria. Methodological work carried out at the OECD is used to determine these criteria. (OCDE 2011)

- **Import to Export Coverage Ratio**

Import to Export Coverage Ratio measures the ratio between the exported value and the imported value of each product.

- **AI R&D projects**[5]

Since AI is an emergent technology many of its most revolutionary developments are still in a pilot stage. Therefore, a measure of the potential interest in adopting AI-enabled automation

[5] Based on Boavida & Candeias (2021) Recent Automation Trends in Portugal: Implications on Industrial Productivity and Employment in Automotive Sector. *Societies*, 11, 101. https://doi.org/10.3390/soc11030101

systems is to perform an assessment of how many projects, in the manufacturing sector, are being funded.

The number of projects and its respective budget, was assessed through a data analysis in the Portuguese databases of R&D projects, funded by the European Regional Development Fund (ERDF), for the automotive sector.

A search string was constructed based on core concepts associated with industrial AI (algorithm, artificial intelligence, augmented reality, automated decision-making, computational vision, machine learning, predictive analysis, robot), constrained by keywords related to manufacturing and the **automotive sector**, as presented in Table 1. To make sure all projects related to the automotive industry were detected, three extra criteria were used: searching by the names of the eight car manufacturers in Portugal, based on the data from the European Automobile Manufacturers' Association—ACEA [6]; selecting projects from the automotive sector (NACE 29.10 and NACE 29.32); and selecting projects finished by the end of 2021, to have substantial results applied in real production environments.

Table 1 - Search strings adopted in the identification of funded AI projects in the automotive industry with an end date of 2021.

| Group 1—By Technologies | Group 2—Automotive Sector |
|---|---|
| Keywords: algorithm, artificial intelligence, augmented reality, automated decision-making, computational vision, machine learning, predictive analysis, robot | Keywords: manufacturing, Industry 4.0, automotive, car<br>Keywords: Auto Europa, Volkswagen, Caetano, PSA, Peugeot, Citroen, Renault, Toyota<br>NACE 29.10 and 29.32 |

#### 3.4.1.3. Semi-structured Interviews

**Semi-structured interviews** were used to gather facts (number of automation systems, applications where automation systems are currently used), description of processes (organisation of work), expert knowledge (AI-enabled automation systems design, development, installation, employment, organization of work, public policies), background information (experience, strategy for industry 4.0, public incentives) and opinions and perceptions (effects on AI-enabled systems, expectations, concerns).

[6] ACEA. Available online: https://www.acea.auto/figure/interactive-map-automobile-assembly-and-production-plants-ineurope/

An Interview Protocol was designed with standardized questions and topics according to the type of stakeholder group (Organisations from the science and technology Portuguese system, Industry, Representatives of Social Actors) identified through the Document Analysis.

Each stakeholder group had different subgroups (Technology providers, End-users, Academia, Social actors), and for each sub-group, at least two different profiles (robot supplier/ integrator, manufacturer/ parts supplier, RTOs/University/Technological Center, Sectoral Associations/ Workers' Representatives) were interviewed to make sure most perspectives were captured.

**The sample of interviewees consisted of 5 from Technology providers, 5 from End Users, 4 from Academia and 2 from Social Actors, in a total of 16. The manufacturing sectors covered were: automotive, metalworking, moulds and ceramics.**

According to RGPD and as discussed in the beginning of each interview, the name of the interviewee and the organisation he belongs to was anonymized with a code.

Finally, both deductive and inductive analyses were performed to confirm hypotheses and feed the scenario analysis. The deductive analysis generally applies theory to the data to test the theory. It **organizes data into categories to maintain the alignment with research questions. The inductive analysis is done** through the collected data and allows codes to provide the concept identification as they emerge. **It identifies representative data to support findings.**

#### 3.4.1.4. Testimonial Evidence

Group testimony enables interactions that can be used to explore similarities and differences among participants, to identify tensions or consensus in a group, or to explore ideas for subsequent research and collaboration. In this case, a groups discussion between workers' representatives and unions. The testimonial evidence collected was on examples and different concerns and expectations of workers from the automotive industry about implications of AI-enabled automation systems. This evidence is recorded in the Workers' Representatives Report.

#### 3.4.1.5. Observation

Evidence is obtained by direct inspection or observation of people, property, or events. In this case, two site visits were conducted and 4 videos were observed. Each visit lasted half a day, after the interview. The visits were done to two factories from the ceramics sector (EU4RID, mass production; EU5VED, customized production). It was possible to observe the production process, from the feed of the raw materials until the packaging of the products.

Evidence on the type of products and process, organisation model, AI-enabled automation systems, interaction human-machine, work environment and workers were recorded as notes in the respective interview notes.

Videos visioning had around 20 min. Two of them were about AI-enabled automation systems in automotive OEMs. Evidence was recorded in the respective interviews' notes (TS1CEO&IM, EU2MPD).

The other two were about the same ceramics' factories of the visits and it was possible to see in more detail some aspects of the production process (EU5VED) and a prototype of an AI-enabled automation system currently being developed (EU4RID). Evidence was also recorded in the respective interview notes.

#### 3.4.1.6. Scenarios

The scenario exercise consisted in the following stages:

**1) Stakeholders categories definition**

Based on the documental analysis, different relevant actors were identified, from the areas of automation and AI technologies. Relevant actors from the research disciplines of social sciences, from wider scientific community, from technology transfer actors, technology suppliers, technology users, industry associations, workers' committees, and public policy agents, were also identified. An aggregation of these actors was made according to the following categories:

- **Entities of the Scientific and Technological System**: represent researchers in the field of automation technologies, industrial engineering and artificial intelligence with a perspective on the limitations and future potential of technology, especially in the long term; researchers in the field of social sciences with a perspective on the effects of technology on employment, work organization and qualifications; specialists from technology centers in the manufacturing industry with a perspective on the implementation of technologies in companies;

- **Business Entities**: represent technology suppliers with the perspective of those who provide automation and AI technologies (e.g. industrial robots, software integrators), of what is their current and future state, in the short/medium term; and end users (e.g. automotive, automotive components and accessories, metalworking, mouldmaking, ceramics, electronic components) with a perspective on the effects on employment, productivity, competitiveness, innovation, qualifications and on the need for training;

- **Entities representing social actors**: represent sectoral associations with a perspective on the necessary training offer, incentive policies, legal framework and public policies; and workers' committees of user companies (e.g. Automotive OEM, automotive components and accessories suppliers, logistics, metalworking) with a perspective on the effects on working conditions, on employment and on involvement in the digitalization strategy.

### 2) Key Factors identified

Major issues (qualifications, work organization, public incentives, strategy, skills/training needs) were identified, which, according to an OECD report (OECD, 2005a), can affect the introduction and performance of automation and AI technologies by influencing the direction the future may take:

- **Qualifications –** refers to the level of qualifications acquired in the workplace for which there is no definition. According to the Portuguese statistics database of Ministry of Labour (MTSSS, Quadros de Pessoal) the levels of qualification in an occupational context are distributed among several levels, from unskilled professionals to senior management, however, it is an abstract concept that has no direct statistical basis since workers are classified as “semi-skilled” become “qualified” based on years of professional activity experience. The level of training to access the qualification level is vague and there is no correspondence to the levels used in the European Union (eg., CEDEFOP). However, the worker's experience and knowledge in a given task can be an important component for their successful performance and, in some cases, due to the characteristics of the task (eg. non-existence of specific training for the task, variability of products, empirical knowledge, etc.) it can be difficult to reproduce.

- **Work Organization** – refers to the work process (the way occupations are defined and carried out) and organizational practices (management and production methods accompanied by human resources policies) that influence the design of the job. The concept of work organization includes external factors, such as the economic and legal environment and technological factors that reinforce or promote new organizational practices.

- **Public Incentives** – refers to public support programs to encourage the implementation of public policies and that can contribute to the acceleration of certain situations, as is the case of industry 4.0 and AI.

- **Company Strategy** – refers to the long-term plan that guides decision-making and helps to achieve the company's objectives and its strategic goals through the organization, allocation and use of its resources (e.g. financial, facilities, inventory, technological and human) in order to support their economic activities.

- **Skills** – refers to the demonstrated ability to use knowledge, know-how, experience and professional, personal, social, or methodological skills, in work or study situations and in personal and professional development. Competences are not limited to cognitive elements (e.g. use of theory, concepts or tacit knowledge) but also include functional aspects, including technical competences, as well as interpersonal attributes (eg. organizational and social competences) and ethical values.

- **Adoption of AI-enabled automation systems** – refers to the adoption of AI systems at the machine and production process.

### 3) Data analysis

The interviews should be analysed by grouping the perspectives from the different stakeholders' groups, by major issues. This will reveal different points of view regarding what the 'real problems/issues' are and these will feed the various scenarios.

### 4) Drivers and Barriers

Main **drivers and barriers** were listed which could affect the key factors. Forces to consider include the '**STEEPED**': **Social, Technological, Economic, Environmental, Political, Ethical and Demographic.**

Towards Scientific Foresight in the European Parliament: In-depth Analysis (Van Woensel & Vrščaj, 2015):

- **Social** aspects cover changes in social and cultural values and lifestyles.
- **Technological** aspects include how, and in which directions, technology is developing and the diversification of the use of techno-scientific devices.
- **Economic** aspects cover issues related to conjuncture, production systems, different distribution and trade systems, and consumption of goods and services.
- **Environmental** aspects embrace interactions with our natural habitat and our biophysical environment which is our planet. This category also includes the availability of natural resources.
- **Political**/legal aspects describe developments or changes in various policy-making and legislative systems or forms of governance.
- **Ethical** aspects cover individual preferences about the diverse values embedded in the broader society.
- **Demographic** aspects entail various aspects of society, looking at the society as a collection of a varied set of social groups based upon parameters such as age, gender, religion, origin, profession, education, income level, etc.


Figure 9 - STEEPED (EU)

Source: Van Woensel & Vrščaj, 2015: 14

### 5) Scenario logics

A small number of exploratory scenarios were identified based on potential developments, obstacles and opportunities, relationships between factors and choices and long-term consequences.

The axes along which the scenarios were built were a) adoption of AI-enabled automation systems and b) qualifications. These two factors, based on the literature review, validated by the evidence collected, are the most relevant ones to consider effects at the level of employment and work organisation.

Assumptions were made for low level and high level of complexity of AI-enabled automation systems adoption and low level and high level of qualified workforce leading to different scenarios:

**Scenario I**: low adoption of AI-enabled automation/ low level of qualifications of the workforce
**Scenario II**: low adoption of AI-enabled automation/ high level of qualifications of the workforce
**Scenario III:** high adoption of AI-enabled automation/ high level of qualifications of the workforce
**Scenario IV:** high adoption of AI-enabled automation/ low level of qualifications of the workforce

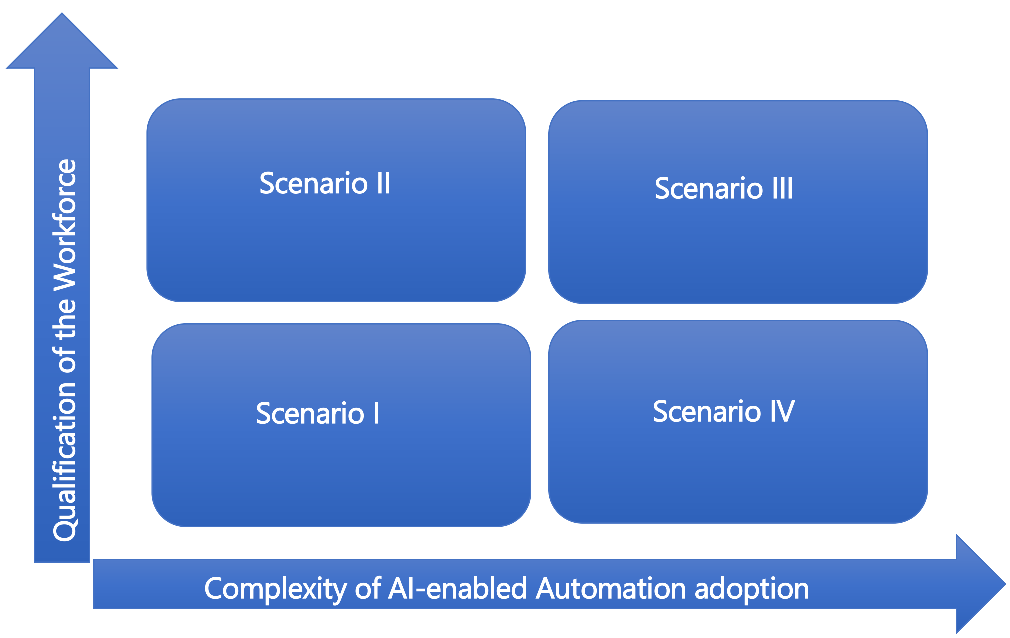


Figure 10 - Scenarios Logics

The organisations' behavior, in the different scenarios or even the shift between scenarios, can be affected by unexpected, but plausible, situations. These unexpected events are called **Wild cards** and may have major consequences. The wild cards identified were: **energy crisis; electrification.** The present energy crisis is not new. The Meadows et al.' report for the Club of Rome on the *Limits to Growth* (1972) already demonstrated 50 years ago the limits of planet resources, and the oil crises from 1973 was just a symptom. However, it can still be presented as a wild card.

The recent energy crisis became a "wild card" for the present scenarios because of the pressure on the European energy market and on the supply's disruptions brought by Russia's invasion of Ukraine. Even if Portugal was not directly affected, markets in Europe are being affected and most Portugal's exports of the manufacturing industries are to other countries in Europe. Thus, Member States are called to accelerate their clean energy transition (save energy, diversify energy supplies, accelerating the rollout of renewables, reduce fossil fuel consumption in industry and transport) in order to reduce the EU's dependence on Russian fossil fuels[7]. However, in the short term, if the war continues and the transition to renewable sources does not materialize in time to give solutions to the energy shortages that Europe is facing, this can be a problem affecting the adoption of AI-enabled automation and even put industries at risk.

Electrification because the change to electric vehicles will create disruption in the automotive sector, in OEMs and components suppliers, and in the mould-making tools sector. The automotive sector in Portugal is dominated by components suppliers and the mould making sector has a strong weight in the economy.

Exploratory scenarios start from the current situation and from past and present trends. Assumptions are made about uncertainties relating to the environment and factors of change, leading to pictures of plausible, possible futures. Next, by "backcasting", meaning, "working back" from the future towards the present, tracing potential sequences of critical events and changes, **recommendations were developed to avoid a particular scenario and promote de desired scenario.**

As a summary, Figure 11 presents the design of the methodology approach to apply the methodology of this research study.

[7] Communication REPowerEU Plan COM(2022)230

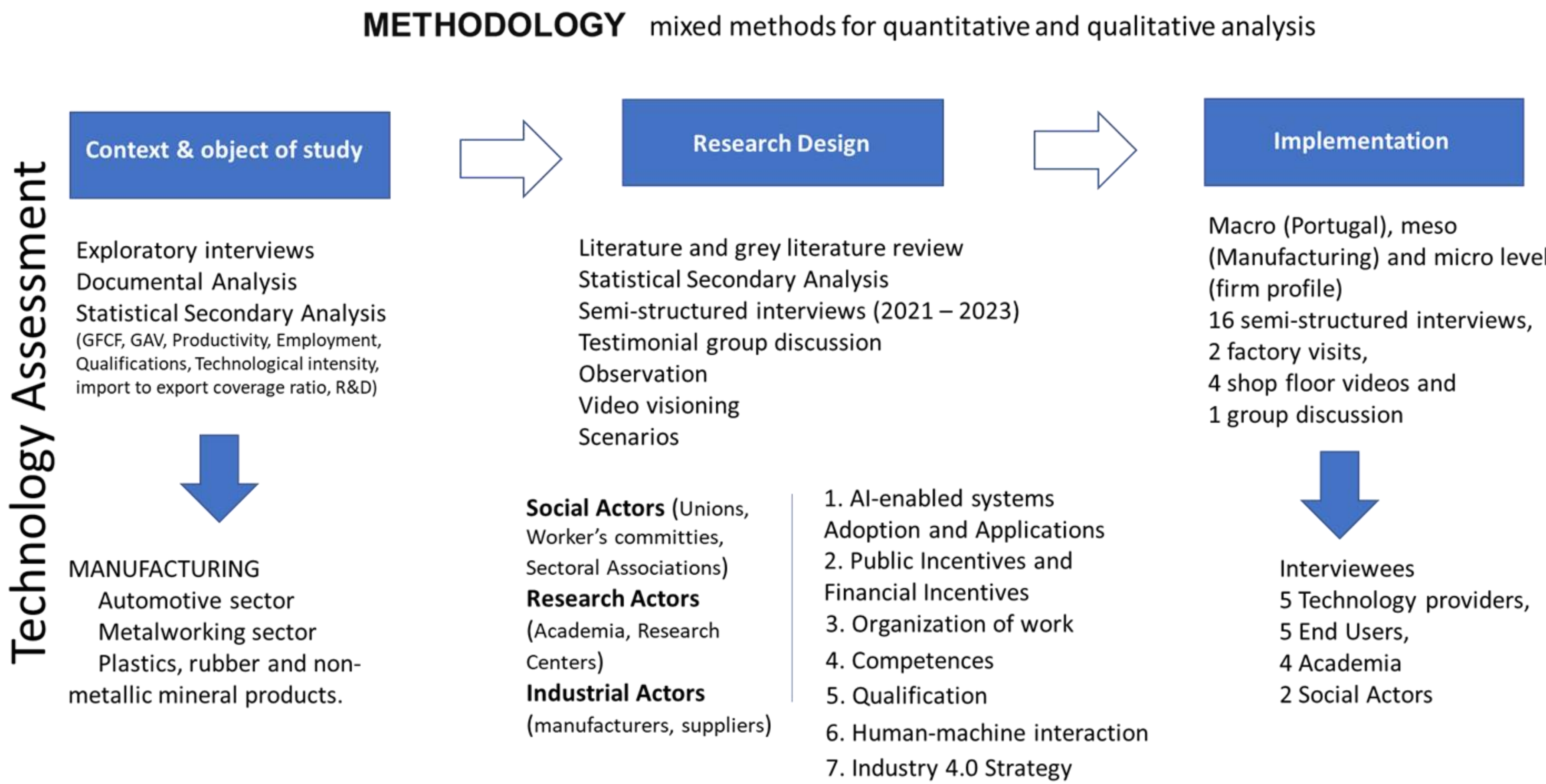


Figure 11 - Technology Assessment Design

# CHAPTER 4. DESCRIPTION OF THE CONTEXT AND OBJECT OF THE STUDY

## 4.1. Portugal - contextual data

This chapter presents the contextual data related to the situation of AI-enabled automation in Portugal, between 2010 and 2021, resulting from the documental and statistical analysis of main relevant documents and indicators. This will help to understand how AI is, and will be, impacting employment and work in Portugal and guide further collection of information and data on the main indicators that may unveil that impact relation. Having that done, the empirical data collection will be justified and the dimensions for the technology assessment considered.

It also presents an overview of stakeholders' discourses about potential advantages and risks of AI. Next, sectors for further analysis are chosen and, public policies for industry 4.0 and AI in Portugal are described, highlighting its features and constrains. At last, an overview of what kind of AI-enabled automation is already implemented in Portugal and what is the status of Industry 4.0 is presented as well as some preliminary conclusions before the following Chapter 5 – Results and Discussion.

### 4.1.1. Documental Analysis' Results

From the documental analysis on documents about the effects of digital technologies, including AI, which was scarce, resulted in the compilation of the following studies (Reports, Scientific Studies and MA and MSc dissertations), in table 4.

Through these studies it was possible to observe the growing concerns around automation, industry 4.0 and AI and on the effects these technologies could have in society and productivity. Around 2013 the concerns were regarding conservative automation technologies (industry

3.0) and only from 2018 onward, there was a shift to human robot interaction (industry 4.0) and from 2020 onwards a strong focus on AI was observed.

**Main constrains** to the adoption of industry 4.0 technologies are, still today, and among other factors related with:

a) job polarization in manufacturing industry;
b) low average qualification of the workforce;
c) scarcity of requalification schemes for industry 4.0, especially in initial training and "on-the-job" training;
d) technological challenges;
e) many companies are still in transition towards industry 3.0;
f) management awareness and understanding on the topic of industry 4.0;
g) short-term management strategies;
h) narrow focus on the variety of possibilities for work organization innovation;
i) difficulty for companies to find people with the right skills;
j) absence of a policy intelligence to promote human-centred concept of Industry 4.0.

On the other hand, according to Rita Araújo and João de Jesus MA theses, employment was not decreasing with the introduction of automation. On the contrary, the number of workers were increasing due to high demand and the correlation between the number of robots introduced and the number of workers, with a college degree, was almost a perfect linear correlation. And it would have improved if it was not the pandemics crisis. However, the projections for the future (CIP 2019) were very negative unless the workforce was requalified. People, seems to be the critical point in the digital transition, whether at the level of management, organization of work, qualification and skills.

In 2013, a study on job polarization, technological change and routinization (Fonseca, T., et al, 2013) concluded that both employment and wage premium increased for abstract tasks in relation to manual ones, noting a decline for routine manual tasks. They also found that job polarization in Portugal was being technology driven. This could be observed in the within-industry employment changes in occupations translated in the larger growth in top and bottom paid occupations versus the middle paid. In 2018, Rita Araújo MA thesis about robotization of productivity and employment reported a positive relationship between robotisation and employment. She also noted that the routine task intensity Index (RTI) had been decreasing between 2007 and

2012, meaning routine tasks had been decreasing in companies and that this could be explained by the transfer of low-skilled jobs, to more skilled jobs, arising from the use of a larger number of industrial robots.

In João de Jesus MA thesis (2019) on industry 4.0 impact in employment in Portugal, the correlation between the number of robots and employees with a college level of education, showed almost a perfect linear correlation. And, that the overall employment numbers would probably correlate at an even higher level to the number of robots, had it not been for the financial crisis that affected Portugal throughout this time period. Despite the growing automation of production processes, the total number of workers in the surveyed companies has been increasing due to the increase in demand. However, investment in requalification is still low, especially in initial training and "on-the-job" training, according to João Duarte from Nova SBE/CIP.

In 2017, studies on digital economy in Portugal (Mateus, A., et al, 2017), on Industry 4.0 (CIP's study) and on the impact of industry 4.0 in SMEs (COTEC's study) reported about current and future challenges arising from these transformations. The challenges for the future in industry are related with combining flexibility and efficiency in production methods; adapting to channel transformation; harnessing information to anticipate customer needs and offering customized products. Many of these challenges are related with data collection, processing and advanced analysis, low volume series, big product diversity and shorter response times.

According to COTEC's study there was a need to complete the Industry 3.0 transition before moving to 4.0: "I would be happy to be 3.0 today." mentioned by one of the companies surveyed. According to Mateus, A., et al, based on literature review of several other studies (McKinsey, BCG, EY, Accenture, PwC, Deloitte, WEF) concluded that, to be successful, the focus of digital cannot be only technological, not an IT strategy or a one-shot investment, but rather **focus on organisational transformation that requires time and continuous investment**. In fact, the Alexandra da Silva MA dissertation (2018) reported that with the increase of Industry 4.0, companies were changing and investing in technological advances such as digital or autonomous processes and this was leading to **changes in the structure** of human resources, both in the introduction of more **qualified and more specialised** individuals in current and emergent IT issues, and in the relocation or **training** to existing workers in order to be able to keep up with the new changes.

The COTEC's study also acknowledges that with Industry 4.0, everything was speeding up, therefore it was ever more important to get the management basics right. One CEO pointed to a Portuguese culture of short-termism that might get in the way of creating a management capability to integrate the new processes. This was also reported in the CIP's study (2018); most companies and their management teams were having difficulty in capturing the potential impact of digital technologies and on the urgency of implementing them. According to COTEC's study the biggest issue is always the people. They highlight the shortage of hard skills: people who know materials, algorithms, automation to be one of the main problems. From the Fonseca, et all (2018) study it was also concluded that the mismatch between the supply and demand for skills, due to the technological change, was one of the probable causes for the high prevalence of long-term unemployment, representing more than 50% of total unemployment in the last decade.

In 2018, the book of Moniz gave an overview of the situation on the technical and sociological debates about the relationship between technology and work, and more specifically about robotics, in Portugal. In his book, he refers to issues related with the interaction individual-robot, in industrial applications, which are mainly associated with work, and also associated with the perception of the work environment. Therefore, according to Moniz, the challenges lie in the sphere of alternatives in terms of work organisation and decision-making processes. Moniz also raised **concerns regarding the principles and problems of ethical, legal and social nature associated with developments in the domain of autonomous robotic systems and about the mental load and the complexity of the information to be handled by humans which could represent a limit to the diffusion or development of these systems**.

In 2019, another NovaSBE/CIP study (2019) about the Future of Work in Portugal, focused on requalification, presented very negative scenarios for the future. According to this study, Portugal has a high automation potential, in which 50% of the time spent on work tasks is likely to be automated using existing technologies, and this could increase to 67% in 2030 with the emergence of new technologies. According to this study, half of the tasks that have the potential to be automated by 2030, which implies a reduction of 1.1 million jobs, the jobs more affected will be those concentrated in predictive and physical occupations, data processing and collection, and in the manufacturing, wholesale and retail trade, administrative support and government, and agriculture sectors.  Although 0.6-1.1 million new jobs could also be created due, on the one hand, to direct growth in sectors linked to the supply and maintenance of automation-related technologies, and, on the other hand, to economic growth that originates from the increased productivity that automation provides, in net terms, around 700,000 workers will have to change their occupation or acquire new skills by 2030. However, they present positive prospects if, with the growing automation, a requalification of the workforce occurs giving Portugal an excellent opportunity for workers to change from low to high value-added tasks, which will increase the productivity of workers and companies.

Companies in the manufacturing sector (CIP, 2019) were the ones which made the largest investments in automation in relation to company revenue (9% - 45%) but the productivity levels have increased steadily throughout the years in which the automation level has risen. They have also reported that the biggest barrier to adopting new technologies is the need to adapt human resources.

In 2020, a study about Industrial AI in Industry 4.0 (Peres, R., et al, 2020) makes a systematic literature review on the potential of Industrial AI. According to this paper, Industrial AI carries the disruptive potential to profoundly change the role of the human in modern manufacturing and the way these systems interact with people. It gives the example of how human-machine interaction can assist personnel through virtual or augmented reality to improve and facilitate operations such as maintenance and assembly, or even in cases of remote diagnosis. Additionally, while they present the benefits of using this technology, they also draw attention to the need for enterprises to invest in proper training and acquisition of talent to ensure the full potential of these systems can be harnessed.

In 2021, a study also on Artificial Intelligence (Castro, J and Teles, V., 2021) and its pathway and opportunities, claims that whereas SME's are lagging in the potential use of AI solutions, recently founded companies, with little or no legacy processes, are part of those who are most aware of AI potential and more willing to exploit it, especially companies in the technological sector and dealing with vast amounts of data. On the manufacturing industry, where several AI applications are being deployed, among others, in the quality area to achieve the "zero-defect" goal, and in systems that make recommendations to the commercial area or manage inventory and the supply chain**, data collected at the shop-floor level is still difficult**. However, according to this study, with the emergence of distributed and smart systems and sensors at the machine and process levels (the Internet of Things – IoT within Industry 4.0), such data collection will become more widespread and potentiating more sophisticated AI applications.

In 2022, a study on the automotive sector (ILO, 2022) claims that the current focus is on digitalization rather than automation, as automation levels in the industry are traditionally high. In fact, specific tasks are unable to be automated (e.g. fine assembly and controlling) and automation has focused on repetitive tasks and those damaging to health, according to the study. While automation technologies seem to be present (albeit to a different extent) across most of the Portuguese automotive sector, many Industry 4.0 technologies and digitalization elements appear to be more elusive; many digitalization technologies are common, such as real-time data analytics displayed on shop floor screens, ERP systems, production indicators on mobile devices, interconnected machinery and digital production planning systems However, to be able to take the full benefit of all of these it would also be needed to have data from the shop floor and this is still difficult. Moreover, Internal Combustion Engines (ICE) will vanish in the medium term and electrification is at the center of changes in the automotive sector.

**According to that ILO study (2022) companies reported that there has been no job destruction but rather displacement, others have noted that there had been layoffs, e.g. due to automation; however, they seem to agree with the fact that the introduction of a new industrial robot typically entails less human labour**. Thus, further areas at risk are logistics, where more autonomous systems require less worker input. Finally, the study highlights that obstacles towards further technological developments and difficulties in **accessing financial capital** (especially in smaller businesses) and **hiring workers with advanced digital skills are the most relevant ones.**

Although some studies on the impacts on employment, work organization and qualifications exist, some limitations and needs for further research were identified. Main **limitations on these studies** were:

a) most of the empirical studies did not had visit to companies, observation to the workplace and register actual cases of AI;
b) it was not clear if SMEs underestimate the challenge of Industry 4.0;
c) few studies have been carried out empirically;
d) not many situations that allow for extensive observation, the O*NET descriptors might have limitations to its applicability to Portugal's context;
e) lack of data on robot industrial stock in Portugal and,
f) in most cases, the number of robots was based on approximations.

Main **recommendations** were to deepen understanding of these issues by collectively designing a set of scenarios of how developments may play out in Portugal. These scenarios should have the involvement of diverse participants from industry, government and civil society. It would be necessary to do more case studies that allow for more effective and extensive empirical verification.

Further recommendations were pointing to do this analysis for more recent years and delve deeper into the companies, the solutions and strategies they have implemented and what the impact is on their workers assigned to routine tasks. The estimated econometric model could be improved by introducing a larger number of variables. This study should be deepened with the aim of studying whether there is a set of occupations that are more susceptible to robotization, as well as studying how robotization might affect the demand for new labour.

There is a need to study the effects of robotisation in different activity sectors to find out whether there are Portuguese sectors where there is more susceptibility to robotisation and job losses than others. As well, such analysis should focus on the impacts of robotization on firm competitiveness and on the increase of productive efficiency. Finally, there are no studies on the determinants of the adoption of industrial robots in Portugal by companies in order to better understand the intrinsic characteristics of companies that lead to the adoption of these technologies.

Table 2 - Compilation of studies around the implications of digital technologies in Portugal

| Year | Document | Type |
|---|---|---|
| 2022 | ILO (2022), "Charging ahead: The future of work in the Portuguese automotive sector", Geneva | Report |
| 2021 | João Castro and Vasco Teles (2021), "Artificial Intelligence pathways and opportunities: A View from Portugal" Fundação Francisco Manuel dos Santos, FFMS | Report |
| 2020 | Peres, R. et al. (2020) "Industrial Artificial Intelligence in Industry 4.0: Systematic Review, Challenges and Outlook", IEEE Access, Vol. 8, December 2020 | Scientific Study |
| 2019 | João Duarte (2019) "O Futuro do Trabalho em Portugal: O Imperativo da Requalificação", NOVA SBE/CIP. | Report |
| | João de Jesus (2019), "Industry 4.0 Impact on Employment in Portugal", Master thesis on Aerospace Engineering, Lisbon Univ., Instituto Superior Técnico | Master Thesis |
| 2018 | COTEC Portugal/KPMG (2018), "i4.0 Scoreboard ", COTEC | Report |
| | António B. Moniz (2018), "Robótica e Trabalho: o futuro hoje", FLAD/Glaciar | Scientific Study |
| | Alexandra da Silva (2018), "Impacto de soluções de Indústria 4.0 no Mercado de Trabalho em Portugal", MA dissertation on Economy, Porto Univ. School of Economy | Master Thesis |
| | Rita Araújo, (2018), "Robotização da Produção e Emprego", MA dissertation on Economy of industry and firms, Minho Univ., School of Economy and Management | Master Thesis |
| 2017 | CIP (2017), "O conceito de reindustrialização, Indústria 4.0 e Política Industrial para o século XXI" | Report |
| | Augusto Mateus et al. (2017), "Avanço da Economia Digital em Portugal", EY-AM&A | Report |
| | COTEC Portugal/Roland Kupers Consult (2017), "Impact of Industry 4.0 on Portuguese SME's", COTEC | Report |
| 2013 | Fonseca, T.; Lima, F.; Pereira, S. (2013) "Job polarization, technological change and routinization", Doctoral Grant SFRH/BD/93390/2013 (T. Fonseca) | Scientific Study |

### 4.1.2. Evolution of the investment on gross fixed capital formation (GFCF)

To assess the investment in AI-enabled automation, in Portugal, the GFCF indicator was analysed.This indicator consists of resident producers' acquisitions, less disposals, of fixed tangible or intangible assets, according to Eurostat. This covers in particular machinery and equipment, vehicles, dwellings and other buildings. The GFCF is a key determinant of both aggregate demand and supply. This indicator was used for the analysis of investment on technology, once "machinery and equipment" represents one of major component of this indicator.

According to Figure 12, it is possible to observe a growth tendency in GFCF, in the manufacturing and agriculture, animal production, forestry and fishing sectors while all the other are decreasing or maintaining its GFCF until 2008. In 2008 is the year when the financial crisis affects Europe, including Portugal, and, as a consequence, the GFCF decreases in all sectors until 2012. However, from this year onwards, along with the slow economic recovery of Portugal, GFCF starts to increase again, with the exception of the extraction industry. It is also possible to observe that the GFCF is higher in the manufacturing industry.

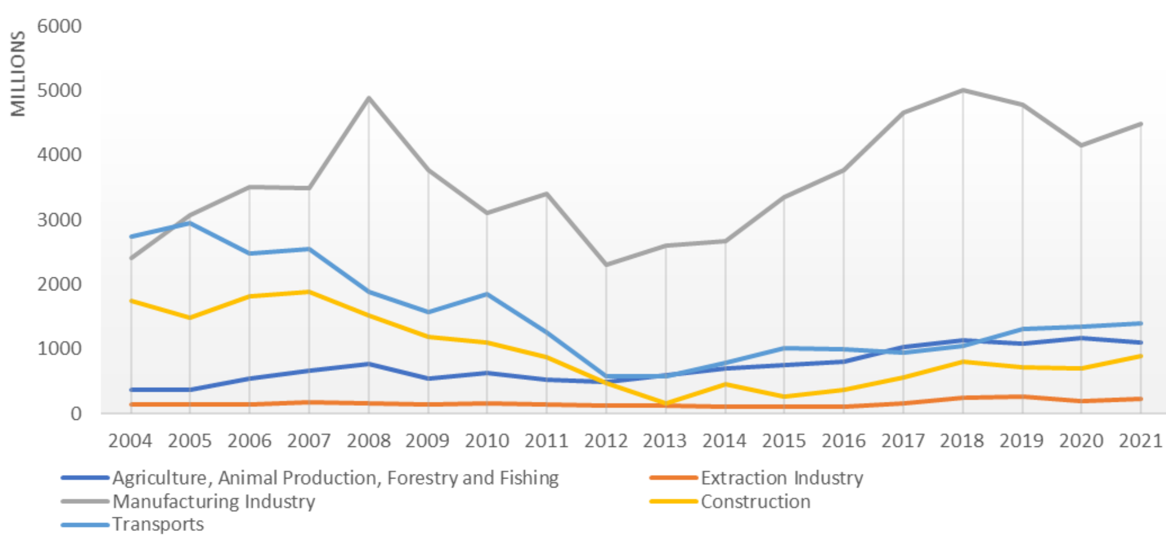


Figure 12 - Variation of GFCF (M€), between 2004 and 2021, by economic sector, in Portugal.
Source: INE

In Figure 13, we can observe the evolution of GFCF, between 2004 and 2020, in the manufacturing Industry, by economic activity. In this case, we can observe a rapid increase in GFCF in manufacturing industries, which only slowed down between 2008 and 2012 (economic crisis). From Figure 13 it is possible to understand that manufacturing industries are undergoing a strong modernization process. This capacity has been revealed in a set of indicators, in particular, in the export capacity of this sector. In 2019, before the pandemics, the Automotive sector was the one where the GFCF was bigger, followed by plastics, rubber and non-metallic mineral products production sector and metalworking.

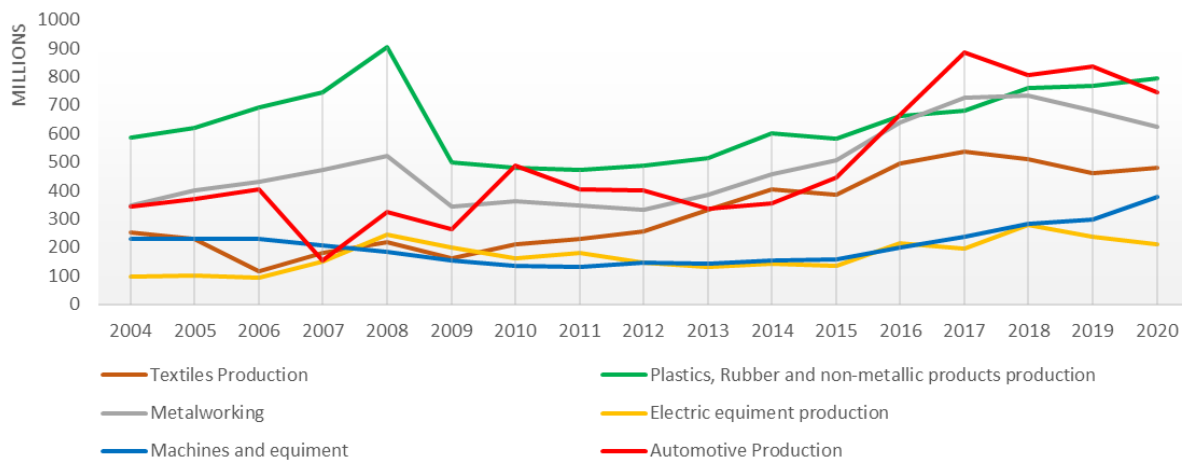


Figure 13- Variation of GFCF (M€), between 2004 and 2020, by economic activity, in Portugal-
Source: INE. PorData

The investment growth in AI-enabled automation observed in INE statistics can also be seen in the empirical data from the Portuguese R&D projects' database, funded by European Research and Development Funds (ERDF)[8], in the period of 2008 to 2020 (Boavida and Candeias, 2021). According to Boavida and Candeias' calculations on the Portuguese R&D Projects' database, funded by the ERDF, which includes several types of projects (eg., research-oriented,

[8] Note: the ERDF is a European Union Public Fund, managed at national level, which aims to strengthen economic and social cohesion in the European Union by correcting imbalances between its regions: European Regional Development Fund 2014–2020 – Regional Policy – European Commission (europa.eu).

industrial research-oriented pilots, and projects to mobilise R&D activities between companies and universities), from a total of 3.151 research and innovation projects (3.422 M€), 543 R&D projects are related to AI with a budget of 655 M€, corresponding to 19% of the total investment in R&D projects. Moreover, 34% of the total investment in R&D projects related to AI were on the automotive sector (225 M€).

### 4.1.3. Features of the labour market

To assess the features of the labour market, in Portugal, the Employment and Worktime week indicators were analysed for the manufacturing industry since this was the economic sector with the biggest GFCF (Figure 6).

Figure 14 shows the variation of employment in the manufacturing industry. It is possible to observe a decrease in the number of employees, in Portugal, until 2013. Is this an effect of automation? In this case, this decrease can be associated with the economic crisis that was still affecting the country at that time. The manufacturing industry was able to keep employment more less stable along the years. The Manufacturing Industry is the economic sector with the biggest number of employees, when compared to the other production sectors (figure 8), and thus, where effects of adoption of AI-enabled automation could be felt more strongly. The service sectors were not considered because the technology and employment features are completely different and would need a totally different setting of methodological approach.

According to the literature, with bigger investments in automation, less time for work. However, it is not possible to observe a decrease in employment (Fig.14) although there were investments in technologies (Fig.12) in those sectors.

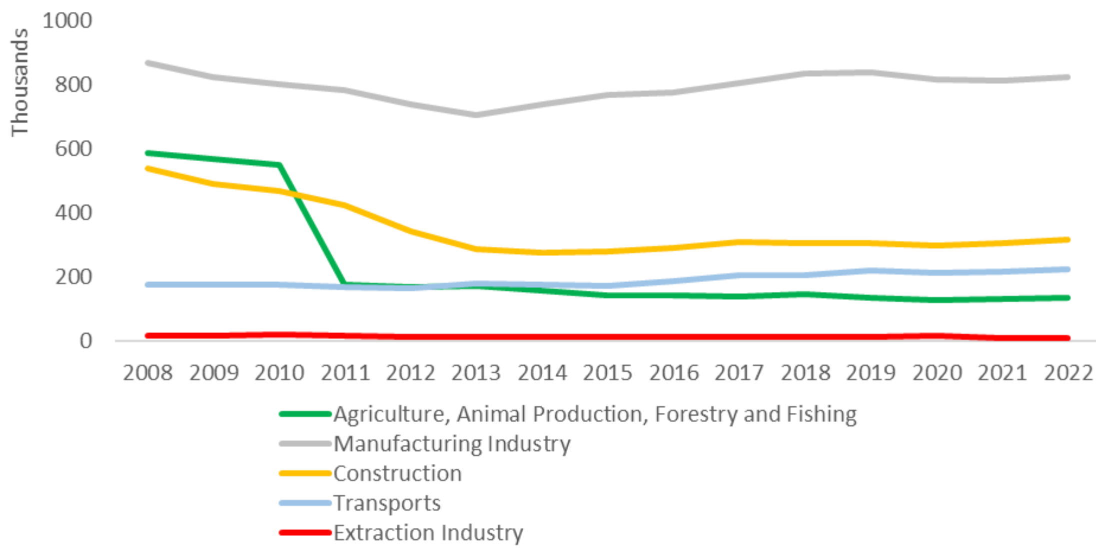


Figure 14- Variation of the number of employees (thousands), between 2008 and 2022, in Portugal. Source: INE, PorData

According to Figure 15, which shows the variation of the average worktime week, between 1990 and 2022, in Portugal, it is possible to observe, a tendency for the manufacturing average worktime week to decrease in line with the overall one. Taking in account the national legislation for worktime limit to the 40 hours worktime it can be observed a decrease in the average worktime week, from 1990 onwards, then it stabilized and decreased again slightly from 1996 onwards, some variations upwards and downwards until 2011, time when it decreased slowly again until 2019. Finally, between 2019 and 2020 there is a big decrease probably due to pandemics and a recovery in 2021 to 34h/week.

Therefore, from 1990 (40h/week) until 2021 (34h/week), there was a time reduction, on average, of 6H/ week which was the result of labour agreements and related legislation along the years.

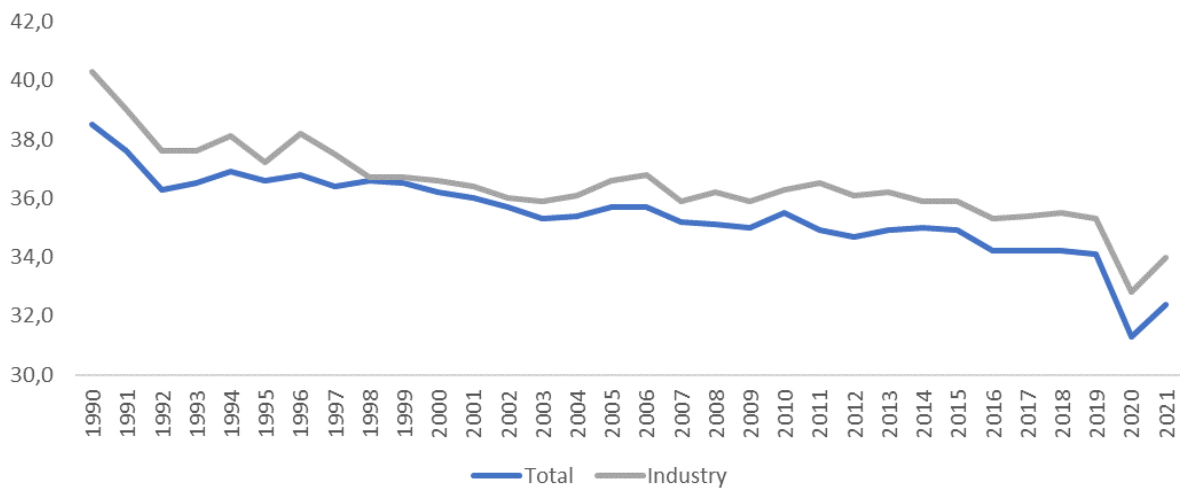


Figure 15- Variation of the average worktime (h/week), between 1990 and 2021, in Portugal.
Source: INE, PorData

Manufacturing industries, such as Automotive, Metalworking and Plastics, rubber and non-metallic mineral products (figure 16) have increased their number of employees from 2013, on-wards.

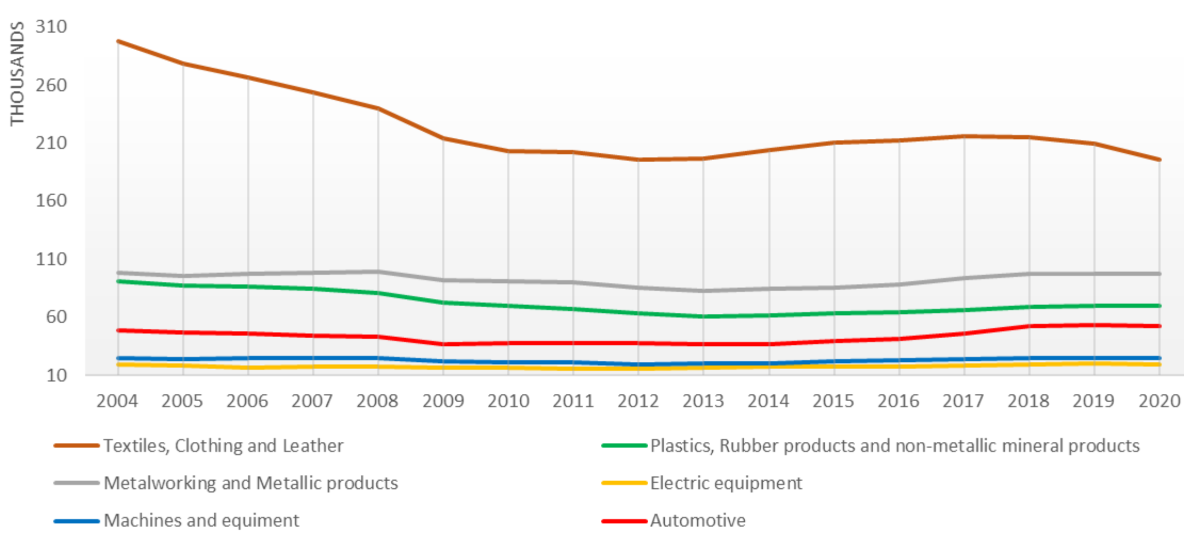


Figure 16– Variation of the number of employees (thousands), between 2004 and 2020, by economic activity, in Portu-gal.
Source: INE, PorData

The Textiles, clothing and leather industries has also showed a slight increase in the number of employees which decreased from 2018 onwards and Electric equipment and machines and equipment were relatively stable in the period analysed.

### 4.1.1. Productivity

To assess the features of Productivity, in Portugal, the Gross Value Added (GVA) and Productivity indicators, on the Manufacturing industry were analysed.

Figure 17 shows a comparison between GVA, between economic activities within the Manufacturing sector, in Portugal, from 2004 to 2021, where it can be observed that the Textiles sector is the one with a higher GVA and Machines and Equipment, Automotive and Metalworking are the ones with a bigger GVA growth along the years.

A slow growth can be observed on the automotive and metalworking GVA until 2015/2016 when a big automotive manufacturer (VW – Autoeuropa) started producing two new car models. From 2014 onwards, it is possible to observe an increase in the GVA growth of the sector of Plastics, Rubber and non-metallic production because of the new factory of Visabeira Group (non-metallic production). Due to the pandemics in 2020, the demand for products decreased which affected the production and, consequently, GVA.

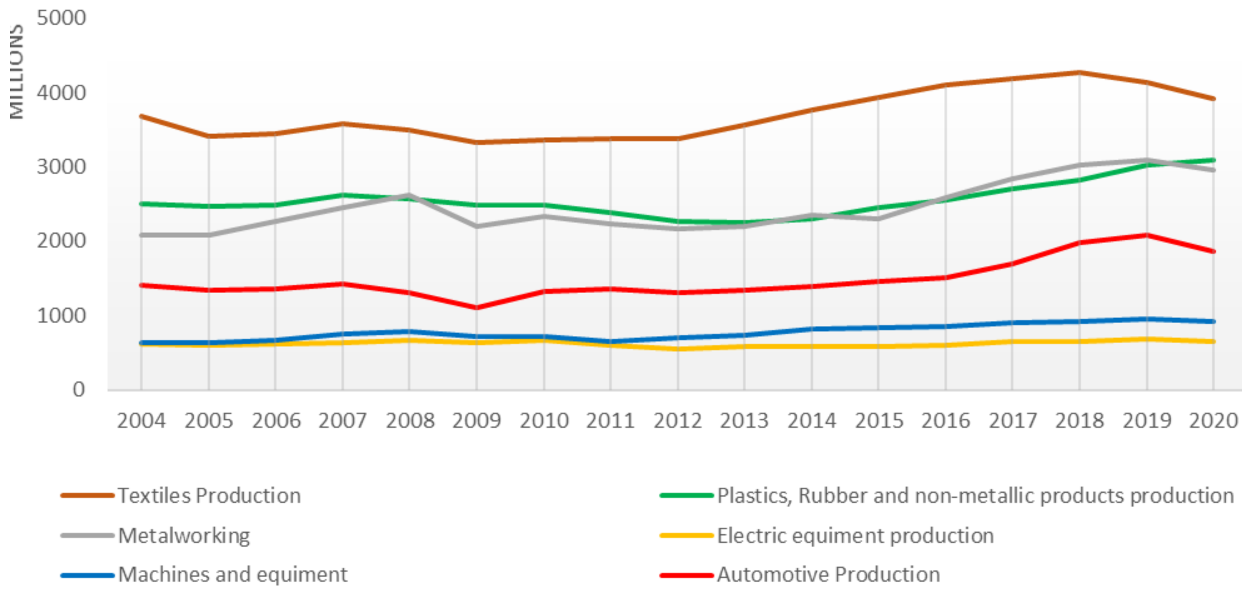


Figure 17 – Variation of Gross Value Added (M€), in Portugal, between 2004 and 2020, by economic activity. Source: INE, PorData

Productivity can be increased by working faster, usually by improving production technologies, or by reducing the number of employees. In figure 18, it can be observed the variation of productivity within the Manufacturing sector, in Portugal, between 2004 and 2020. Until 2019, before the pandemics, the sectors with the biggest productivity were Plastics, Rubber and non-metal mineral products and the automotive sector. All sectors, with the exception of electric equipment production sector, showed signs of productivity increase after the financial crisis of 2008.

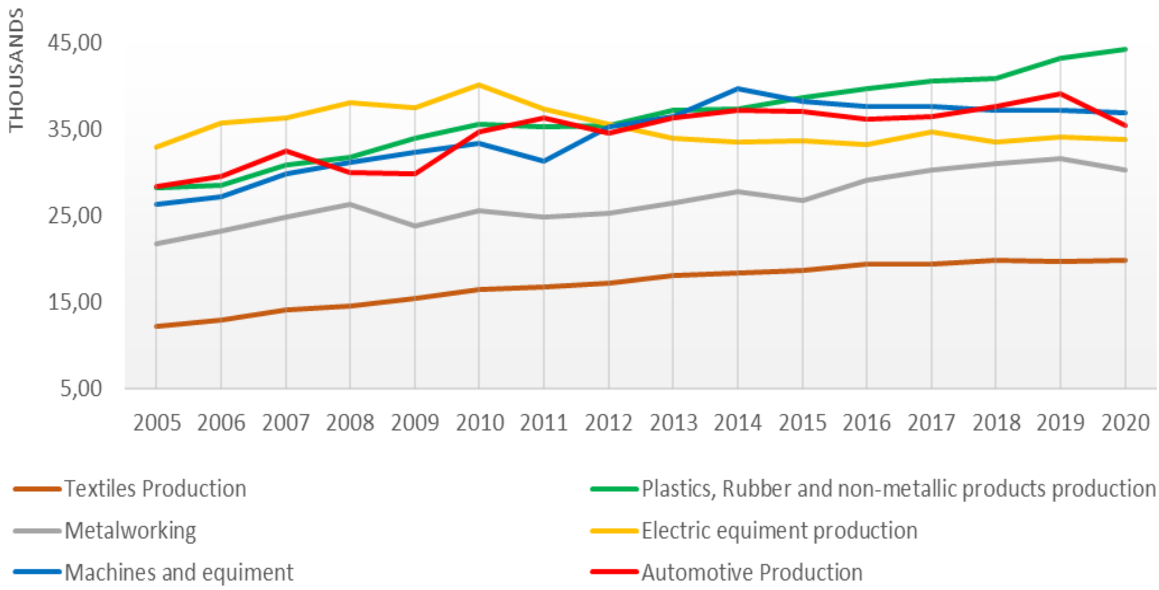


Figure 18- Variation of Productivity, in Portugal, between 2004 and 2020, by economic activity.
Source: INE, PorData

As a conclusion, it can be said that the implications of technology on productivity have to be considered carefully. Elgozy already said that, "given that the productivity of a shop floor is measured by the number of pieces produced per productive worker in a given period of time, the transition from manual machine tools to chained machines causes an improvement whose rate of increase oscillates between 15 and 20. If we consider, not just an automated production cell, but the whole of a factory or an administration, the average increase in productivity becomes evidently less high, since certain services are not automatable at all, and some are not at all" (Elgozy, 1968: 472-473).

In the same direction, Moniz refers that "in a factory that uses robots, the overall levels of labor productivity in that unit will be an average that includes the result of operating with the robots and also with the conventional machines or manual workstations of that same unit. If we consider a broader statistical analysis, we will already have to consider sets of production units with some of these advanced technologies together with others that do not have these technologies" (Moniz, 2018: 48).

### 4.1.1. Qualifications and competences[9]

To assess the features of the employed workforce, in Portugal, the qualification and competences indicators, on the Manufacturing industry, were analysed.

According to a recent OECD study, it is said that "between 2009 and 2019, the share of young adults aged 25-34 years-old with low education level halved" (OECD, 2022: 90).

According also to time series presented in the Figure 14, the schooling level in the manufacturing structure is gradually changing with time. It has moved from a workforce mainly with basic, compulsory school (elementary and primary school) to a workforce concentrated in the secondary school level (30%) with a slightly increase in the workforce that obtained a tertiary level degree (graduation – 10%, MSc – 2%), in Portugal, between 2010 and 2021.

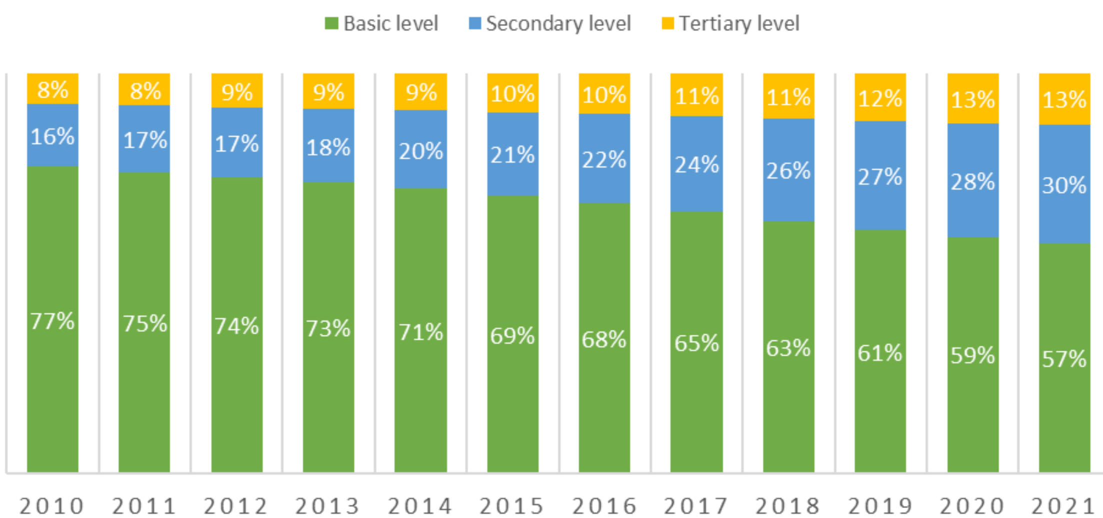


Figure 19– Variation of the weight of the schooling level of workers in the Portuguese manufacturing sector between 2010 and 2021

Source: Quadros de Pessoal (Quadro 36) 2010, 2011, 2012, 2013, 2014, 2015, 2016, 2017, 2018, 2019, 2020 and 2021, Ministry of Labour (MTSSS)

[9] Sub-chapter based on Moniz, A.B., Candeias, M. and Boavida, N. (2022) 'Changes in productivity and labour relations: artificial intelligence in the automotive sector in Portugal', *Int. J. Automotive Technology and Management*, Vol. 22, No. 2, pp. 222–244; DOI: 10.1504/IJATM.2022.10046022 (https://www.inderscience.com/info/inarticle.php?artid=124366)

Within the manufacturing industry, in 2020, the economic activities with at least half of its workforce with a schooling level above basic schooling are Machines and equipment, Automotive and Plastics, Rubber and non-metallic mineral products (figure 20).

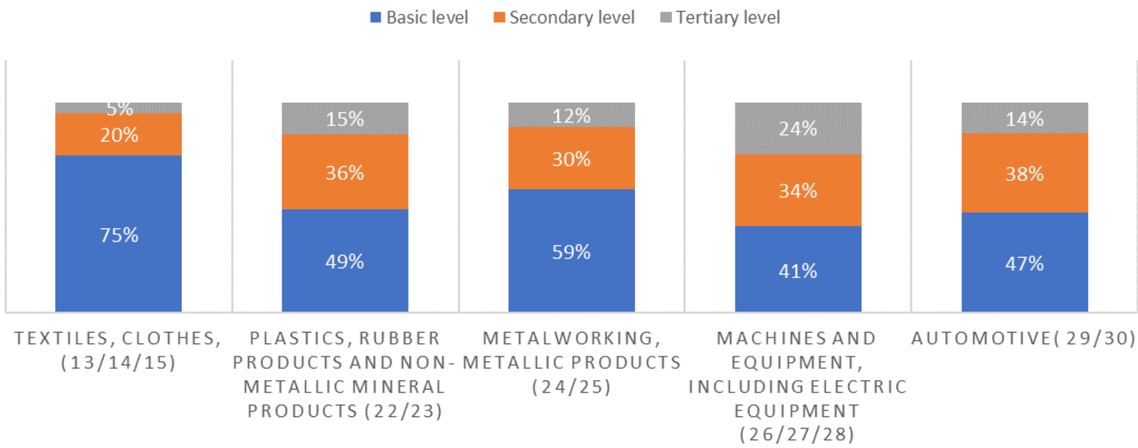


Figure 20- Variation of the weight of the schooling level of workers in the Portuguese manufacturing sector, by economic activity, in 2020.
Source: Quadros de Pessoal (Quadro 36),2020, Ministry of Labour (MTSSS)

At the same time, the share of low-skilled employees in the employment structure of the Portuguese manufacturing sector stays stable around 8% until 2018 (figure 21) and the share of semi-skilled workers is stable between 2011 and 2020, around 24%. Only the semi-skilled and low-skilled indicator was used because the statistical definition for the classification of 'qualified and highly qualified' workers in the statistical database of the Ministry of Labour is not precise. Most workers classified as 'semi-skilled', become 'skilled' after few years of professional activity in a company. Even the training access to the level of qualification is vague. In all, they do not correspond to the levels used in EU, for example, by CEDEFOP. Therefore, due to the classification of low-skilled and semi-skilled to be more precise, the variations based on the total volume of these groups can be presumed.

Results are presented in Figure 21 which clearly shows that the share of low skilled workers in the manufacturing sector tends to be relatively stable until 2018, after which increases by 1% before the pandemics and decreases 1% in 2020, the year of the pandemics. That happens even when the semi-skilled workers represented almost 1/4 of the total number of employees.

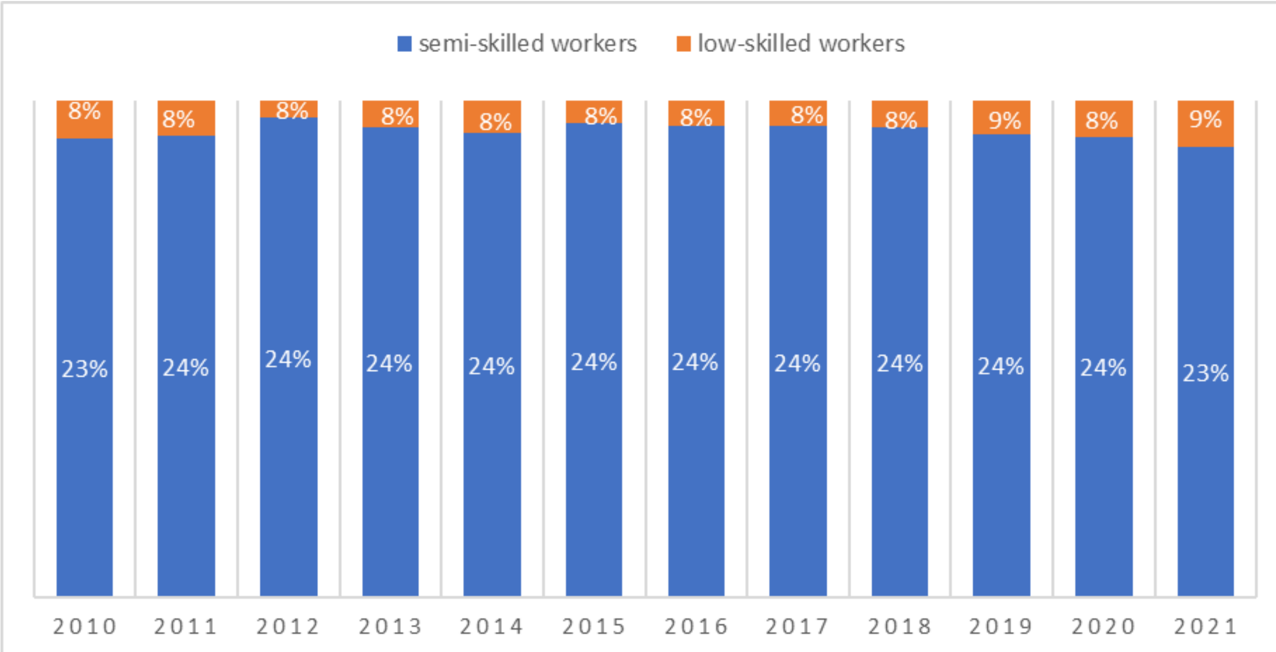


Figure 21 - Variation of the weight of low skilled workers in the employment structure of the Portuguese manufacturing sector, between 2010 and 2020.
Source: Quadros de Pessoal (Quadro 53),2010, 2011, 2012, 2013, 2014, 2015, 2016, 2017, 2018, 2019 and 2020, Ministry of Labour (MTSSS)

In 2020, for the different economic activities of the Manufacturing sector, the ones with less low-skilled employees are among the Automotive and Machines and equipment sector (figure 22).

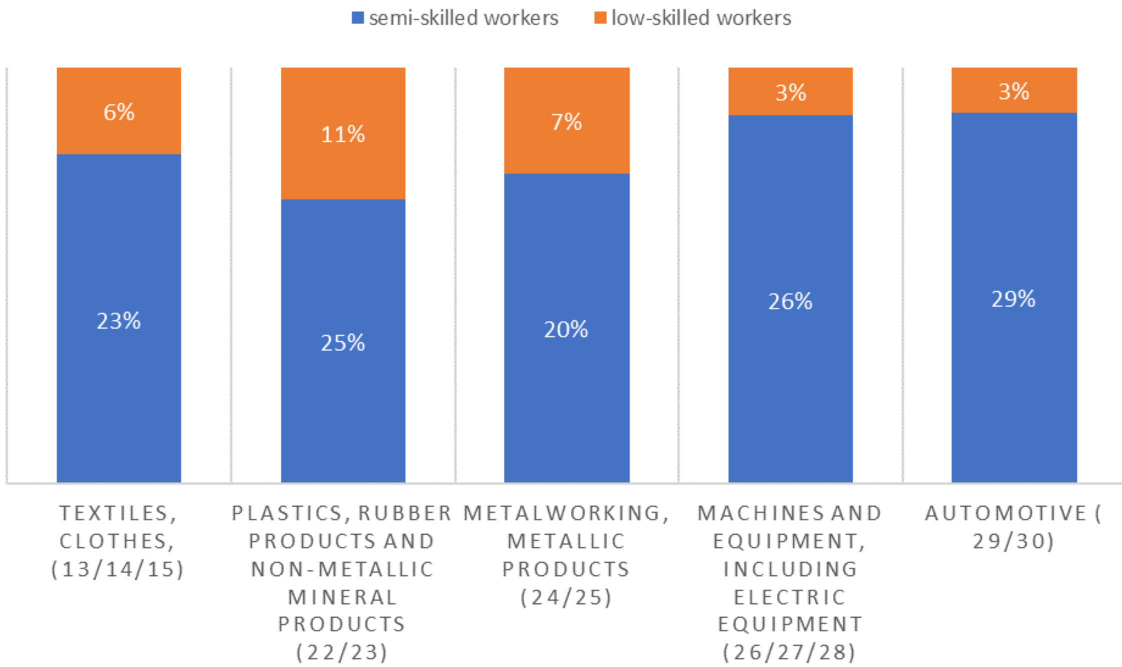


Figure 22 – Variation of the weight of low skilled workers in the employment structure of the Portuguese manufacturing sector, by economic activity, in 2020.
Source: Quadros de Pessoal (Quadro 53), 2020, Ministry of Labour (MTSSS)

### 4.1.6. Internationalization process[10]

To assess the features of the internationalization process, in Portugal, the Import to Export Coverage Ratio indicator, on the Manufacturing industry, was analysed.

The indicator Import to Export Coverage Ratio (%), which measures the ratio between the exported value and the imported value of each product and its variation, between 2004 and 2020, in the different economic activities of the Manufacturing sector, in Portugal, can be observed in Figure 23. Above the black line means that exports were bigger than imports and below the black line, the other way around.

[10] Based on Moniz, A.B., Candeias, M. and Boavida, N. (2022) 'Changes in productivity and labour relations: artificial intelligence in the automotive sector in Portugal', *Int. J. Automotive Technology and Management*, Vol. 22, No. 2, pp. 222–244; DOI: 10.1504/IJATM.2022.10046022 (https://www.inderscience.com/info/inarticle.php?artid=124366)

Therefore, the sectors of Plastics, rubber and non-metallic mineral products and Textiles, clothing and leather production sectors are economic activities where exports were higher than their imports, in the period analysed. In this period, machines and equipment imported more goods than exported its products. Automotive, Metalworking and Electric equipment, only between 2011 and 2013, for the automotive, 2015, for the metalworking and 2016, for the electric equipment, had their exports higher than their imports. From 2017 until 2020, the automotive sector raised its exports and in 2020 its exports were higher than its imports contributing to a positive commercial balance. Electric equipment has not shown signs of recovery in exports until 2020 and Metalworking started increasing its exports again only by 2019 but its commercial balance was still negative by 2020.

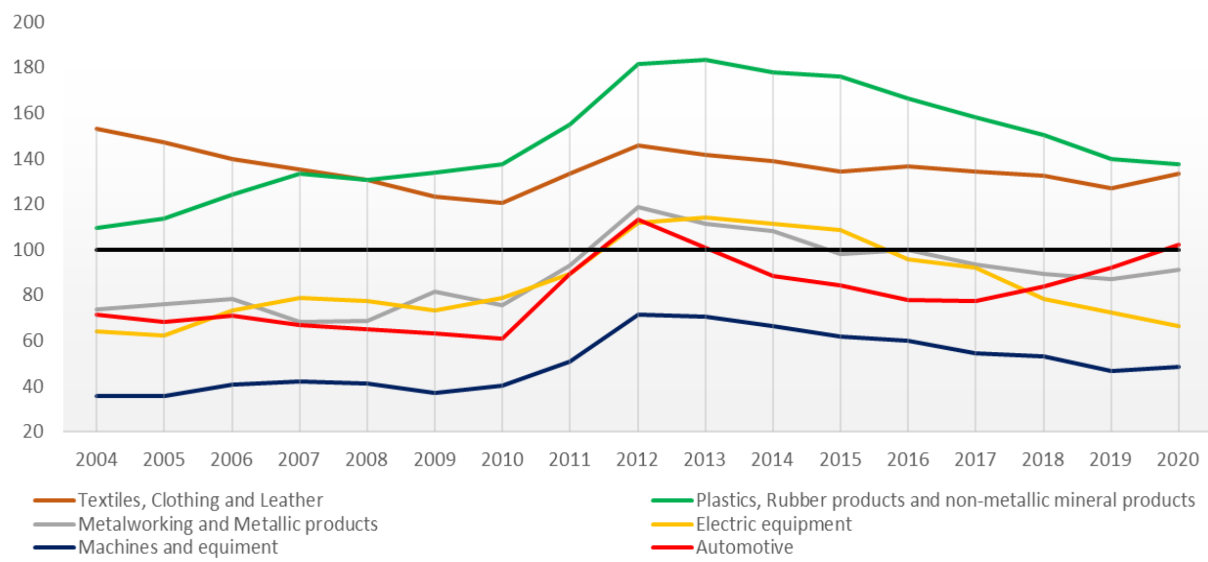


Figure 23– Variation of the Import to Export Coverage Ratio (%), in the Portuguese manufacturing sector, by economic activity, between 2004 and 2020.
Source: INE. PorData

### 4.1.7. Relevant Actors and AI discourses in Portugal

From the documental analysis resulted the understanding of the current discourses around AI-enabled automation in Portugal and the identifications of the types of stakeholders' groups relevant to perform interviews.

AI technology is defined by the ability of a machine to perform cognitive actions normally associated with humans, such as logical reasoning, problem solving and processing large volumes of data.[11] And for this very reason, Manuela Veloso, professor at the Machine Learning department, Carnegie Mellon University, says that "this path is inevitable" in a RTP program [12] (March 2017). The volume of data is increasing and to take advantage of the information contained in the data requires help from AI technologies (automation, data processing, etc.). However, if it is inevitable, then it creates the need and urgency for today's society to prepare for tomorrow's challenges.

The first challenge was mentioned by the Minister of Economy of the XXI Government of Portugal, Manuel Caldeira Cabral, when recognising that legislation can have a negative impact on the implementation of new technologies and showed concern about the necessary balance between creating the conditions to promote innovation and the stability of the economy "It is important that legislation is not a brake, but also not a component of instability" in (Dinheiro Vivo, December, 2017). Another challenge is related to the social inequality that may be created, as Luis Moniz Pereira, researcher at the Computational Science and Informatics Laboratory of NOVA School of Science and Technology (FCT-UNL), states "I believe that we will evolve into a society of castes, in the sense that we will have above all, the owners of the robots, then the administrators of the machines, then their executives and, finally, the exploited. For some to create wealth they will have to exploit others. This will generate revolts, and the robots will be used to protect the higher castes and dominate the population." In (Vision, November 2018).

With a less pessimistic view, António Brandão Moniz, author of the book "Robotics and Work" (2018), professor at FCT-UNL, agrees that there will effectively be a transformation of work. However, he is of the opinion that there will not necessarily be a direct replacement of jobs, what

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[11] https://news.microsoft.com/pt-pt/2018/10/09/empresas-portuguesas-abaixo-da-media-europeia-na-aplicacao-de-inteligencia-artificial/

[12] https://www.rtp.pt/play/p3189/e278689/fronteiras-xxi

will occur is an automation of tasks, not the replacement of the person "There are complex tasks that cannot be replaced by robots" in (Jornal de Negócios, October 2018). The replacement of people may happen, but it is not for reasons that concern technology, but rather the lack of qualified human resources (CIP/NovaSBE, 2019).

And specifically, in Portugal, given that the qualification levels of the Portuguese, despite the improvement in recent years, still remain very low.[13]

Daniela Braga, CEO of the start-up Definedcrowd, imagines a more optimistic scenario "Certain repetitive jobs will be replaced by artificial intelligence, which will leave us more free time for creative and strategic components" in (Expresso -Economia, June 2019) arguing that AI improves people's lives by creating more specialised jobs. Agreeing with Daniela Braga, Nuria Oliver, National Computer Science Award 2016, director of data science research at Vodafone, considers that "It is very important that we see artificial intelligence as an opportunity to improve society, to survive as a species. However, we have to prepare and train ourselves so that it can be a reality" in (Expresso, May 2019). Artificial intelligence will have a huge positive impact on society, however, there is fear about what this rapid diffusion of machines in such a short time will have, particularly on employment. Hence the need for an adequate educational policy, since being a user of technology is not the same as understanding how it works, and currently children are not prepared to come to occupy these new jobs that will be required in the coming years.

This dimension that the adoption of AI needs qualified human resources is shared by Alípio Jorge, coordinator of the Portuguese AI strategy, coordinator of a research group at INESC TEC, "We need Information Technology and Computing professionals at various levels (...) universities, polytechnics, schools and companies will have a very important role in this training that, in many cases, will be of reconversion, taking advantage of professionals from other sectors" in (Expresso -Economia, June 2019). Also defending requalification is António Saraiva, President of the Confederation of Portuguese Business (CIP), "It is clear that the loss [of jobs] can be compensated by the creation of others, if there is an effective reconversion in which we all participate. This is a national goal, we have to effectively train adults and that is where the click lies to take advantage of these opportunities" in (Público, January 2019).

The potential of this technology depends on the ability of companies to harness it. If there is no investment to achieve the digital transformation of the industry, it may lose competitiveness and, consequently, contribute to the elimination of jobs due to company closure**. It is necessary**

[13] https://ec.europa.eu/digital-single-market/en/desi

**to work in anticipation and invest in the qualification of human resources, through an effective requalification plan that involves the public sector, companies and education and training institutions.** Despite the challenges already identified, the Minister of Science, Technology and Higher Education of the XXI and XXII Portuguese Governments, Manuel Heitor, considers, even so, that Portugal has competences and knowledge in terms of AI that have to be used to create jobs "Portugal in AI is one of the best at European level. What we want is to increasingly participate actively in the European context and ensure that AI, also in Portugal creates jobs" in (Jornal de Negócios, February 2019).

Also defending the requalification was António Saraiva, President of the Confederation of Portuguese Business (CIP), "It is clear that the knowledge in AI in Portugal has been enhanced in the participation in European initiatives so that it can have an impact on job creation in Portugal. In addition to the challenges already identified, Portugal still has challenges in implementing AI for industrial activities since, to take advantage of its full potential, certain conditions must be established, such as, digital transformation of the industry, digital skills in human resources, as already mentioned, data to train the algorithms and sensors, internet of things and computerised processes to access data.

To overcome these challenges several national strategies have been launched: Industry 4.0 (2017)[14] , Estratégia Nacional para as Competências Digitais –INCoDE 2030 (2017)[15] and Estratégia Nacional para a Inteligência Artificial – AI Portugal 2030 (2019)[16].

And there are already success stories in national companies, both in terms of technology users and technology suppliers. For example, Altice already uses AI and predicts that the use of AI will be the trend in the Telecommunications sector "We have been working a lot on the predictive part of AI, on anticipating problems. The traditional telco world as we knew it 10 years ago is tending to disappear, merging with AI" says Frederico Vaz, Director of Altice, in (Executive Digest, November2018)[17].

For its part, Bosch has been working in Artificial Intelligence applied to different business areas, from autonomous driving to industrial processes, passing through the aerospace industry.

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[14] https://www.iapmei.pt/PRODUTOS-E-SERVICOS/Industria-e-Sustentabilidade/Transformacao-digital/Industria-4-0.aspx

[15] https://www.incode2030.gov.pt/

[16] https://www.incode2030.gov.pt/sites/default/files/julhoincodebrochura.pdf

[17] https://executivedigest.sapo.pt/xv-conferencia-ed-quais-os-limites-da-inteligencia-artificial/

More than replacing humans, Artificial Intelligence is seen at Bosch as a tool to increase the capabilities of humans as Francisco Duarte, Bosch Industry 4.0 coordinator, refers "Everything we do in terms of software engineering is to extend the capability of humans" in (Executive Digest, November 2018)[18].

At the level of companies providing AI based solutions, a SME that stood out was Outsystems. This company aims to make it easier to incorporate next-generation artificial intelligence into customer experience, explains António Alegria, Head of artificial intelligence at OutSystems" The combination of low-code and artificial intelligence answers one of the biggest challenges that does not allow these companies to move forward - the shortage of talent " in (Computerworld newsletter, newsletter, June 2019). New artificial intelligence and machine learning capabilities in its low-code development platform will provide organisations with the ability to leverage automation to create self-service portals, answer text and voice queries, improve customer service and more. These are just a few examples but who listens to Magda Mata, Industry Lead at Microsoft Portugal, realizes that there is potential for many more applications since the adoption of AI will increase productivity "Artificial Intelligence will provide substantial insights into operations and the market, enabling more informed decision-making, anticipate trends, make more accurate predictions, facilitate process optimization and reduce costs." in (Expresso -Economia, May 2019).

There will be a change in the way one looks at the position of manufacturer in the value chain; the manufacturer is no longer just the producer, but the means that connects the whole life cycle of a product. Finally, Prof. António Ulisses Cortês, Professor of Law at the Catholic University of Portugal draws attention to the importance of building an Ethical Charter of Artificial Intelligence since AI can promote the sustainable development of peoples, however, there are risks inherent to technological power "The power of technology implies ethical sense of responsibility, of a responsibility that will have to be situated beyond paralysing fears, but also reckless fantasies." in (Economic Journal, July 2019).

The process of assessing the impact of the adoption of AI technologies in Portugal is an ongoing process. Several challenges have already been identified: legislation; fast and adequate response to the adoption of AI; social inequalities; skills and requalification; digital transformation of the industry, digital skills in human resources; data to train the algorithms and sensors, internet

[18] https://www.dinheirovivo.pt/economia/inteligencia-artificial-e-robotica-em-destaque-no-aniversario-do-dinheiro-vivo/

of things, computerised processes to access data and the use of ethics and responsibility in the development and application of AI. However, the general feeling is that AI could bring more advantages than disadvantages to the human condition as long as the conditions for this are in place and ethics and responsibility are at the foundation of this new transformation.

Some quotes refer to the potential of AI to improve quality of life and quality at work as well as being an opportunity for societal improvement. This feeling is especially dominant among public decision-makers and the economic sector. The scientific community and associations are less expansive and, identify the beneficial potential of AI, provided certain conditions are in place and overcoming the identified challenges, namely education, training in digital skills and in particular in AI, awareness of society in this area and investment. However, it can be verified that some initiatives in this direction have already been promoted, as is the case of public policies: Estratégia Nacional Indústria 4.0 (2017), Estratégia Nacional para as Competências Digitais –INCoDE 2030 (2017) e Estratégia Nacional para a Inteligência Artificial –AI Portugal 2030 (2019). However, although there are some successful cases of companies using AI, such as Vodafone, Altice Labs and Bosch, about 75% of the national companies do not have digital maturity, according to the EY Portugal study (Augusto Mateus, 2017). And even though there are also some examples of companies created in this new business area of AI, like Microsoft Portugal, DefineCrowd and Outsystems, they are still making their way in the market and its end is unknown.

Therefore, it is possible to conclude that, despite the positive signs that AI shows it is still too early to draw conclusions. It will be necessary to further analyse each of the challenges to AI adoption in the various dimensions under evaluation. Furthermore, it does not yet seem to be clearly identified the impact that the adoption of AI will have on employment since there seems to be a dichotomy between replacing people and replacing tasks that may lead to an increase in people's capacity or the need for requalification. There is no clear favourable or opposing position and therefore the analysis will be more on finding solutions to overcome the challenges.

The stakeholders' groups relevant for interviews are, thus: organisations that provide the technology (AI-enabled automation solutions); organisations that use AI-enabled automation (end users from different manufacturing sectors), academia (academic profiles from computer engineering and social sciences and Humanitites) and organisations representing social actors (workers' representatives, sectoral associations).

## 4.2. Chosen sectors in the manufacturing industry

Often, investment in automation, which can be both automation hardware (e.g., mechanical parts, and/or the electrical and electronic parts) and software (Vogel-Heuser et al., 2015) are made to perform upgrades in the manufacturing sector. The GFCF was used (figure 6) as a proxy for the AI-enabled automation and it was possible to conclude that the Manufacturing industry was the one with a higher GFCF and also the one where there was a higher growth in GFCF after the economic crisis of 2008, from 2012 until 2020. The worktime week reduction, on average, of 6h/ week, between 1990 and 2020, in the manufacturing industry, in Portugal (figure 9), was also possible due to the labour agreements and legislation that have been accepted also because of the strong modernization process the manufacturing industries were undergoing at that time.

Although it could be observed a growth of investments in automation technologies since 2012, in manufacturing industries, as stated above, the employment, increased between 2013 and 2019 (figure 8), in line with Acemoglu and Restrepo (2018). According to these authors, this can be explained by several countervailing positive effects. In 2020, there was a slight reduction which can be attributed to the pandemics. Moreover, the Manufacturing Industry is the economic sector with the higher number of employees, when compared to the other sectors (figure 8), and thus, where effects of adoption of AI-enabled automation could be felt more strongly. The service sectors were not considered because the technology and employment features are completely different and would need a totally different setting of methodological approach.

Manufacturing industries are from several different sectors of production. From literature, production can be continuous (eg., chemical, food and beverages, pharmaceuticals, etc) and discrete (eg., automotive, metalworking, etc.). The continuous production sectors have been automated for some years now and therefore, it is not expected that, even with emergent technologies, it will undergo big changes at the level of work and employment. On the other hand, discrete manufacturing still has many occupations and tasks done manually by the workforce and thus, it can be strongly affected with the adoption of AI-enabled automation technologies.

According to Arnold et al. (2018), within the same occupation, the automation potential can vary greatly from job to job; threats in occupations vary significantly by qualifications and by countries.

Within the manufacturing industries, in the discrete manufacturing production sectors, different sectors have different features and different occupations. Therefore, to understand the potential effects of AI-enabled automation in the employment and work and in what conditions these effects can be accelerated or inhibited, different sectors which have been adopting automation technologies were chosen, in Portugal, so its potential effects could be assessed.

All manufacturing sectors in Figure 7 have shown an increase on its GFCF from 2013, onwards, but, in 2019, before the pandemics, the Automotive sector was the one where the GFCF was higher, followed by plastics, rubber and non-metallic mineral products production and metalworking sectors (figure 7). In this same sectors, (figure 10) the number of employees have also increased from 2013, onwards, ando also the GVA (figure 12) and productivity (figure 13). In line with Acemoglu and Restrepo (2018), this can be explained by the efficiency effect of automation technologies, which increases the competitiveness of the companies in theses sectors, increasing their market share and thus, needing to hire more employees to respond to the high demand from the market.

The schooling level in the manufacturing structure has gradually changed with time by moving from a workforce mainly with basic, compulsory school (elementary and primary school) to a workforce concentrated in the secondary school level (30%) with a slightly increase in the workforce that obtained a tertiary level degree (graduation – 10%, MSc – 2%), in Portugal, between 2010 and 2021 (figure 14). Within the manufacturing industry, in 2020, the economic activities with at least half of its workforce with a schooling level above basic schooling are Machines and equipment, Automotive and Plastics, Rubber and non-metallic mineral products (figure 15) and also the ones with less low-skilled employees, are Automotive and Machines and equipment (figure 17). At last, regarding the internationalization process (figure 17), only the automotive sector shows a growth of exports since 2017, and also metalworking and textiles, clothing and leather since 2019.

For the reasons stated above, the sectors chosen to deepen the analysis of the effects of AI-enabled automation in the employment and work were: **Automotive (manufacturers and components for automotive), Metalworking (moulds and metalworking) and Plastics, rubber and non-metallic mineral products (ceramics).**

For the sectors chosen, comparison between countries were analysed to understand what the position of Portugal at the macro level is. The R&D intensity of a country depends on its industrial distribution, and there are industrial sectors with high to low technological intensity (Sandven & Smith, 1997). Given that different countries, have different industrial structures, to validate the relationship of innovation by AI and the effects at the level of productivity and employment, and be comparable between countries, it is necessary to ensure that the same indicators are used for the same industrial sector (meso level) (Smith, 2006). On the other hand, within the same industrial sector there may be differences at company level, according to their profile, their positioning in the value chain and according to their products (micro level).

## 4.3. Conclusions about the chosen sectors

In conclusion, three different sectors were chosen with the following features at the macro, meso and micro level.

- **Automotive Sector – NACE 29**

In 2020, although without a big expression, in terms of employment (**0,9% - share of employment in the total employment of Portuguese economy**), as in countries like Czechia (3,7%), Slovakia (3,2%) and Hungary (2,3%) companies from the automotive sector (manufacturing motor vehicles, trailers, semi-trailers and vehicle components) have a very significant weight in the Portuguese business fabric. In this year, the automotive sector was leading the national manufacturing exports (20.2%) and will remain the second largest with the greatest contribution (3.8%) of exports to the national Gross Domestic Product (GDP), with 82.8% of the value of production with cross-border destinations.

The value of the sector's exports reflects, however, and in largely as a consequence of the pandemic crisis of COVID-19, a decrease of more than 10.6% in 2019, bucking the growth trend of the last decade. In effect, the dynamics created by the pandemic, with less investment in productive capacity, led the sector, for the first time since 2013, to a lower investment rate than the average of national non-financial companies.

It is important to bear in mind the major transformation phase that the sector is going through and that thousands of jobs and factories face major challenges as a result of the need to convert production lines to enable the manufacture of more sustainable vehicle models and components, in line with the ambitions of the European Green Pact and the measures proposed in the

"Fit-for-55" legislative package of 2021, which sets a minimum of 55% reduction in greenhouse gas (GHG) emissions.

These impacts are felt throughout the value chain, in which other sectors of high strategic value for the national economy participate, such as textiles or leather, in the field of technical application in the vehicle interiors segment, which reveals the capacity for innovation and technological development of these industries.[19]

In 2020, the Portuguese automotive sector had **752 companies, employing more than 43.2 thousand people,** a number that has suffered a reduction of more than 2.4% in relation to 2019, but on an increasing trend since 2010, with average annual increases of around 3.7%. The interactive map of the European Association of Automotive Manufacturers (ACEA) identifies 5 production and assembly units in Portugal: Volkswagen AG (Volkswagen, Seat), Toyota Motor Europe (Toyota), Stellantis (Peugeot, Citroën), Daimler Group (Fuso) and Caetanobus (Caetano, Cobus).

The sector gained 63 companies in 2020, reaching 752 units, with the components subsector, the most significant, representing about 68.4% of the total Portuguese automotive sector, and the sub-sector in which the increase in the number of companies was also greater, while the sub-sector of manufacture of motor vehicles lost 4 units. By 2020, the 37 companies of the latter, together with the components subsector, accounted for about 84.6% of the labour force, 86.1% of GVA and 87.1% of the sector's exports of goods[93].

According to OCDE 2011, **automotive is a medium-high technological intensity sector**, since, at the outset, the probability of these sectors investing more in technology is higher. Furthermore, it has a **high industrial production activity** and is characterised by being one of the sectors that is **at the forefront of technology** due to the constant **need for innovation, efficiency and quality**. Its products vary between **simple and complex geometries**, of **high quality**, are **standardized** and follow a model of **mass production.**

- **Manufacture of fabricated metal products, except machinery and equipment - NACE 25**

[19] João, M. & Fernandes, F. (2022), "A Indústria Automóvel em Portugal", Cadernos Temáticos, with a characterization of the automotive industry (Division 29 of CAE Rev. 3 and subsectors) in Portugal, with official statistical production data for the reference period from 2010 to 2020, DGAE; Direção-Geral das Atividades Económicas (dgae.gov.pt)

In 2020, the Portuguese NACE 25 sector accounted for **11.7 thousand companies which employed 93.1 thousand people**. Around 85% of the companies have between 1 and 9 workers. Even without a big expression, in terms of employment (**1,9% - share of employment in total employment of Portuguese economy**), as in countries like Czech Republic (3,7%), Slovakia (3,2%) and Italy, Germany and Croatia (2.2%) companies from NACE 25 have a significant weight in the Portuguese business fabric (1,5% - share of GVA in total GVA of the Portuguese economy (current prices)), which is lower than Slovenia (3%), Germany, Italy and Slovak (2%) and Hungary and Bulgaria (1,6%). However, it is higher than Sweden (1,2%), Spain and Finland (1,2%) and Belgium, Denmark, France and Latvia (1%).[20] The total share of this sector (eg., moulds, metalworking) in the total of Portuguese exports represents 5,3% and exports go mainly (around 55%) to European countries.

According to OCDE (2011), this sector is a **medium-low technological intensity sector**. According to the type of subsector its features may vary. For example, if it is the **moulds sector**, its **products are complex with standardized geometries, high quality and follow a model of customized production.** On the other hand, if it is the **metalworking sector**, its **products are simple with standardized geometries, medium quality** and follow a model of **mass production**.

- **Manufacture of other porcelain and ceramic products, non-refractory - NACE 234**

In 2020, the Portuguese ceramics sector accounted for **914 companies which employed 13.2 thousand people**. This subsector represents 30,6% of the labour force in NACE 23 and more than 85% of the companies have between 1 and 9 workers. The GVA share (1,3%) in total GVA of Manufacturing industries is the highest in Europe, followed by Poland (0,5%) and Hungary and Romania (0,3%). It has also the highest **share of employment (1,8%) in total employment of Manufacturing** industries in all Europe, followed by Hungary (0,6%) and Poland and Romania (0,5%). The Portuguese ceramics sector, in 2020, had a share of exports in the total Portuguese exports of 0,8% with around 55% of its exports to Europe.

According to OCDE (2011), the ceramics sector is a **medium-low technological intensity sector**. Its products may **vary from very simple, standardized geometries, low quality** and follow a model of **mass production** or to **very complex and tailored geometries, high quality with a model of customized production.**

[20] Structural Business statistics (EUROSTAT)

## 4.4. Role of public policies in these sectors

There are in place some European and national policies to support industry 4.0 in the chosen sectors. At the European level, the European Commission has set as one of its priorities the creation of a Digital Single Market (DSM). The DSM "is one in which the free movement of goods, persons, services and capital is ensured and citizens and businesses can enjoy access to and exercise online activities in a transparent manner, under conditions of fair competition and with a high level of consumer and personal data protection, regardless of their nationality or place of residence" (COM(2015) 192)[21]. The Strategy for the DSM was built on three pillars: improving access for consumers and businesses to digital goods and services across Europe; creating the right conditions for the development of digital networks and services (infrastructure and regulation); optimising the growth potential of the European Digital Economy (investing in infrastructure, research, innovation, inclusion and skills).

As in Europe, also in Portugal, the policy oriented towards the digital economy is relatively recent. In fact, under the **Technological Plan** launched in **2005**, which materialized the governmental agenda to improve the competitive capacity of the Portuguese economy, with measures promoting knowledge, technology and innovation, the **Digital Agenda 2015** (RCM nº225/2010) was created in **2010**. This Digital Agenda was based on five lines of action: new generation network, better governance, education of excellence, proximity health and intelligent mobility. These lines of action were intended to respond to the digitalisation challenges the country was facing at that time. However, given the strong development dynamics of the digitalisation of economies and the focus of the Digital Agenda 2015 being restricted to the public sector (it did not involve the private sector or civil society) and having a very restricted scope, in **2012**, the Government launched the **Portugal Digital Agenda** (RCM nº112/2012), composed of six areas of intervention, aligned with the priorities of the Digital Agenda for Europe: access to broadband and the digital market; investment in R&D and innovation; better digital literacy, skills and inclusion; combating tax, contribution and benefit fraud and evasion; responding to societal challenges; entrepreneurship and internationalisation of the ICT sector.

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[21] COM(2015) 192 final "A Digital Single Market Strategy for Europe", European Commission

To align this strategy with the time horizon of funding instruments between 2014-2020, the first **amendment of the Portugal Digital Agenda** was made in **2015.** Besides updating the deadlines for the measures proposed in the initial version, some measures were reformulated to ensure a deeper alignment with other government strategies (e.g. Agenda for the Competitiveness of Commerce, Services and Catering 2014-2020). This update sets and confirms ambitious goals and objectives, maintaining a strong commitment, public and private, oriented to put Portugal at the forefront of the Digital Economy in the European Union.

Despite being in an intermediate position in the DESI 2017 (Digital Economy& Society Index), Portugal presents important weaknesses in the field of human capital in ICT. Thus, in response to this weakness, and in line with the trends noted above in terms of digitalisation and the growing dynamics of the penetration of digital technologies in economic activities, the Government launched the program **Portugal INCoDe.2030, in 2017**, aiming to address three major challenges generalise digital literacy, with a view to the full exercise of citizenship and inclusion in a society with increasingly dematerialised practices; stimulate employability, professional training and specialisation in digital technologies and applications; guarantee strong participation in international R&D networks and production of new knowledge in digital areas. The measures that make up the program are structured around five main axes of action, whose logic of organisation is related to the level of skills they aim to achieve. With this program the intention was to position Portugal and the Portuguese in the top group of European countries in terms of digital skills[22].

Also aligned with the European strategy, the government commitment to the digitalisation of the economy and society of Portugal is materialized in **The Portugal Industry 4.0 initiative**. This initiative is the umbrella and most comprehensive public policy instrument, which was developed in a participatory way, between **2016** and 2017, with several key actors (including more than 100 relevant entrepreneurs and institutions) in the process of digitalisation of the economy, mainly of some sectors central to the specialisation profile of the Portuguese economy and its regions, namely fashion & retail, automotive, tourism and agro-food. In **2017**, the Portuguese Industry 4.0 initiative emerges, therefore, as a way to boost the conditions for the development of national industry and services according to the basic principles, technologies and knowledge of the digital economy model that will mark the so-called fourth industrial revolution.

[22] INCoDe2030. Available online: https://www.incode2030.gov.pt/ (accessed on 31 May 2021)

In the scope of this initiative, the needs of the Portuguese business fabric were identified and measures were proposed (of public and private nature) in order to achieve three main objectives: accelerate the adoption of the technologies and concepts of Industry 4.0 in the Portuguese business fabric; promote Portuguese technological companies at an international level; turn Portugal into an attractive pole at an international level for investment in the Industry 4.0 context.

According to the Portuguese Agency for Innovation and Small and Medium Enterprises (IAPMEI) website, the Industry 4.0 initiative is integrated in the National Strategy for the Digitization of the Economy, with the objective of generating favorable conditions for the development of national industry and services in the new paradigm of the digital economy. It was organized in two stages. **Phase 1, from 2017 to 2019**, was above all demonstrative and mobilizing and was based on six priority areas of action: human resources training, technological cooperation, creation of the startup I 4.0, financing, investment support, internationalization, and legal and regulatory adaptation[23]. **Phase II, from 2019 to 2021**, intended to be transformative and it was estimated that public and private investments would mobilize the amount of EUR 600 million over two years, involving 20,000 companies in the various initiatives, training more than 200,000 workers, and financing more than 350 transformational projects[24].

The implementation strategy covered various sectors of activity and included nine lines of funding and credit, aimed especially at SMEs, new sector clusters, specialised courses, consortia and incubators born from business partnerships, as well as the promise of international showcases to promote Portuguese technology companies worldwide. The range of 60 measures that constitute this initiative, would impact over 50 thousand companies operating in Portugal and would allow training over 20 thousand workers for the digital economy. The injection of about 4.5 billion euros in the economy, of which 2.26 billion euros would be guaranteed by the European Structural and Investment Funds through Portugal 2020 (e.g. industry 4.0 R&D vouchers, manufacturing production systems transformation incentives, and infrastructure update incentives)[25] foresaw the awareness, adoption and massification of technologies associated with the concept of Industry 4.0 in the following 4 years. Thus, measures were also created to encourage the participation of

[23] IAPMEI. Available online: https://www.iapmei.pt/Paginas/Industria-4-0.aspx (accessed on 31 May 2021)

[24] IAPMEI. Available online: https://www.iapmei.pt/Paginas/Industria-4-0-Fase-II.aspx (accessed on 31 May 2021)

[25] IAPMEI. Available online: https://www.iapmei.pt/PRODUTOS-E-SERVICOS/Incentivos-Financiamento/Sistemas-de-Incentivos/Arquivo/Incentivos-Portugal-2020/Industria-4-0.aspx (accessed on 23rd April 2023)

the initiative's stakeholders in standardisation activities and the development of the national regulatory framework.

In **2020**, a global strategic vision for the digital transition was defined, which, with a transversal approach, identifies the main challenges of the Portuguese society and materialises the operationalisation of policies in this area. In this context, a new national institutional framework for digital transformation was created for companies, the Public Administration and citizens in general, embodied in the new **Action Plan for Digital Transition**, with the purpose of accelerating Portugal, without leaving anyone behind, and projecting the country in the world. The Action Plan for Digital Transition, approved through the RCM no. 30/2020 of 21st April, reflects the strategy defined for the digital transition and condenses the Government's vision in this domain, materialised in a structure that contemplates three main pillars of action: Pillar I - Empowerment and digital inclusion of people; Pillar II - Digital transformation of the business fabric; Pillar III - Digitalisation of the State, as well as an additional dimension of catalysing that creates the basic conditions for an accelerated digitalisation of the country[26].

These measures are considered, at this date, essential for the digital transition and, considering their quantity and diversity, as well as the complexity associated with their implementation, coordination and monitoring, the follow-up of the Action Plan for Digital Transition will be ensured by the Portugal Digital Mission Structure and groups all policies and strategies for digital transition (e.g., InCoDe.2030, I4.0, etc.) under the same framework program which has been funded through the European Regional and Development Fund (ERDF) - Portugal 2020, the Recovery and Resilience Fund (RRF) - Recuperar Portugal and future ERDF - Portugal 2030..

Especially relevant for the chosen manufacturing industries (Automotive, Ceramics and Metallic products) are some measures under the i4.0 program of the Action Plan for the Digital Transition, namely under the Capacitar i4.0 program which has the following objectives[27]:

- Promote a **network of i4.0 academies** in companies that develop qualification plans for their active employees in response to the challenges of the 4th Industrial Revolution, in the fields of "knowing-knowing", "knowing-being" and "knowing-doing", reducing set-up times at the start of a new function and increasing the efficiency of the person and the company, as well as the quality of the product or service;

[26] Available online: https://www.portugal.gov.pt/gc22/portugal-digital/plano-de-acao-para-a-transicao-digital-pdf.aspx (accessed on the 23rd of April 2023)

[27] IAPMEI. Available online: https://www.iapmei.pt/getattachment/PRODUTOS-E-SERVICOS/Industria-e-Sustentabilidade/Transformacao-digital/InCoDe-2030/Capacitar-i4-0/Capacitar-i4-0-(1).pdf.aspx (accessed on the 23rd of April 2023)

- Fostering and enabling the development of **learning factories in i4.0 academies**, as demonstrators of innovative technologies, processes, operations and methodologies;
- Boost the **hiring of researchers in critical i4.0 areas** to ensure technical and scientific excellence in i4.0 academies;
- Stimulating inter-company actions promoted by entities in the business environment and qualification centres with proven experience in providing individual and collective training services for people, which contribute to the development of digital competences;
- To create and test instruments for **assessing the maturity of companies** faced with the challenges of Industry 4.0

Some initiatives funded by RRF under C16 – Companies 4.0 are[28]:

- **Digital Jobs + 2025** - training programme in digital technologies that aims to respond to the challenges and opportunities of various business sectors, namely **industry**, commerce, services, tourism and agriculture, the sea economy and construction, sectors strongly impacted by digital transformation processes and the COVID-19 pandemic. This program is a specialization strand of the "Portugal Digital Academy" operationalizing the training in a face-to-face and blended learning format. It is aimed at company workers regardless of their level of digital skills, and should contribute to improving them in alignment with the specific needs of the business sector and the business area where they currently operate. This initiative will be developed in close articulation with business confederations and associations and it is expected to reach 800,000 trainees with digital skills diagnostics, individual training plans and access to online training, of which 200,000 will cumulatively attend face-to-face or blended training.

- Transformation of Portuguese SMEs' business models and their digitalisation, aiming at greater competitiveness and resilience. It integrates the promotion of business digitalisation through the acceleration and automation of decision-making and execution based on artificial intelligence, the redesign of value and supply chains, optimising speed and resilience and the use of cross-sector data spaces, supported by European cloud infrastructures and edge computing, innovative, secure and energy efficient, providing companies with a repositioning of their business in a digitally advanced ecosystem. It encompasses the **National Network of Test Beds**, among others; a national network of test beds through infrastructures that aim to create the necessary conditions for companies to develop and test new products and services, and to accelerate the digital transition process, either via a physical space or a virtual simulator;

[28] Recuperar Portugal. Available online: https://recuperarportugal.gov.pt/2021/06/13/investimento-td-c16-i01/ (accessed on 26th April 2023)

- **Digital Innovation Hubs** - the DIH are structures that aim to centralize a set of services to support the digital transition of companies, in more accessible conditions, focusing this process in three disruptive technologies: AI, HPC and Cybersecurity. This programme aims to expand and develop a national network of DIH, reinforcing the investment foreseen, complementing the one already under development under the Digital Europe Programme (DEP) in order to reach a total of 126 additional hubs, thus allowing to increase the coverage of a more comprehensive number of clusters and regions covered by the programme and strongly stimulating collaboration and technology-based innovation;

Finally, very recently (of 20th of April 2023), as a novelty introduced with the reprogramming of the Portuguese RRP, 60 million € will go for Industry 4.0 Projects as a new complementary support measure to be introduced in the component 16 Companies 4.0[29].

The new measure aims to support investment projects in Industry 4.0 technologies with a grant of up to €200,000, contributing to **organizational and process innovation** in more than 200 Small and Medium Enterprises (SMEs), aimed at the implementation of technological solutions that fall within at least one of the following areas of action:

- Digital transformation of operational processes including production and logistics management and planning;
- Solutions for storage, management and advanced data processing;
- Artificial intelligence solutions applied to the productive process;
- Digital twins (new digital models), simulation, and industrial modelling;
- Design and additive manufacturing;
- Augmented reality, virtual reality and artificial vision applied to processes;
- Collaborative and cognitive robotics, human-machine interface, cyber-physical systems;
- Sensing and advanced electronics, IoT, Cloud and Edge solutions;
- Networking, communication, and advanced computing infrastructures associated with processes;
- Innovative software, interoperability of systems.

[29] Recuperar Portugal [Recover Portugal]. Available online: https://recuperarportugal.gov.pt/2023/04/21/60-milhoes-de-euros-do-prr-para-projetos-para-industria-4-0/ (accessed on 29th April 2023)

Although not specific for the manufacturing Industrial sector or AI-based automation systems adoption in the shop floor, but also relevant to accelerate digital transition in this regard, are other initiatives[30] such as:

- **Digital Maturity Assessment:** Considering that the digital transformation of an organization is a journey, an ongoing process that requires vision, knowledge, strategy, best practices, and digital technologies, knowing where to start or which priorities to focus on in the future is not always obvious. That's why it's important to know the business' current level of digital maturity, understand the organization's digital potential, and define its priorities. To support this activity, self-diagnosis instruments (eg. Theia and Shift to Future 2) were developed based on brief and easy-to-answer questionnaires, covering several layers of analysis. After completing the self-diagnosis, the organization will receive its corresponding level of digital maturity, as well as a set of recommendations for defining objectives and priorities.

- **UPSKILL -** It is a professional requalification program in digital technologies aimed at unemployed or underemployed people, providing them with intensive training in higher education institutions, and subsequent integration in the labor market. What sets this program apart is that the training content, location and number of trainees are defined by companies according to their needs, easing employability at the end of the training. Main benefits expected from this program are the retraining of people from other fields into ICT professionals; investing in qualified work with better pay and strong employability and meeting businesses' specific hiring needs.

- **Technological Free Zones | ZLT -** It is a "safe space" where companies can test innovative products, services, business models, and delivery mechanisms without immediately incurring all the normal regulatory consequences related to the activity in question. They are intended to allow testing and experimentation in a real or near real environment, with direct and permanent control by the competent regulatory authorities, particularly in terms of testing, provision of information, guidelines, and recommendations, corresponding to the concept of regulatory sandboxes. The goal is to take advantage of all the opportunities brought by new technologies, namely: **Artificial Intelligence**; Blockchain, Robotics, Internet of Things, Big Data, 5G Network, etc.

[30] https://portugaldigital.gov.pt/en/accelerating-digital-transition-in-portugal/corporate-incentive-systems/

## 4.5. AI technologies used in Portugal

To understand how are AI technologies being used in the production systems in Portugal the recent developments of investment on robotics and on numeric controlled machine tools are analysed. This type of equipment is programable and the technological development have implied elements of AI, namely machine learning, sensors and, more recently, use of internet of things.

### 4.5.1. Robots under operation and trends

In previous chapters, it was defined that most of the machinery that requires programming procedures have elements of AI technology. In this sense, AI-enabled automation systems have been introduced in the manufacturing industry infrastructures with some delay comparatively to other European countries (figure 24). According to Figure 24, it seems that the investment trend on robots encompasses economic environment issues, but there is quick reaction, as can be observed. In 2020 there was a decrease in the percentage growth for Asia (-8%, or –6 thousand installations) and America (-17%, or –8 thousand installations), but in the following year there was a quick recovery.

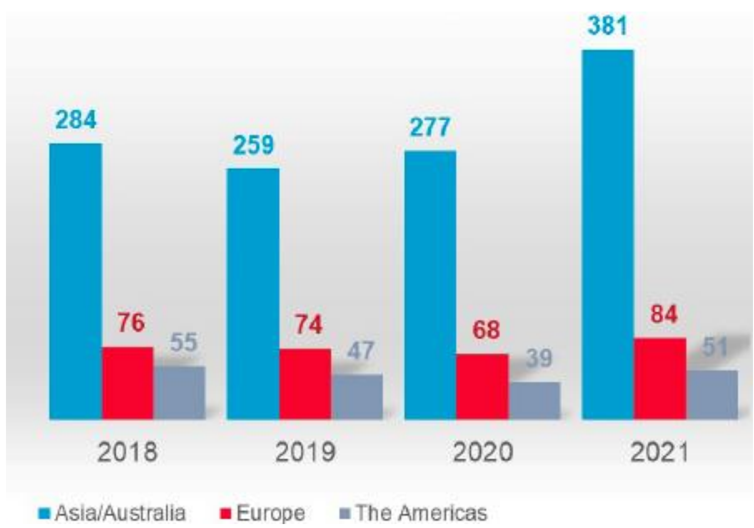


Figure 24 - Annual installations of industrial robots by world region, thousand units
Source: IFR

The difference in the fields of application of almost all industrial robots is based most exclusively on their terminal elements and, logically, on their programming. In Figure 25, it can be observed that the Automotive sector, in 2019, was the sector with the biggest number of industrial robots, followed by the electrical/electronics sector and by the metal and machinery sector. However, although all sectors showed an increase on the number of industrial robots until 2021, in this year the electrical/electronics sector have been the sector with the most industrial robots, surpassing the automotive sector. This is probably related with the pandemics crisis and semiconductors shortage which affected strongly the Automotive sector.

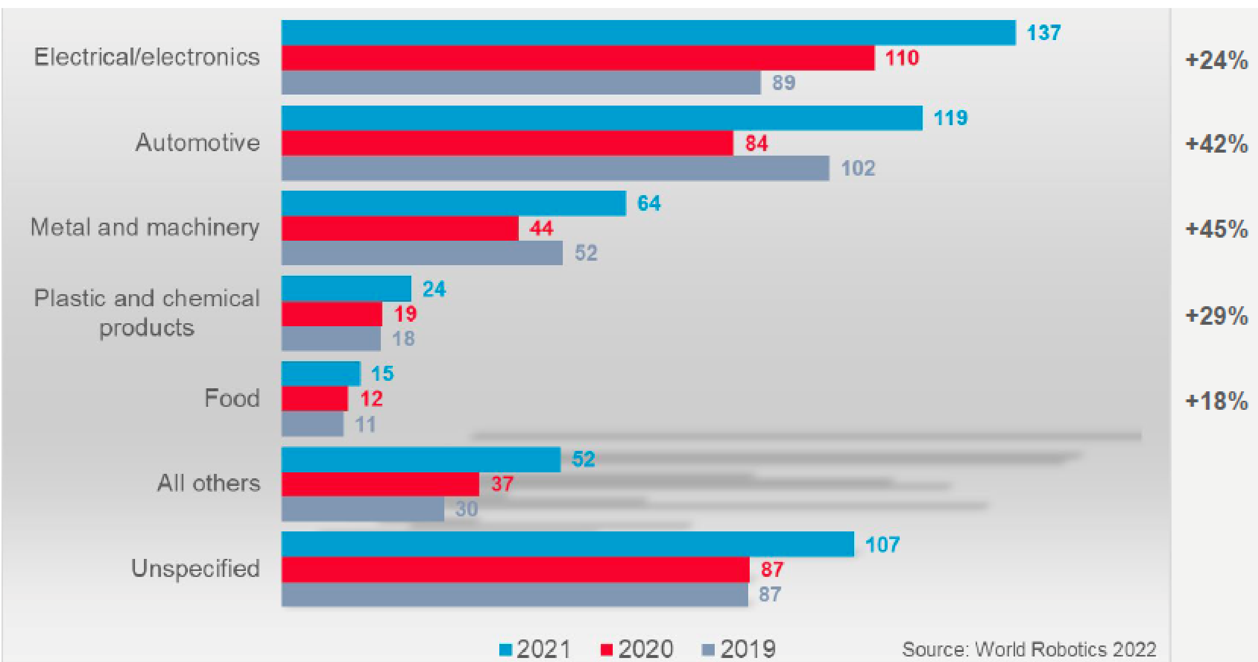


Figure 25 - Annual installations of industrial robots by industrial sector (world total), thousand units. Source: IFR

AI-enabled automation systems, such as industrial robots, are covering several areas of applications (figure 26). Industrial robots are used the most in handling, followed by welding and the least used is in processing.

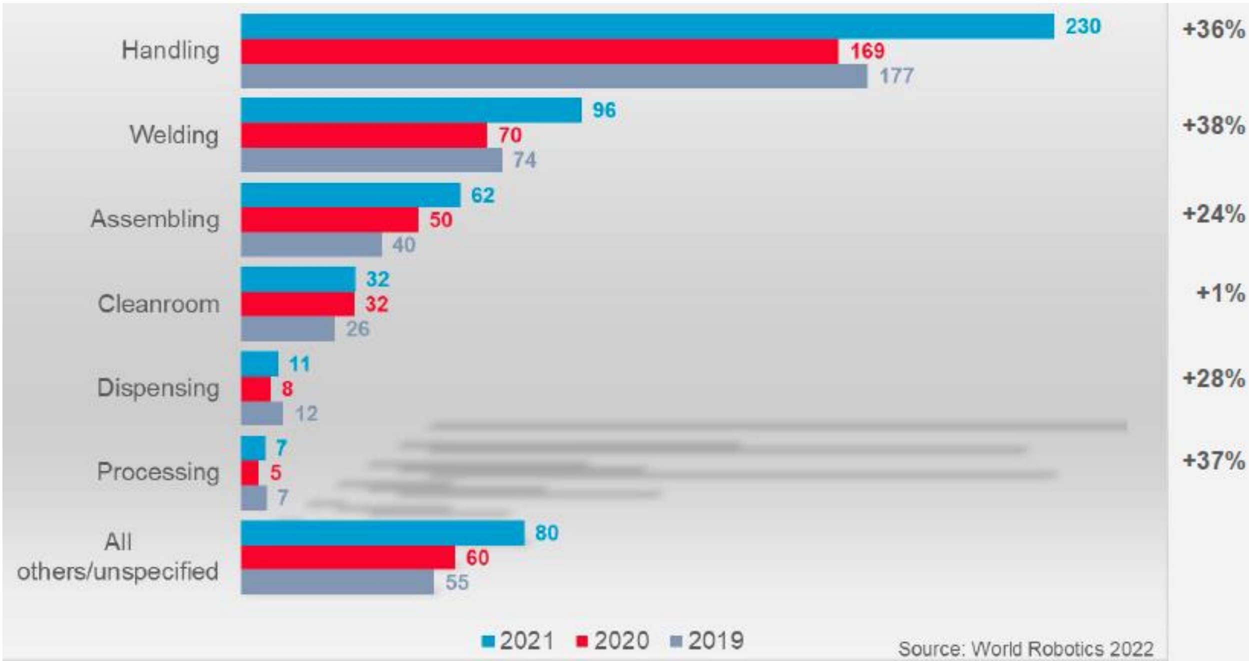


Figure 26 - Annual installations of industrial robots by application (world total), thousand units.
Souce: IFR

On the Portuguese case, there is not information on the most recent years. However, as mentioned by the ILO report on the future of work in Portugal, "the number of industrial robots has increased steadily, from 695 units in 2010 to 2,191 units in 2017 (Nunes Bentes de Jesus 2019; IFR 2021)" (ILO, 2022: 46). In this same report there are even some concrete numbers presented (table 3):

Table 3 - Number of industrial robots in the automotive sector, Portugal, 2007–2017

| | 2007 | 2008 | 2009 | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 | 2016 | 2017 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Automotive | 484 | 518 | 614 | 695 | 781 | 930 | 1,012 | 1,172 | 1,410 | 1,948 | 2,191 |
| Motor vehicles | 99 | 115 | 121 | 130 | 131 | 142 | 151 | 205 | 278 | 423 | 443 |
| Parts and accessories for motor vehicles | 240 | 258 | 348 | 420 | 505 | 643 | 716 | 822 | 987 | 1,525 | 1,748 |
| Electrical and electronic equipment | 0 | 0 | 18 | 65 | 145 | 233 | 247 | 274 | 348 | 465 | 617 |
| Other parts and accessories | 0 | 0 | 19 | 37 | 42 | 53 | 65 | 124 | 176 | 266 | 358 |

**Source** *Adapted from Nunes Bentes de Jesus (2019); IFR (2021).*

Although these figures should be confirmed, it seems that the recent years had a steady increase. But the concrete evolution is not accurate. Both quoted sources do not make any evidence on how data was collected (ILO report and J. Jesus MSc dissertation). Both mention IFR figures, but this source did not publish the methodological approach for the Portuguese case.

The following table 4 provides the IFR on the operational stock of industrial robots in the different sectors in Portugal.

Table 4 - Operation stock of industrial robots, Portugal, IFR (2007-2017)

| IFR Class | Categories, divisions and classes of economic activities, ISIC, rev. 4 | 2007 | 2008 | 2009 | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 | 2016 | 2017 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| A-B | Agriculture, Hunting, Forestry; fishing | 0 | 0 | 0 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| C | Mining and quarrying | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| D | Manufacturing | 816 | 1001 | 1221 | 1462 | 1654 | 1914 | 2135 | 2457 | 2832 | 3606 | 4154 |
| 10-12 | Food products and beverages; Tobacco products | 9 | 18 | 53 | 72 | 85 | 94 | 119 | 149 | 156 | 168 | 199 |
| 13-15 | Textiles, leather, wearing apparel | 0 | 0 | 0 | 0 | 0 | 0 | 3 | 6 | 6 | 7 | 7 |
| 16 | Wood and wood products (incl. furniture) | 1 | 1 | 1 | 10 | 11 | 11 | 16 | 18 | 25 | 26 | 29 |
| 17-18 | Paper and paper products, publishing & printing | 0 | 0 | 5 | 5 | 21 | 21 | 21 | 21 | 21 | 23 | 60 |
| 19-22 | Plastic and chemical products | 56 | 74 | 90 | 97 | 110 | 125 | 143 | 204 | 255 | 343 | 454 |
| 19 | Chemical products, pharmaceuticals, cosmetics | 3 | 5 | 5 | 5 | 6 | 6 | 8 | 10 | 10 | 12 | 12 |
| 20-21 | Unspecified chemical, petrolium products | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 4 | 4 | 4 |
| 22 | Rubber and plastic products without automotive parts | 53 | 69 | 85 | 92 | 104 | 119 | 135 | 194 | 241 | 327 | 438 |
| 229 | Chemical products unspecified | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 23 | Glass, ceramics, stone, mineral products n.e.c. (without automotive parts) | 1 | 1 | 7 | 7 | 7 | 9 | 15 | 15 | 15 | 18 | 20 |
| 24-28 | Metal | 250 | 365 | 400 | 515 | 561 | 631 | 711 | 771 | 824 | 943 | 1045 |
| 24 | Basic metals (iron, steel, aluminium, copper, chrome) | 12 | 12 | 20 | 22 | 22 | 25 | 34 | 34 | 38 | 38 | 74 |
| 25 | Metal products (without automotive parts*), except machinery and equipment | 229 | 330 | 345 | 454 | 491 | 557 | 617 | 660 | 693 | 799 | 858 |
| 28 | Industrial machinery | 9 | 23 | 35 | 39 | 48 | 49 | 60 | 77 | 93 | 106 | 113 |
| 289 | Metal unspecified | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 26-27 | Electrical/electronics | 8 | 16 | 39 | 44 | 48 | 52 | 54 | 59 | 65 | 67 | 65 |
| 275 | Household/domestic appliances | 8 | 8 | 28 | 31 | 31 | 31 | 31 | 31 | 31 | 31 | 23 |
| 271 | Electrical machinery and apparatus n.e.c. (without automotive parts) | 0 | 0 | 3 | 4 | 7 | 8 | 8 | 8 | 13 | 13 | 15 |
| 260 | Electronic components/devices | 0 | 8 | 8 | 8 | 8 | 9 | 11 | 12 | 12 | 12 | 14 |
| 261 | Semiconductors, LCD, LED (incl solar cells and solar thermal collectors) | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 1 |
| 262 | Computers and peripheral equipment | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 263 | Info communication equipment domestic and professional without automotive parts | 0 | 0 | 0 | 0 | 0 | 2 | 2 | 6 | 7 | 7 | 9 |
| 265 | Medica, precision and optical instruments | 0 | 0 | 0 | 1 | 2 | 2 | 2 | 2 | 2 | 3 | 3 |
| 279 | Electrical machinery unspecified | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 29 | Automotive | 484 | 518 | 614 | 695 | 781 | 930 | 1012 | 1172 | 1410 | 1948 | 2191 |
| 291 | Motor vehicles, motor vehicle engines and bodies | 99 | 115 | 121 | 130 | 131 | 142 | 151 | 206 | 278 | 423 | 443 |
| 293 | Parts and accessories for motal vehicles: | 240 | 258 | 348 | 420 | 505 | 643 | 716 | 822 | 987 | 1525 | 1748 |
| 2931 | Metal prodcuts | 0 | 0 | 18 | 65 | 145 | 233 | 247 | 274 | 348 | 465 | 617 |
| 2932 | Rubber and plastic | 0 | 0 | 19 | 37 | 42 | 53 | 65 | 124 | 176 | 266 | 358 |
| 2933 | Electrical/electronics | 0 | 0 | 53 | 58 | 58 | 59 | 65 | 73 | 77 | 77 | 85 |
| 2934 | Glass | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 2939 | Other | 0 | 0 | 0 | 0 | 0 | 28 | 60 | 72 | 107 | 140 | 442 |
| 2999 | Parts and accessories unspecified | 240 | 258 | 258 | 260 | 260 | 270 | 279 | 279 | 279 | 577 | 246 |
| 299 | Automotive unspecified | 145 | 145 | 145 | 145 | 145 | 145 | 145 | 145 | 145 | 0 | 0 |
| 30 | Other Transport equipment | 1 | 1 | 5 | 7 | 7 | 8 | 8 | 8 | 8 | 8 | 8 |
| 91 | All other manufacturing branches | 6 | 7 | 7 | 10 | 23 | 33 | 33 | 34 | 47 | 55 | 76 |
| E | Electricity, Gas and Water Supply | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 1 | 1 |
| F | Construction | 0 | 0 | 29 | 30 | 30 | 30 | 30 | 32 | 35 | 39 | 39 |
| P | Education, research and development | 3 | 3 | 10 | 13 | 14 | 16 | 18 | 21 | 22 | 23 | 23 |
| 90 | All other non-manufacturing branches | 0 | 0 | 0 | 0 | 0 | 0 | 4 | 4 | 4 | 4 | 4 |
| 99 | Unspecified | 1073 | 986 | 884 | 774 | 673 | 563 | 478 | 354 | 265 | 268 | 400 |
| | TOTAL | 1892 | 1990 | 2144 | 2280 | 2372 | 2524 | 2666 | 2870 | 3160 | 3942 | 4622 |

The large number of industrial robots are, in Portugal, under operation in the manufacturing sector (4156 from a total 4622, for 2017, which represents 90%). In this industry, major sectors that use robots are the automotive (2191) and metal sector (1045).

Despite a high initial cost, automated systems and, in particular, robots, can represent a cost saving considering comparable units of time. However, despite this trend towards cost reduction driven by technology, the relationship it may have on productivity is still a matter of controversy.

Another argument that justifies the investment on robotics is the increase in the cost of human labor. The processes of organizational innovation that took place in Scandinavia in the 1960s and 1970s were due to two types of reasons:

1) in the postwar period, the younger population entering the labor market was more educated. Therefore, the demands on the need to change the work content were higher. And at that time, these demands were parallel to those of salary increase and decrease in the number of weekly working hours;
2) levels of productivity and quality should increase in order to keep the sustainability of the economic model of social democratic policies. With labor costs rising and with the need to maintain or increase productivity levels, social agreements were established between the various social partners. Entrepreneurs and large public companies have found solutions to this problem with increased investment in technology and organizational development (cf. Moniz, 2018: 53-54). However, this pressure of higher labour costs is not a criterion for capital investment in Portugal.

### 4.5.2. NC machine tools under operation and trends

Portugal produces machine tools but is a minor player in this field. The Portuguese manufacturing industry is basically a “consumer” of machine tools, and the industrial automation in this country was done around the capacity building with the numeric controlled (NC) machine tools.

On NC machine tools, the data produced by CECIMO, once it is the European Association of the Machine Tool Industries and related Manufacturing Technologies, was used. This organization brings together 15 national associations of machine tool builders, which represents, approximately, 1500 industrial enterprises in Europe (EU + UK+ EFTA + Turkey), over 80% of which are SMEs. CECIMO covers 98% of the total machine tool production in Europe and about 1/3 worldwide. According to Figure 27, with a share of 39.8%, Germany remains the largest CECIMO MT producer, closely followed by Italy (25.2%) and Switzerland (10.0%). As in previous years, these three countries represent over three-quarters of CECIMO's production.

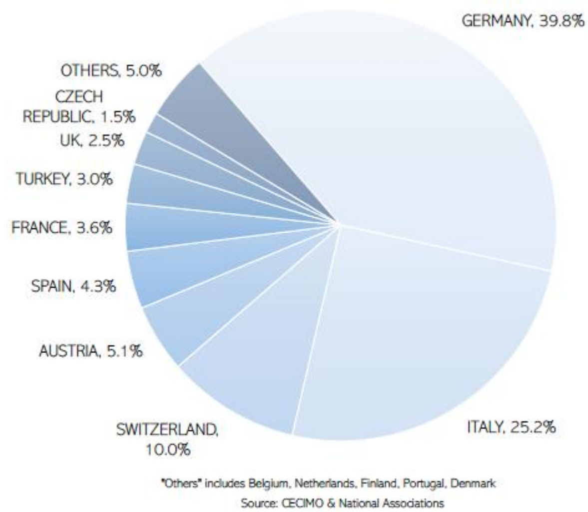


Figure 27 - CECIMO machine tool (MT) Production shares 2021.
Source: CECIMO.

Although at a lower level, the CECIMO countries retained the largest market share, representing around 31% of the world share. Behind the CECIMO countries, China tops the list (30%), followed by Japan (12%), the United States (9%), South Korea (5%) and the Taiwan Region (4%) (figure 28).

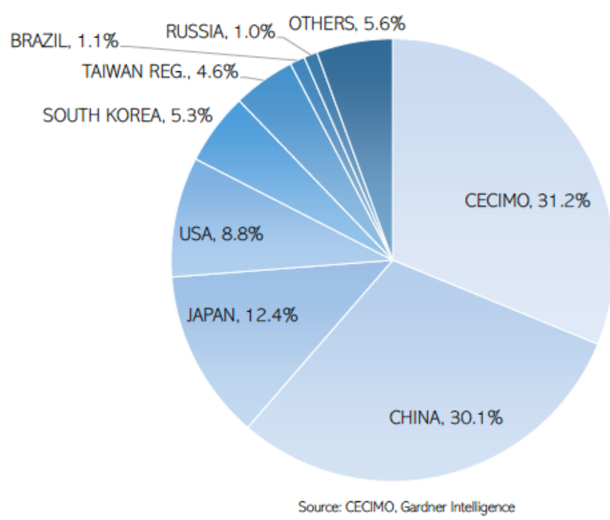


Figure 28 - Global MT Market share 2021.
Source: CECIMO.

On the recent trends for the automotive industry, it is interesting to register the CECIMO forecasts of investment on machine-tools. This European association mentions that "for global industry and MT's major purchasing sectors, the highest rate of production growth in 2023 is expected to be in the aerospace and motor vehicle (automotive) sectors". It is important to highlight that Oxford Economics has updated its forecasting methodology to better reflect the impact of rising EV and hybrid penetration rates on MT demand. According to the new methodology, MT demand intensity across three different powertrains is more accurately accounted for and the analysis shows that building hybrid vehicles requires a 5.5% increase in MT investments compared to ICE vehicles while building EV vehicles requires a 38.5% decrease in MT investments compared to ICE vehicles" (CECIMO, 2022: 12). The reference to CECIMO means that only Austria, UK, Germany, France, Italy Czech Republic, Switzerland and Spain are the considered countries for these calculations (figure 29).

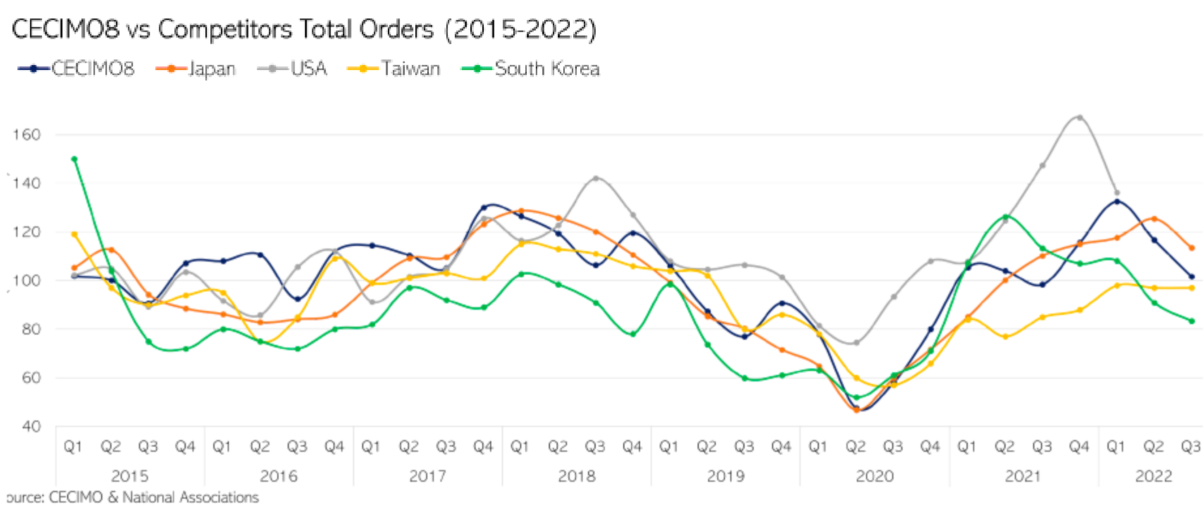


Figure 29 - Recent evolution of machine-tool (MT) new orders, thousand.
Source: CECIMO.

CECIMO comments on these trends referring that "even if the severity of a crisis depends on several quite unpredictable factors, in the economic commentary, HPO emphasized some indications on the duration of the next crisis by analysing past crises. Based on the HPO analysis (figure 30), the average duration from a high to low crisis point is between 1.7 and 2.8 years. Returns are much more variable, from 1.8 years to 8.8 years after the financial crisis" (CECIMO, 2022: 12).

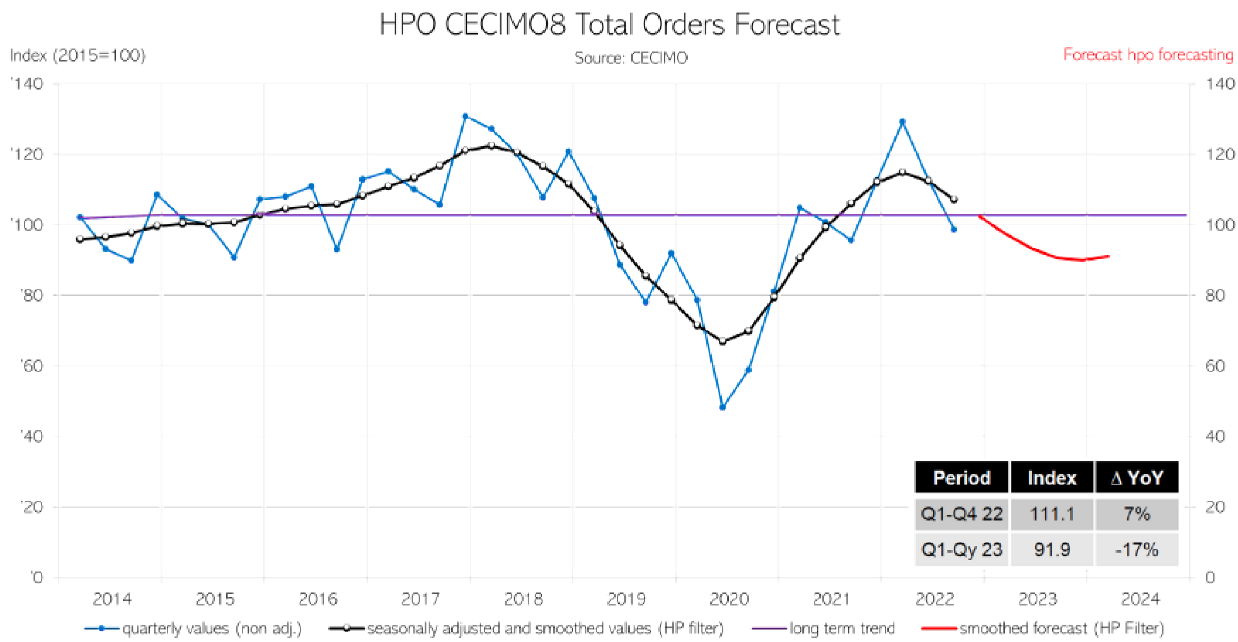


Figure 30 - CECIMO Orders Forecast.
Source: CECIMO.

On effect of the investment on machine-tools is the accomplishment of production capacity. In other words, when this capacity decreases, the order for new machines increases. The following figure 31 is very explicit on this variation.

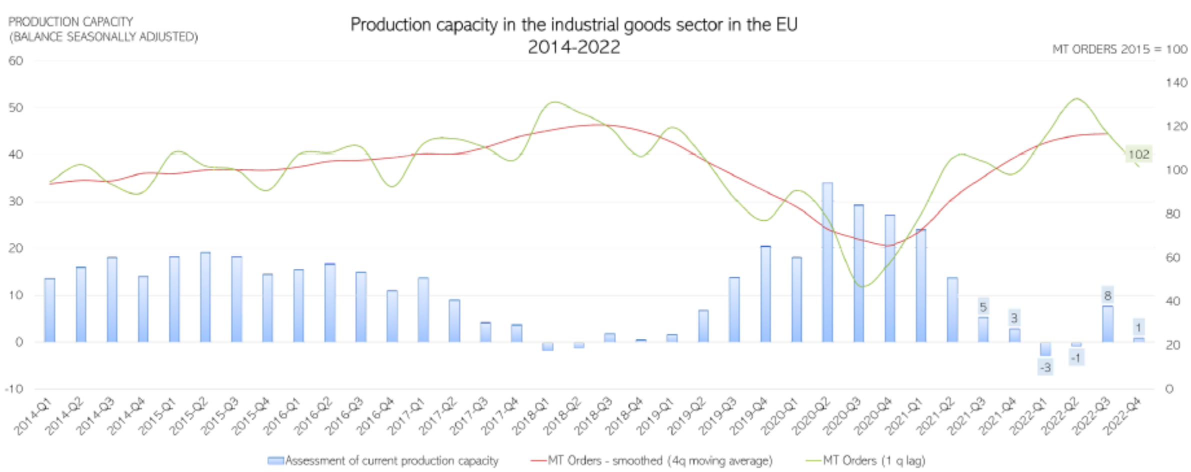


Figure 31 – Production capacity in the industrial goods sector in the EU (2014-2022).
Source: CECIMO.

The CECIMO report reveals that “the fourth quarter of 2022 brings the level of spare capacity in the EU's industrial goods sector to close to zero. Although this level of spare capacity is not in line with current trends in CECIMO total orders, it is important to note that many manufacturers, including MT manufacturers, are still in the process of resolving order backlogs from the previous period” (CECIMO, 2022: 16).

Thus, after the 2008 financial crisis, the Covid19 pandemics played an important role on the decrease of MT orders. The same happens with the Ukraine war (from Q2 of 2022). From the previous figure it can also be concluded that, when the production capacity increases, the MT orders also increase with a delay of about one year. For example, there was an accentuated decrease from 2017-Q1, and the 2018-Q1 represented a last peak for MT orders (figure 26).

What may be conclude about these trends? First, the variation of production capacity does not depend only on the available machinery. Second, the prognosis for medium-long term (5 to 10 years) have to consider potential “wild cards”. These ones were, for the last years, represented as health pandemics, war conflicts, with consequences on energy supplies shortages, economic tensions, inflation, and major uncertainties. Probably, the investment on MT trends reveals more clearly these problems than the case of other technologies.

## 4.6. And, what about the Industry 4.0 in Portugal?

The introduction of the concept Industry 4.0 in Portugal is expected to be highly permeable in at least two parts of the economy. First, the high and medium-high intensive manufacturing sectors - responsible for 37% of the value of the exports goods in 2015 (Eurostat) - are naturally more prone to endogenize technologies that could improve production. The exposition of these companies to German production systems and globalized competitive markets is significant because they are under the influence or control of multinationals (many of German origin) and/or are considerably oriented to export. Second, the energy sector is capital and technology intensive with low levels of employment and was responsible for 3% of the GDP in 2014 (OECD STAN). Here, technologies that can contribute to improve efficiency are hypothetically rapidly endogenized with new digital systems. The efficient and relatively emerging sector of wind energy, for example, is significantly controlled by foreign capital (German, Chinese and Spanish), supposedly able to assimilate Industry 4.0 technologies.

Problems still persists in the Portuguese manufacturing system. In the COTEC report on Industry 4.0 process, mentioned that "a much-discussed characteristic of Industry 4.0 is the promise of cost reduction and greater efficiency through much tighter supply chain integration. This raises two challenges. Firstly, the need to integrate the company's processes internally first, which by itself requires substantial effort. This means to complete the "Industry 3.0" transition before moving to 4.0. A more structural second problem is that few customer relations are ready or stable enough to implement the level of potential integration. The necessary standards are not in place to be able to integrate flexibly with multiple customers, so it will initially need to be built on stable long-term relationships" (COTEC, 2017: 18).

On technology transition, the limits are still evident in Portugal. The investment on Industry 4.0 concept seems not to be a clear technology change: "This is basically an issue of educating the people, not capital investment", continues the COTEC report. "Most big short-term investment decisions that were mentioned by interviewees concerned buildings, integration programs – not specifically new Industry 4.0 technology. For example, interviewees mentioned experimentation with additive manufacturing (3D printing), but mostly for niche or prototype application – general manufacturing is still through injection moulding; so, no displacement of core process. 'It is really a continuous evolution, that you try to integrate over time. Not a discontinuous revolution'." (COTEC, 2017: 18)

According to COTEC (in the same 2017 report), the reality and the evolution of Portugal in terms of Industry 4.0 was characterized and comparison between Portugal positioning against European peers was performed.

To accomplish this, the i4.0 Index, which is a synthetic index, composed of 8 dimensions, specifically developed with the objective of measuring the basic conditions and the competitiveness of Portuguese SMEs in an Industry 4.0 context, was used.

The performance of 18 European Union countries according to their basic conditions (Readiness) and the competitiveness of SMEs in the i4.0 context (Integration) was assessed with 35 indicators.

According to the i4.0 Index, Portugal belongs to the group of mid-tier countries in terms of performance in the i4.0 context, occupying 12$^{th}$ position. It is closer to the group of lagging countries than to the leading group; - 1.6 points difference regarding the last country of the leading group (United Kingdom) and 0.7 points regarding the first of the lagging group (Italy). (COTEC,

p. 4). The dimensions where it presents a lower ranking, 14th and 12th position in the ranking, respectively, are "i4.0 Technologies" and "Technological and Innovation Ecosystem".

At last, Moniz in his book about Robotics and Work, presents an overview of the technical and sociological debates about the relationship between technology and work, and more specifically about robotics, in Portugal. He uses mainly secondary data analysis (INE-Employment Survey, National Accounts, Enterprise Survey, Personnel Tables-MTSS, PorData, IFR World Robotics) and technological assessment studies to analyse the situation in Portugal (Moniz, 2018).

According to this author, industrial automation is achieving more advanced capabilities that contribute to improved production processes in terms of higher performance levels, better quality standards and greater technical flexibility. However, there are limits in robotics research which can be seen as a problem that will need to be solved, and therefore can simultaneously represent challenges to be overcomed. He assesses that the domain of autonomous robotic systems is a topic that reveals some of these important limits. "We can say that research has clearly developed there, but there are principles and problems of an ethical, legal and social nature that are unresolved" (Moniz, 2018). In the area of industrial applications, the limits mainly concern the interaction individual-robot. These are mainly issues associated with work, and also associated with the perception of the work environment.

Another limit, this one to the diffusion or development of these systems, may arise from the mental load and the complexity of the information to be handled by humans. He also found that the effects on security seem to be the most prominent and that the challenges lie in the sphere of alternatives in terms of work organisation and decision-making processes. He also captures the re-emerging concern related to the growing importance of artificial intelligence and its application to production systems and how questions concerning the potential autonomy of technology in relation to the human arise there. At the end he concludes that "We are still, and for some more years, at the level of speculation and the refinement of scientific hypotheses" (Moniz, 2018: 220-221).

## 4.7. Some preliminary conclusions

From the analysis of the secondary data, it was possible to reach to the following preliminary conclusions. Several statistical indicators (GFCF, Employment, GVA, Productivity, schooling level, etc.) were analysed and it was possible to conclude that the Manufacturing industry was the one with a higher investment in AI-enabled automation systems. It was also the production sector where there was a higher growth in this investment after the economic crisis of 2008. Although it could be observed a growth of investments in automation technologies since 2012, in manufacturing industries, the employment also increased, in line with Acemoglu and Restrepo (2018). According to these authors, this can be explained by the productivity effect of automation technologies, which increases the competitiveness of the companies in these sectors, increasing their market share and thus, needing to hire more employees to respond to the high demand from the market.

Within the manufacturing industries, all of the sectors have undergone an increase on its investments in technologies from 2013, onwards, but, in 2019, before the pandemics, the Automotive sector was the one where this investment was higher, followed by plastics, rubber and non-metallic mineral products production and metalworking sectors. In these same sectors, the number of employees has also increased from 2013, onwards, as well the gross value added and productivity.

In 2020, the economic activities with at least half of its workforce with a schooling level above basic schooling are the sectors of Machines and equipment, Automotive and Plastics, Rubber and non-metallic mineral products. The ones with less low-skilled employees are Automotive and Machines and equipment. At last, regarding the internationalization process, only the automotive sector shows a growth of exports since 2017, and also the metalworking and textiles, clothing and leather sectors since 2019. For the reasons stated above, the industrial sectors chosen to deepen the analysis of the effects of AI-enabled automation in the employment and work were: a) Automotive (manufacturers and components for automotive), b) Metalworking (mouldmaking and metalworking) and c) Plastics, rubber, and non-metallic mineral products (ceramics).

For the sectors chosen, comparison between countries were analysed to understand what the position of Portugal at the macro level is. The R&D intensity of a country depends on its industrial distribution, and there are industrial sectors with high to low technological intensity. Given that different countries, have different industrial structures, to validate the relationship of innovation by AI and the effects at the level of productivity and employment, and be comparable between countries, it is necessary to ensure that the same indicators are used for the same industrial sector (meso level). On the other hand, within the same industrial sector there may be differences at company level, according to their profile, their positioning in the value chain and according to their products (micro level). Therefore, the following features of the different sectors are described:

- **Automotive:** High GFCF, employment followed the increasing trend of GFCF; components subsector representing about 68.4% of the total Portuguese automotive sector; mainly exports (87%), medium-high technological intensity sector; products vary between simple and complex geometries; high quality products, standardized product; mass production model.

- **Metalworking, mouldmaking**: The total share of these sectors in the total of Portuguese exports represents 5,3% and exports go mainly (around 55%) to European countries; moderate GFCF, stable employment, medium-low technological intensity sector; if it is mouldmaking (for plastic injection) sector, its products are complex with some standardized geometries, high quality and follow a model of customized production. On the other hand, if it is metalworking sector, its products are usually simpler with standardized geometries, medium quality and follow a model of mass production.

- **Ceramics:** The GVA share (1,3%) in total GVA of Manufacturing industries is the highest in Europe; it has also the highest share of employment (1,8%) in total employment of Manufacturing industries in all Europe; in 2020, had a share of exports in the total Portuguese exports of 0,8% with around 55% of its exports to Europe; medium-low technological intensity sector; its products may vary from very simple, standardized geometries, low quality and follow a model of mass production or to very complex and tailored geometries, high quality with a model of customized production.

From here, it is possible to understand that the employment is indeed changing alongside recent AI trends in Portugal (research question d) and therefore, part of **hypothesis 4** "The implementation of AI-enabled automation technologies in the manufacturing industry results in an immediate productivity increase which, in turn, increases the company's competitiveness generating additional business opportunities and thus, increasing employment." is confirmed.

To assess the level of automation in Portugal, the introduction of AI-enabled automation systems, based on data from industrial robots (Source: IFR) and CNC machines (CECIMO), was used. Based on these data, it was possible to conclude that AI-enabled systems have been introduced in the manufacturing industry infrastructures with some delay comparatively to other European countries.

In Portugal, the large number of industrial robots are in the manufacturing sector (4156 from a total 4622, for 2017, which represents 90%). In this industry, major sectors that use robots are the automotive (2191) and metal sector (1045). Despite a high initial cost, automated systems and, in particular, robots, can represent a cost saving considering comparable units of time. However, despite this trend towards cost reduction driven by technology, the relationship it may have on productivity is still a matter of controversy.

Another motivation to invest in automation is the increase on labour costs, however, this pressure of higher labour costs is not a criterion for capital investment in Portugal. From this conclusion some motivations for the investment and adoption of AI-enabled automation technologies in industrial companies were identified and thus, part of **hypothesis 1** "Motivation for investment in AI-enabled automation is due to the association of these technologies with cost reduction, increased productivity, increased exports to the global markets" is confirmed.

Especially relevant for the chosen manufacturing industries (Automotive, Ceramics and Metallic products) are some policies at national level. Specifically, the measures under the i4.0 program of the Action Plan for the Digital Transition, namely under the Capacitar i4.0 program and also funded by RRF under C16 – Companies 4.0. These are related with training in digital technologies, aimed at company workers regardless of their level of digital skills ("Digital Jobs + 2025"); infrastructures that aim to create the necessary conditions for companies to develop and test new products and services, and to accelerate the digital transition process ("National Network of Test Beds") and services to support the digital transition of companies, in more accessible conditions, focusing this process in three disruptive technologies: AI, HPC and Cybersecurity ("Digital Innovation Hubs"). Very recently, it was announced an addition of 60 million € for Industry 4.0 projects contributing to organizational and process innovation SMEs and aimed at the implementation of technological solutions that fall within technologies of industry 4.0. It is not yet clear how these projects will be evaluated considering the targets of "organizational and process innovation".

Therefore, there are some financial incentives, from public policies, for digital transformation, however, based only in this information, it is not possible to assess, one can only assume, that these incentives were also motivating investment in AI-enabled automation (**hypothesis 2**).

There are some studies on the impacts of industry 4.0, where AI-enabled automation systems are included, on employment, work organization and qualifications. From these it was possible to assess the main constrains to the adoption of industry 4.0 technologies, still today.

Thus, there are some indications on the low awareness and understanding on the topic of industry 4.0 from the management as well as seems that there are inadequate management strategies to this topic what can be evidence for **research question c)**, about an implementation/development strategy previously planned to the AI-enabled automation adoption.

These studies show a narrow coverage of aspects related with work organization (**research question e**) which does not give indications on part of the **hypothesis 4** "(…) However, since there are no changes in the work organization, the employment growth is not sustainable" and on **hypothesis 5** related to changes on the work organization due to the AI-enabled automation adoption. Also, it seems there is a low qualification workforce in companies, but nothing is mentioned regarding increasing work qualifications with AI-enabled automation systems implementation (**research question f**), though one could assume it is not the case since it also seems companies have difficulty to find people with the right skills. Nevertheless, **hypothesis 6** remains to be confirmed.

These studies show an absence of policy intelligence to promote a human-centred AI, what, in relation with the **research questions g and h**, does not give a clear answer on the confirmation of **hypothesis 7** on the visions about the role of humans' interaction with AI-enabled automation. Finally, there is no information about the involvement of the workforce in the adoption process of AI-enabled automation technologies and therefore, **hypothesis 3** cannot be confirmed, based on the analysis of evidence so far.

Although these studies provided already some insights on the research topics of this thesis, some limitations and needs for further research were identified.

Thus, there is still a need to **deepen understanding of these issues by collectively designing a set of scenarios of how developments may play out in Portugal**. These scenarios should have the involvement of diverse participants from industry, government, and civil society.

Additionally, there is a need to **do more case studies, to allow for more effective and extensive empirical verification, and do it for more recent years**. Therefore, these studies should research deeper into the **company's management solutions and strategies they have implemented**, and it would be important to know **what the impact were on the workers of these companies, especially**

**those assigned to routine tasks**. Would these tasks had been transformed into more enlarged scope? Were these workers been substituted by machines? Or those tasks changed to enable a cooperation with AI-enabled machines and systems?

**Finally, there are no studies on the determinants of the adoption of industrial robots in Portugal by companies to better understand the intrinsic characteristics of companies that lead to the adoption of these technologies**. Are they multinationals? Large companies or SMEs? Are they early adopters or laggards? Can we find them mostly in on one sector and one region, or are they dispersed? In those cases, which is the compositions of the internal labour market? And which are the skill needs?

Hence, in line with some of the recommendations derived from the studies analysed above, and in order to better understand some of the findings from these studies, a qualitative analysis was done. The goal was to look also for the scientific evidences that could reply to all of the research questions. Besides that, confirmation (or not) for the research hypotheses was pursued. Thus, interviews, group testimony, observation, and a scenario exercise were done. The application of these techniques was performed according to the methodology of Chapter 3, and the results (and its discussion) presented in Chapter 5.

# CHAPTER 5 RESULTS AND ITS DISCUSSION

## 5.1. Introduction

This chapter presents the results from the **empirical study** on the situation of AI-enabled automation in Portugal, resulting from the interviews, group testimony, observation and scenarios. These techniques will help to collect additional data, specifically qualitative ones, due to the lack of quantitative data associated with some of the dimensions which are analysed in this research study, such as, competences, qualifications, work organization, visions for human-machine interaction, among others. It will help to understand how AI is, and will be, impacting employment and the workplace of manufacturing industries, in Portugal, as well as gather the necessary evidence to confirm the hypotheses of this research thesis.

Moreover, the results will be discussed around the different dimensions on which the research questions and hypotheses were defined: Adoption of AI-enabled automation systems (AI-enabled systems, applications, public polices and financial incentives, work organization), Organisation of the digital transformation process (strategy to the implementation/development of industry 4.0; employment, work organization, work qualification, competences) and Prospects of human interaction with AI in work environment (human-machine interaction).

Finally, the evidence on the documental, statistical, and empirical analysis will be used to construct exploratory scenarios on the future of Manufacturing industrial sectors with the adoption of AI-enabled systems and its implications on employment and the workplace before the following Chapter 6 – Conclusions.

For anonymization purposes, the interviews were coded (Annex 1). For a better understanding of the type of actors involved in the data collected, the coding system is explained hereafter (table 5).

Table 5 – Coding system to the interviews

| | |
|---|---|
| **TYPE OF ORGANISATIONS** | TS - technology suppliers<br>EU – End-Users<br>A – Academia<br>S – Social Partners |
| **PROFILES** | IM – Innovation Manager<br>TC – Training Coordinator<br>SD - Systems Developer<br>SE – Social Sciences Expert<br>PC – Production Team Coordinator<br>PM/ ID – Industry Director<br>CEO/ ED – Executive Director<br>IR – Researcher on AI<br>SR - Social Sciences Researcher<br>S2W – Workers Committee Representative |
| **FOCUS GROUP WITH WORKERS' REPRESENTATIVES, UNIONS, OF THE AUTOMOTIVE SECTOR** | FG Auto |

Source: Author's definition

## 5.2. Analytical dimensions

### 5.2.1. AI-enabled systems Adoption and Applications

Automation and AI technologies are more and more available. Technology providers claim that there are already several applications of automation and AI technologies, such as, transportation (e.g., conveyors, AGVs), handling (e.g., and collaborative robots), welding, machining, painting, assembling (e.g., conventional robots), quality inspection (e.g., computer vision and AI), predictive maintenance (eg., Big data and AI), mass customization (e.g., AI).

They seem to demonstrate the belief in the potential benefits of these technologies and mentioned some (table 6). For instance, TS 1CEO & IM gave an example of a computer vision AI-enabled system:

*"(...) allows to analyze situations that are too fast for the operator to notice, to identify defects that are not visible to the naked eye and is reliable in the decision to reject a non-conforming product."*

End-users have been adopting AI-enabled systems according to their needs for efficiency and competitiveness. They have been integrating in their production systems conventional automation systems for several applications areas. However, AI-enabled systems are more difficult to find on the shop-floor. With the exception of automated inspection systems (AIVs), and intelligent robots, there are not many AI-enabled systems in the shop-floor.

As an example, described by the production coordinator of the metalworking company, which shows increases in competitiveness of the company:

*"We have cells in which we reduced the number of operators, but, overall, we would have increased because we have more cells. In fact, that's the goal of automation; it's to do it (production) more productively, it's perhaps to do it with fewer material or human resources or energy, but we managed to be more competitive, which brought us more business."* EU1SPC

Another example of a benefit brought by the incorporation of a collaborative robot in an assembly line of an automotive manufacturer:

*"(...) previously to the collaborative robot, the operator had to tighten 12 to 16 pins, to fix the brake disc to the wheel hub; we have 4 brake discs per car, so there were 4 operations (4x12/4x16), per vehicle, and with the installation of the collaborative robot it helps him to give the tightening torques. He continues to position the pins, but the main effort of taking a machine, even though being an electronic machine, it still causes impact in the person who is using it, and he no longer has that function. And there it is really collaborative, that is, he does one part (position the pin) and the machine does the other (tighten the pins)."* EU2MPM

Finally, a last example from the ceramics company on stone tableware production highlighting also the benefits of AI-enabled systems adoption for the workers:

*"This automation and AI technologies in the shop floor bring us closer to what is the OECD standard of work quality for human operators*." EU4RID

However, they also pointed out to some limitations (table 7) still. Although there is more alignment between benefits from the adoption of AI enabled systems of different stakeholders' groups and profiles, limitations are more specific to the profile interviewed.

Table 6 – Benefits associated with the AI-enabled systems adoption in the Manufacturing Industries, from the perspective of Technology Providers and End-Users interviewed.

| **Technology Providers** | **End-Users** |
|---|---|
| **Benefits** | |
| Reduction of occupational diseases (e.g. substitution of repetitive and highly loaded tasks by robots) and, consequently, reduction of sickness absenteeism and reduction of health costs; TS1CEO&IM; TS2PTC | "*We need to optimize, increase efficiency (…). Automation allows for bigger flexibility*" EU3TED |
| Predictability, consistency and adherence to delivery times (e.g. automation solutions with less downtime) and consequently increased efficiency, productivity and waste reduction; TS2PTC; TS1CEO&IM | "(…) increases in productivity and reliability on the quality side, and it also provides more predictability, time consistency, reduces costs, and all of this is important to be competitive and get more contracts in the future" EU1SPC; EU4RID |
| Consistency; sensitivity (e.g. computer vision) and consequent increase in quality TS1CEO&IM | "tendency to hire workers was growing due to the increase in the number of contracts." EU1SPC; |
| Increased competitiveness and consequent increase in employment; TS2PTC | Reduces workload, increases efficiency, and substitutes repetitive tasks; EU2MPM; EU4RID |
| | *"Automation and AI Technology are important because of sustainability. We need factories to be more efficient and more effective in their production to reduce the negative impacts in the world around us"* EU4RID |

Source: Authors' compilation

Table 7 – Limitations associated with the AI-enabled systems adoption in the Manufacturing Industries, from the perspective of Technology Providers and End-Users interviewed.

| Technology Providers | End-Users |
|---|---|
| **Limitations** | |
| Investment required is too high for the current performance (depending on solution needed, type of product and number of requirements) TS1CEO&IM | "*in automatic welding there is no flexibility, while in manual welding, if the piece doesn't turn out well, the operator can do something about it.*" EU1SPC |
| "Integration of new generation systems with older systems"; TS1CEO&IM | "*There is some difficulty in keeping staff and it is not always easy to find the right skills in the market*". EU2MPM |
| Fear and distrust of company's owners; TS2PTC | Automation puts a lot of pressure in the workers because it is not adjusted to the velocity of the manual work; EU4RID |
| With the minimum wages practiced in Portugal Industry 4.0 may not be competitive - higher labour costs with technology than with workers; TS1CEO&IM | "Automation is not perfect, and we still have several products that must be rejected due to defects. However, doing the process manually by workers products also had defects and the rejection rate was higher." EU4RID |
| "*In the case of OEMs, with several factories around the world, there is great resistance to the introduction of solutions that are not standard or consistent with other solutions already introduced in other factories*" TS1CEO&IM | "*Automation still cannot replace human competences gained with years of experience on very original pieces, with complex shapes, many different colors.*" EU4VID |
| Danger of large robots; TS2SD | |
| "*Difficulty of operation on shop floor; in simulation it works, but then, in real context it is more difficult*" TS2SD; | |
| Lack of standards; interoperability of solutions; TS2D | |
| Development of technologies does not consider the social context of work; TS2SSE | |
| Fear of sharing data, having data in the cloud, cybercrime; TS2PTC | |
| Industrial infrastructures are not prepared (e.g. industrial machines without internet connection); TS2PTC | |

| Technology Providers | End-Users |
|---|---|
| Limitations | |
| Lack of skills to work with Industry 4.0; TS1CEO IM | |

Source: Authors' compilation

End-users interviewed were from the Automotive, Moulds, Metalworking and Ceramics sector. More specifically, the profiles interviewed were at the companies for several years and had many years of experience. They also have gone through, at least, functions at two different areas in the company (usually, production or maintenance), and were from an automotive manufacturer (EU2MPM), from a metalworking company which also was a components supplier for the automotive sector (EU1SPC), one moulds company (EU3TED) and two companies from the ceramics sector, one of Stone Tableware production (EU4RID) and one of Porcelain Tableware (EU4VID). One of the social actors interviewed was also from an end-user from the automotive sector (components supplier – S2W) and its features were also included in table 8, which sums up main features of this companies related with its economic activity and AI-enabled systems adoption.

Table 8 – Main features of companies interviewed based on the collection of evidence from the interviews, workplace visits and video visioning.

| *End Users* | *EU 1S PC* |
|---|---|
| *Type* | Metalworking |
| *Production* | Mass production |
| *Products* | automotive parts (transmission and shafts, seat installation parts; metal structure for cars, buses and trains) |
| *AI-enabled systems* | 15 robots (between welding and handling)<br>Machines to bending tubes, machining, machining coupled with robots for manipulation; milling, pressing, CNC machines (fully automatic in-line handling robot), parts handling robots,<br>"In terms of AI, we do not have anything implemented right now; we do not have anything that helps us in decision support" |

| *End Users* | *EU 2M PM* |
|---|---|
| *Type* | Automotive manufacturer |
| *Production* | Mass production<br>10/12 thousand units per year<br>48 units/day on a ramp-up to produce 56 vehicles/day |
| *Products* | commercial van (light and component)<br>internal combustion vehicles, electric vehicles |
| *AI-enabled systems* | "Two distinct processes, in which the cabin process has a little more automation than the final assembly of the chassis".<br>AIVs (Autonomous Intelligent Vehicles), AGVs (Automated Guided Vehicles)<br>one or two assembly situations that are in one-piece flow, also on top of AGVs, i.e., not only transporting parts but also transporting workbenches in the layout, which allows us to be flexible, to increase or reduce (shop floor layout) according to the volume |

| *Social Actors/ End User* | *S2W* |
|---|---|
| *Type* | automotive |

| | |
|---|---|
| *Production* | components for automotive |
| *Products* | Plastic parts for automotive interiors |
| *AI-enabled systems* | 40 robots<br>AGVs, Conventional Robots (handling to support injection machines; painting parts) |

| *End Users* | *EU 3T ED* |
|---|---|
| *Type* | Moulds |
| *Production* | Customized production |
| *Products* | mould customized to the needs of the client.<br>(Experience and qualification on the activities only comes by doing; Is not the something that someone who gets out of school can right away do) |
| *AI-enabled systems* | Robots feeding injection and tooling machines.<br>Machines with five axels with pallets (it allows the machine to end a process and start another one automatically) |

| *End Users* | *EU 4R ID* |
|---|---|
| *Type* | Stone Tableware |
| *Production* | Mass production |
| *Products* | Ikea tableware (simple, flat pieces) |
| *AI-enabled systems* | "All of our production process is automated except two areas still: the quality inspection system, for which we are currently developing a solution with promising results, and the packaging area which is done full manually and we have not found a solution yet."<br>Automatic conveyors, Automated moulding; Machine with several robotic arms to removes the material excess on the raw piece, make the edges, etc.; automated glazing; automated painting.<br>computer with a specific software which can show the production process in real-time, machine manufacturing by the minute, and warnings.<br>computer vision with AI inspection system (in development). |

| | |
|---|---|
| | AGVs without magnetic stripes (they have a sensor and navigation system that allows them to go in any direction in the factory, avoid objects, stop in front of an object, know when they have to pick up pieces and where to take it, automatically) |

| *End Users* | *EU 4V ID* |
|---|---|
| *Type* | Porcelain Tableware |
| *Production* | Customized production |
| *Products* | decorative pieces, giftware, hotelware, high quality glass and crystal, and 18/10 stainless steel cutlery<br>(complex, original produts vs flat pieces; quality inspection is done manually) |
| *AI-enabled systems* | Only flat pieces are done by automation equipment.<br>AGVs guided by magnetic stripes |

Source: Author's compilation

A summary of the main features of the different end-users' cases analysed can be found in figure 32.

Therefore, based on the evidence collected through the interviews the following list **of necessary conditions to adopt AI-enabled systems in Manufacturing Industry in Portugal,** is presented:

- technological challenges breakthroughs
- appropriate infrastructure
- access to appropriate skills/skilled workers
- informed management
- studies on effects on work organisation
- a minimum wage increases
- increased cyber security
- workers in cybersecurity trained
- the robot's intentions more explicit (e.g. where it will move to)
- investment

| End Users | EU 2M PM | S2W | EU 1S PC | EU 3T ED | EU 4R ID | EU 4V ID |
|---|---|---|---|---|---|---|
| **Type** | Automotive (OEM) | Automotive (TIER1) | Metalworking (TIER2) | Moulds | Stone Tableware | Porcelain Tableware |
| **Year** | 2021 | 2023 | 2021 | 2023 | 2022 | 2022 |
| **Year** | 2021 | 2023 | 2021 | 2023 | 2022 | 2022 |
| **Production** | Mass production | Mass production | Mass production | Customized production | Mass production | Customized production |
| **Products** | Commercial van ICE, EV | Plastic parts for automotive interiors | Automotive parts (transmission and shafts, seat installation parts; metal structures) | Moulds for plastic injection | Ikea tableware (simple, flat pieces) | Decorative pieces, giftware, hotelware, high quality glass and crystal, and 18/10 stainless steel cutlery |
| **AI-enabled systems** | 3 robots<br>AIVs, AGVs<br>Collaborative robot | 40 robots<br>AGVs,<br>Conventional Robots | 15 robots (welding, handling, manipulation)<br>CNC machines | Robots feeding injection and tooling machines.<br>Machines with five axels with pallets | Automatic conveyors,<br>Automated moulding; glazing, painting<br>Several robotic arms Software to show production process in real-time,<br>AI Computer vision | Only flat pieces are done by automation equipment.<br>AGVs guided by magnetic stripes |
| |  |  | |  |  |  |

Figure 32 - Summary of the cases analysed

### 5.2.2. Public Incentives and Financial Incentives

Technical innovations in the manufacturing industry, like the widespread adoption of cyber-physical systems, the integration of products should be enabled. This means the emergence of smart factories and value chain integration of global business networks. Such integration correlates with a vision of increased control of highly complex and globalised production processes which is also combined with the expectation for a (partial) reshoring of production capacities, in particular, from Asia to Central Europe.

This vision encompasses the development of the Industry 4.0 concept in Germany in 2011, which was strongly supported by policy makers. A national „Working Group Industry 4.0" was established rather quickly, bringing together engineers, software scientists, representatives of the Confederation of German Trade Unions (DGB) and of IT and technology companies as well as the German Federal Ministries of Research and Economy. Other technologies frequently discussed in the context of *Industrie 4.0* are adaptive robotics, 3D-printing and job-related wearables that are slated to contribute to productivity increases. After the initial success of dissemination of this vision, other European countries (and later, USA and China) tried to adopt the same industrial policy.

In Portugal, digital transition structured support into national public policies started in 2003 with Portugal's Digital Agenda. Several initiatives were put in place to advance scientific development, improve qualifications, foster better administration and less bureaucracy, promote innovative networks and reduce the digital divide. However, only in 2015 an initiative aiming at digital transformation of industry was prepared focusing on the acceleration of the adoption of Industry 4.0 technologies and concepts in the Portuguese industrial system (Phase I: 2017-2019) and boost and generalise economic growth through digitalization (Phase II: 2020-2021).

While digital transition was increasing its importance at European Level it also became a priority in Portugal. A secretary of state for digital transition, on the dependency of the Ministry for Economy, was created in 2020 and later, in the same year, the Digital Transition Plan was launched aligned with the Recovery and Resilience Facility for Portugal.

The introduction of the concept Industry 4.0 in Portugal is expected to be highly permeable in at least two parts of the economy. First, the high and medium-high intensive manufacturing sectors - responsible for 37% of the value of the exported goods in 2015 (Eurostat) - are naturally more prone to endogenize technologies that could improve production. The exposure of these companies to German production systems and globalized competitive markets is significant because they are under the influence or control of multinationals (many of German origin) and/or are considerably oriented to export. Second, the energy sector is capital and technology intensive with low levels of employment and was responsible for 3% of the GDP in 2014 (OECD STAN).

Here, technologies that can contribute to improve efficiency can hypothetically rapidly endogenize new digital technologies. The efficient and relatively new sector of wind energy, for example, is significantly controlled by foreign capital (German, Chinese and Spanish), supposedly making it prone to assimilate Industry 4.0 technologies. In sum, Portuguese firms operating in high and medium-high technology and energy sectors exposed to foreign influence are hypothetically prone to endogenize Industry 4.0 in their production system and to impact the labour patterns.

In this context, what was the diffusion and implementation of industry 4.0 technologies, in Portugal, between 2017 and 2022 was analysed. Has the interplay between public policies, state agencies and industrial relations players in the process been articulated, as it was in Germany? What have been the effects of these technologies in workers and organizations? Are the public initiatives in place enough or more is needed?

Results show that these national policies in Portugal were rather limited, and most automotive OEM and suppliers were the main companies that succeeded in receiving the available support incentives.

One of the arguments used to justify the investment in automated systems concerns the need to guide the productive activity towards a better efficiency of the operating costs involved. In this sense, equipment that involves major investment should achieve a greater productive result (higher quantity of products produced per unit of time, or less quantity of wasted material or even less energy per unit produced) than with the existing equipment. It is assumed, in this case, that there is no change in the number or qualification of workers involved in the production of these units (cf. Moniz, 2018: 52). Additionally, the criteria for capital investment in the manufacturing sector is not due to the increase of the labour costs. These have even decreased in recent years. Demands on production quality and reliable automation can be the major reasons, as the literature review demonstrates.

There is a common perception between the interviewees from organizations of science and technology system regarding the existence of public incentives to support the technological digital transformation of industry. However, other dimensions such as skills and organization of work seem not to be not covered.

According to A1ED, until recently, Clusters were the main driver to support technology transformation of industry. For example, PRODUTECH (Production Technologies Cluster), which A1ED is part of and a founding member of it, has been the main driving force of the strategy and support in Industry 4.0:

*"We have been involved, together, in projects with public funding to find solutions that would serve the maximum of companies in the sector, specifically through the participation in the projects 'mobilizadores' (TRL 4 - 6) and, more recently, in the 'agendas mobilizadoras' (TRL 6-9). We also have cross-border projects with organizations more technologically advanced than us.*" (A1ED).

A3SR feels that, in the case of social sciences, is more difficult to have funding that cover effects of these technologies in society at national level.

*"We have some funding through our research unit but most of our projects are funded by EU. Usually stakeholders are involved, such as, unions, professional associations, employer associations. Some of them are about human-machine interaction."* (A3SR)

A1ED has been following closely the public policies and financial incentives for digital transformation of industry. According to him, recently, public incentives to support Industry 4.0, including AI, are in the scope of the Digital Transition Plan, either through Digital Innovation Hubs, funded by the European Digital Program and the Recovery and Resilience Fund (RRF), or through "agendas mobilizadoras", funded by RRF.

*"We are in both of the initiatives* – says one of the interviewees - *PRODUTECH DIH – Digital Innovation Hub for Production Technologies and 'agenda mobilizadora'. In this case, the agenda is a continuation of what has already been done at the level of "mobilizadores" of the production technologies cluster, which includes technologies from software to machine tools, covering all types of companies. In this projects "mobilizadores", activities covered were at research level (TRL4-6), making prototypes and demonstrators, all connected with new technologies, I4.0 technologies, and robotics; was super important 7/8 years ago. In 2022, the "agendas mobilizadoras"*

*formally started and the objective is to transfer the technologies to the market (TRL 6-9). In this project ('agenda mobilizadora'), the maturity and integration of i4.0 technologies can be observed in the companies that participated in the "mobilizadores" and are now participating in the agenda. While the role of companies in the "mobilizadores" projects was to experiment with technologies developed by knowledge centres, research centres (e.g. INESC, INEGI) that were very much driven towards research and development in the engineering area, where companies acted as end-users that would experiment with this solution (user companies), in the agendas one can already see companies that are already using these technologies to manufacture products, products rather than services, products that are already marketable, already using all of these technologies, the IoT, AI, etc."* (A1ED).

In his view, support to digital transition has been done through public policies and financial incentives, previously at the level of research and development and now at the stage of market deployment of the AI-enabled systems.

End-users interviewed were aware of the public policies and financial incentives for industry 4.0, however only in general terms, not in detail. Most of them were from areas that are not connected with innovation and maybe that could be an explanation. On the other hand, they shared examples of adoption of AI-enabled systems funded by own funds because the adoption of these systems raised from a market need. And very often, market needs timeframes are not usually aligned with those of the public funding. For example, the metalworking company had one situation of these:

*"We had to increase capacity to meet the target, which went up, due to the merger of brands (PSA and OPEL) which led to increased volumes. We had to adapt and bought another machine and changed the already robotized process. The first thing we think is "How are we going to do this?" The idea is never to duplicate lines, but how to increase the capacity of the existing line. We performed internal brainstorming processes, discussed the tasks and what changes we could make. In this case, it was in the welding for atomization, to include a machine to make an extra bend in the part, and we managed to increase production capacity. The process design and robot programming were done in-house. We managed to divide the process in two to increase cycle time and we only bought the extra bending machine outside."* EU1SPC

In another situation, which was the case of the automotive manufacturer, they have started to establish a strategy for the factory of the future long before there were any public policies or financial incentives available.

There was one exception, though, in which digital transformation was performed using public funding as was the case of the stone tableware production company:

*"Yes, in fact, many of the company's modernization has been supported by own funds and public funds, European and national."* EU4RID

They have integrated a European project, which started in 2018, on Big Data for Industry 4.0, as a replication pilot. This was an important project for industries to understand how to deal with Big Data produced every minute on their daily activity. Another important project (national) was the one on production capacity increase which allowed EU4RID to have an increase of over 60% in number of pieces produced annually, in order to remain competitive and at the forefront of suppliers in the sector. With this project the promoter managed to strengthen and extend the relationship with its client, who would acquire the pieces produced by the company.

The foreseen investment was above the contracted values due to alterations that occurred in the project, with the acquisition of more automatic equipment that also reinforced the achievement of the objectives proposed for the project. The physical expansion and the acquisition of new equipment for the manufacturing unit, also allowed the development of new products, and it was expected that this would lead EU4RID to reach more markets and increase the levels of competitiveness and excellence of the sector, with the reinforcement of Portugal's position in international markets.

The planned changes in the manufacturing processes would allow for the production of innovative products - decorated stoneware tableware pieces manufactured by mono-baking - creating a differentiation factor for the product and, in turn, adding value to it.

More recently, they are also going to be benefitting from 3 other projects funded by public funds. One (national) which is developing an automatic quality inspection system using computer vision and AI algorithms; another one (European) where they are looking for a solution to automate the packaging, the only area within the factory that is still done full manually; and finally, an RRF project to accelerate the digital transition in the factory. (EU4RID)

It was curious to notice that, of all the companies, EU4RID was the one with more automated systems and the most modernized and technological advanced factory of all of the interviewed.

Nevertheless, the interviewees mentioned that there is a need to support a balance of investment and regulatory policies in matters of AI and automation because the risks related with data and of authorized/ non-authorized usages of AI technology. Other issue is the lack of investment policies towards education and training to complement with technology development. A limitation of the European Innovation Policy in the matter seems to be that educational efforts mostly vanish in the technology maturation process. It is the perception of A2IR, supported by A3SR, which also adds the need for research studies on effects of automation and AI Technologies in the society.

Although very recently (20$^{th}$ April 2023), it was announced by the government, an additional of 60 million € for Industry 4.0 projects contributing to organizational and process innovation in SMEs and aimed at the implementation of technological solutions that fall within technologies of industry 4.0, it is still not in place and its implementation cannot be assessed. However, it is rather positive that the organizational and process innovation of companies is specifically mentioned.

### 5.2.3. Organization of work

AI-enabled automation brings socio-technical dimensions. It is not just a technical or engineering problem or solution.

From the perspective of technology providers two situations are happening with the introduction of automation and AI technologies. In one, there are adjustments in work organisation to accommodate the technologies, resulting in workers being displaced to other tasks, for example:

*"For example, there was this client where we started to introduce robots and workers were afraid to be dismissed by substitution by robots. In some workplaces robots did substitute human workers but they were displaced to other workplaces. This company, for between 3 or 4 years, increased the number of robots from 0 to 30 and the number of employees doubled. Thus, not*

*always the introduction of robots leads to unemployment. Workers can be displaced to another workstation; the robot can be doing a task and the worker is already preparing for the next step." (TS2PTC)*

In other situations, there are adjustments in the organisation of work so that technologies improve working conditions and worker performance at their workstation, for example,

*"In a car manufacturer, the gearbox is a heavy part and it is easier to move it using TS2P's robotic arm. This equipment is full of sensors, which is not always the case in other brands, and the worker just directs the part while the robot holds the load."* (TS 2P TC).

End-users report the same situations. Either a displacement effect, as the example in the automotive manufacturer:

"*Worker's multitasking depends on the assembly station, it depends on the activity the person has, for example, in the painting process, the operator used to do the entire painting process, with the installation we are doing of these painting robots, he no longer does that function at all, there are two machines doing this work."* (EU2MPM)

Or an augmenting capacity of the workers performance with the introduction of collaborative robots. (EU2MPM).

According to the interviews, rotation is usually practiced at the shop floor (EU4RID, 3SW, EU2MPM) because the rotation of workstations also prevents occupational diseases from spreading. It usually happens in a team of seven people where, normally, one of them is the team leader. The team leader ensures that people rotate every two hours at each workstation. However, it was also evident that it was not only the welfare of workers that was behind the principle of rotation but also the company's interest to have such well-trained workers doing any job in the production area, as long as the functions are the same. Although practices of rotation were found, enlargement of tasks were not. Maybe because work organization set-up has not been directly associated with the introduction of new systems but are currently used practices in some of the companies interviewed.

According to the representative of workers' committee from the components supplier to the automotive sector, not always rotation is practiced:

*"When there are people who have some difficulty in doing a certain function, they (team managers) don't want to use them, because the other one makes more pieces and knows how to do it better. Then, in order to guarantee the achievement of the production goal, teams do not rotate and that will harm everyone on the production line. When this happens, we submit a complain to the supervisors of the production line when these practices were not respected. We even go to the production line and check it, because there is a document posted with the rotation of jobs, and when we suspect that this document is not being properly followed, we ask the workers directly, and if the workers themselves are afraid to tell us, we go there every few hours to see if the worker has rotated or not."* (S2W)

The representative of the workers' committee of a component's supplier to the automotive sector adds another situation that usually companies have difficulty in declaring. The situation of dismissal of workers after adoption of automation systems is described and, in his view, this will continue to happen:

*"We are now going to install a robot that will dismiss 3 workers. And this will continue. For example, we have a pilot plant in Spain, Tarragona, where there are practically no more people working in the injection area. And this is a pilot plant that the S2W group developed, and they are very pleased. They have practically no people working there. I don't know if this was discussed with the unions in Spain or not, or with the workers' committees. On this production line, where the injection machines are, the part comes out, there are robots that remove the part, there are some small tasks that have to be done on the part that the robot itself does, then there is a robot that fetches the boxes from a certain rack and loads them directly onto the truck, without the need for a forklift. So, if here we have, in our injection moulding, around 50 people, imagine the drama if this whole area is automated. We believe that in the next 10 years, this type of automation could happen in this factory."* (S2W)

According to the representative of the workers' committee of the components supplier to the automotive sector, there is not much possibility for reallocating the dismissed workers. Usually the workers dismissed are low-qualified workers which are difficult to accommodate to other workstations. According to him, and since the automotive sector is very dependent on the production volumes, the workers from companies without work councils are more easily dismissed. In his experience, when a robot is introduced to substitute non-qualified workers, there are no changes to the organization of work and the worker is dismissed:

*"For example, in the case of the adhesion workstation, if there was a worker there adhering for 8 hours a day, I mean, it's not 8 hours because of the rotation, this is even one of the most complicated posts in ergonomic terms, that rotation which takes place every 2 hours will no longer exist at that workstation, because the workers will only rotate through the other positions and not this one, since this one will no longer need workers"* (S2W)

The examples found are all of simple operation tasks where automation systems were implemented, with the exception of the automated computational vision quality inspection systems. **This means that, until now, in the sectors studied, AI is still not able to replace most of the human skills and thinking but can replace humans operating simple tasks, in line with the framework explained by Autor (2003, 2015).**

Regarding the involvement of the worker in discussions about changes on the shop floor and about the dialogue with them when developing automation solutions, when installing the robot and about its use, different perceptions from the technology suppliers were found.

In the case of the development and installation of automation and AI solutions, when designed by the integrator, in some cases, there is usually no interaction with the engineers of the user company, the technical requirements are sufficient to develop a solution and, in the case of installation, there is also no dialogue with the workers. Although integrators value the knowledge and experience of engineers and workers, in the case of small companies, they do not have enough resources to allocate to this type of interaction. (TS 1 CEO & IM)

In other situations, the dialogue and involvement, either at the level of the installation with the workers or at the level of the development of the solutions with the engineers, depends on the integrator and the user company.

There are cases where, before the robot is introduced on the shop floor (installation process), the integrator goes to the factory to study the process and when they are on the assembly line they collect the opinion of the workers, for example,

*"(welding) The robot was going to perform the worker's task (replacement) and the worker explained to us (integrator) the best way to approach the piece with the torch. (...) In some companies, the workers were free to share their experience and knowledge about the workstation. It depended on the company, but also on the perception of the workers, and sometimes the company management itself, about the impact that robots could have."* (TS 2P TC)

In other situations, either due to workers' mistrust or companies' lack of openness there was no interaction (e.g. not allowing dialogue with workers) or they did not have access to all the information, as the following citation shows:

*"In the past (2016), there was mistrust. When workers saw us coming, they thought they were going to lose their jobs and they didn't give us relevant information."* (TS 2P TC)

In the case of robot suppliers, there is some interaction with integrators and user companies. There is dialogue to gather information about the type of application and get feedback on the solutions developed. However, from the software engineer's point of view, this interaction alone is not enough, they also must think about the next steps, how to implement the solution, how to develop interfaces that allow them to program the applications and how to make it work, for example,

*"They (integrator) came here, and we had to solve some tasks with graphical programming. We (software engineer from the robot supplier) asked if it was OK like this, what was wrong, what was the time for delivering the solution. Another challenge is about the feedback we get.*

*Sometimes we are told it is fine and easy to use and sometimes we are asked why it doesn't parameterize automatically."* (TS 2S D)

On the end-user's practices, only the automotive manufacturer confirmed there was a dialog between the shop floor and the programming experts.

*"There is a dialog between the people from the production area and the programming area. When you start defining a process to be automated, you try to understand what the challenge is, what the requirement is, and from that requirement you start preparing how to achieve that result; when we are talking about this type of technology and component transfer, we try to make the machine work as independently as possible from the operator, but, sometimes, the operator has to do some actions; we have several cases."* (EU2MPM)

According to EU2MPM, usually they have monthly meetings with the workers' representatives, especially for health and safety issues, but also to deal with project issues, what is going to be done next month or that year, plus the projects planned for the future.

*"When we start to do a design activity for a technological solution, for production, for example, the people that are in the assembly stations are involved. We listen to them, learn from them and sometimes they give us ideas to solve some of the challenges, most of the challenges we have. We also bring them closer to the project so ghosts are not created. (...) We are just now installing some painting robots here on the axle line, axle painting, in which, from the very first moment we involved people, that is a process done in three phases; when the operator is in the third phase he will have to do something else, but for him it is ok, because he was also tired of that, he had to walk there, every 3 minutes, painting an axle. He is happy of robots appeared to replace him."* (EU2MPM)

The automotive industry, because of the influences of German and Japanese management, all have some work organisations arrangements. According to the representative of the workers' committee of a components supplier to the automotive sector, they are not involved in the choice of the AI-enabled automation systems, but they are involved in the discussions about the adoption of the new systems. They managed to create the practice and influence the company's culture of having a dialogue between workers and factory management.

*"We've had more difficulties with certain factory management, others less so, but we've managed to have more dialogue, and whenever there's a discussion about changing the shop floor layout, which has an impact on the workforce, we're always involved; when we're not, we ring all the bells, because we want to be involved."* (S2W)

Moreover, they give their opinion on AI-enabled systems implementation processes, even if not in a structured way (in a case-by-case scenario), they also have an ergonomics memorandum, which is where all the issues are covered. Even with the legal part, the space in which the worker must be working, what he cannot have around, if there is a 90 cm or 1 m access corridor, between machines, emergency exit, everything related to legal issues is in that document. This document was created by S2W itself, revised by the workers' committee and framed in some way with the laws in Portugal. An example of the influence of the workers committee on the implementation of an AGV was described by S2W:

*"For example, the AGVs, which are those small robots that transport, in terms of in-house logistics, everything that is packaging. They came to make changes, yes, in terms of occupational diseases, because having forklifts circulating there and the workers who drive them, also manifest occupational diseases, but these AGV's that were put into circulation, we were consulted for their placement on the shop floor. And we said "so why does it have to be a reduction of 3 jobs this year? why can't it be gradual and do it in 2 or 3 years?" This has already happened on our side."* (S2W)

**It seems there is dialogue but, other than a few exceptions, it seems the design, development or implementation of AI-enabled systems do not have social dimension in consideration.**

The main motivations for the adoption of AI-enabled systems are still productivity, efficiency, cost reduction and predictability, according to the end-users interviewed:

*"The requirements for them (mother company) to be able to invest in this AGV technology was related with, the main one, without a doubt, a process point of view. It was to ensure the flow of the process; I am responsible for internal logistics and I know that, really, it is totally different to have a line with cadenced production and then have a storage area where trucks are unloaded, where parts are stored, which is chaotic work and very difficult to organize, and our goal is to have as many activities associated with cycle time, production cadence, and the more we can associate to cadence the more efficient we can be, because we have optimized the resources."* (EU2MPM)

Although management have ergonomic and safety issues in consideration, they are not the first criteria to develop or implement an AI-enabled system. Therefore, if both efficiency, productivity, and safety can be combined it is easier for management to authorize AI-enabled systems investment. (EU2MPM)

According to the social sciences expert, there is research in the analysis of organizational dimensions of work in complex environments, though it is not very looked for by companies. However, his focus has been in the automotive sector, where he has studied both the human-machine interaction in such environments and the potential impacts on the labour market and on employment in general. (A3SR)

### 5.2.4. Competences

From the perspective of technology providers, there has been a great effort in the development of software and the user interface to make the system more intuitive, both for those who use it and for those who must make programming changes and carry out the maintenance of the equipment, so that no specific skills are needed to do so (TS 2S D). However, automation technology suppliers (hardware and software) and integrators (software and AI) opinions diverge regarding programming robots' complexity, the training needs to work with and program the robots and if systems are more intuitive.

Integrators consider that robot programming is more complex but more intuitive and therefore does not require additional specific training, however, those who program the robots need to have certain skills (TS 1 CEO & IM).

Automation technology suppliers, on the other hand, consider that the programming is the same for all automation solutions and there is no substantial difference in the case of conventional robots, but for certain applications (e.g. welding), there are specific technology packages. One of the after-sales services of automation suppliers is training. Their training is directed towards maintenance operators, project managers, production line leaders who may need to program the robot (e.g. change the position, requirements for new products, duplicate the program for other machines). There is demand for training, but so far, it has not been a limiting element to adopt robots in the industry; they have carried out many training activities.

"*We have two training courses:*

*- **training for operators** (2 days): held at the automation supplier's premises, where there are two industrial cells with robots capable of simulating any industrial application and with the aim of learning how to manipulate the robotic systems; learning how to put it in a position, how to make it move and, when the robot stops, how to put it in safety mode to start the production line again. Normally, each company sends 10 to 15 operators at a time.*

*- 2 levels of **training for programmers** (5 days each): carried out at the premises of the automation supplier in the same two robotic cells; the workers arrive without any knowledge of robot programming and at the end of the training they know how to program one. Usually this training is for integrators who send around 3 or 4 workers."* (TS 2P TC)

They also mention that they have noticed that the workers have more skills and are more qualified than before, so the expectation for the training course is high. However, there are always two types of workers, those who go with the expectation of learning new things and have the willpower to do anything, and others who are there only because their employer requires them to. While they don't consider robot programming to have evolved in complexity, they acknowledge that programming robotic cells and collaborative robots is more complex.

*"Whereas it is intuitive to program a robot (the operator puts the robot in position and saves that position, takes it to another position and saves that other position, and so on) in AGVs, for example, there is already a map; it already requires another type of skills. I started programming PLC's and used logic. The transition from PLCs to robots was easy. The transition to collaborative robots or to AGVs is a little different. They already need knowledge of information and communication technologies (e.g. maps, networks, GPS, algorithms, etc.). And also, at the installation level that complexity is taken on, in these smart products."* (TS 2P TC)

In Industry 4.0 the goal is to create more easily and quickly interchangeable programs with a user-friendly interface so that programming skills are not required every time something needs to be changed in the program. In this situation, there is a risk that the integrator is no longer needed in the process as any professional without skills can do it. There is an expectation that in the future, programming will be simpler due to the trend for frequent changes. Products change every two years which makes it necessary to adjust the production line and systems. Therefore, it is expected that the programming language, the installation, the changes, the training, will be more accessible for everyone. (TS 2P TC)

Organizations from the science and technology system also agree with the increase in complexity of the technology. For example, in the center for technological innovation in metalworking, whose activities are related with transfer of technology and training, they have been increasing their knowledge and competences in industry 4.0 technologies, specifically in de area of IoT, Machine Learning, Additive Manufacturing, so they can help the metalworking industry when they look for support on testing these technologies (A1ED). They have set-up a FAB LAB where industry can test these technologies, see the effects, increase their skills, and train their workers. To be able to run the FAB LAB (3 people permanently) they used the protocols they have, for several years, with their European counterparts (universities and institutes from Germany, Switzerland, Austria, Italy).

*"They are technologically more advanced than us and that is why we send our employees there to have training with them. Then, we replicate it in Portugal."* (A1ED).

In another research center (A2IR), in the area of information and communication technologies, they also have facilities which companies can use to test industry 4.0, including AI, technologies. Moreover, since 2017, they have set-up a training activity on industry 4.0 (with a partner) because they realized the need from Industry to know more about this topic and the need for managers to understand it better and how it could affect their companies. It was such a success that they have replicated this training action and increased their offer. Nowadays they have 3 types of training actions related with Industry 4.0:

- Advanced Program Industry 4.0 (68h)

**Target**: Managers and middle and senior management of industrial and technology-based companies (e.g., operations, production, logistics, engineering, technology and innovation); Managers, engineers, entrepreneurs and consultants who aspire to lead the implementation of Industry 4.0.

**Description**: The pressure to respond to the growing complexity and global competitiveness with high levels of efficiency and quick response (flexibility), as well as the ongoing digital transformation, the new materials and the new manufacturing processes, and the need to rapidly evolve towards a sustainable industry are at the genesis of the so-called fourth industrial revolution. How to deal with these challenges, what to do, in which to invest, with which priorities, are issues that are at the top of the agenda of the managers who aspire to lead the implementation of this transformation at the technological, processes and people level.

- Digital Transformation of Industry and Manufacturing (36h)

**Target:** Product/ systems development engineers; Consultants; Multidisciplinary teams associated with innovation projects and digitalisation of production processes; Leaders and managers of innovation, engineering, production

**Description:** There are more and more intelligent production systems able to automatically make decisions about their production process. These systems, called cyber-physical systems, have an enormous impact on productivity and the ability to respond and adapt to customers. The central objective of this program is to provide key concepts and tools that allow to evolve from the current productive reality to the new paradigm of intelligent production., where participants will have the opportunity to understand how new technologies, smart sensors and machine-learning, can impact on productivity increase. Participants will be exposed to these technologies and to digital approaches oriented to production and smart processes, getting prepared for the implementation of innovative projects on manufacturing.

- Fundamentals of the 4th Industrial Revolution (6h)

**Target:** Management and Administration

**Description**: It aims to empower managers and entrepreneurs to prepare companies for the challenges of Industry 4.0. It addresses the different technologies of Industry 4.0, such as: Robotics and Collaborative Applications, Industrial Internet of Things, Artificial Intelligence, Additive Manufacturing, Smart Logistics, Simulation Tools and Augmented Reality.

The perception of research and technology organizations is that there is a lot of training available on industry 4.0 and emergent technologies like AI, advanced computing, Big Data. However, until know, it was oriented to the managers and engineers and not so much to the workers that have to deal with these technologies in their professional activity.

PRODUTECH Cluster, the Production Technologies and Manufacturing Cluster, was the main facilitator of digital transformation of industry (A1ED) and it will continue to have this role within the Digital Innovation Hubs – co-funded initiative of European Commission and Member States to accelerate the digital transition of industry, particularly SMEs, by giving access to testing facilities, support to companies in their digital transformations processes, give training to its workers, support to find financing and facilitate networking between technology providers and users.

The PRODUTECH DIH has started operating in October 2022, but it is too soon to have an assessment of its potential effects in industries. The expectation is that it will contribute to a more efficient, productive, qualified workforce and competitive industries.

### 5.2.5. Qualification

From the perspective of technology providers, both integrators and robot suppliers identify three possible situations: the worker's qualification is maintained, and the robot has a collaborative role, performing only the most stressful tasks (e.g. moving heavy parts) or the worker loses qualifications as his tasks are replaced by the robot (high degree of automation) and his role is only supervisory, prepared to intervene if something goes wrong. For example,

*"(...) in case a pick & place robot has placed the part on the line in a position for which the handling robot cannot perform its task, the operator has to stop the line, place the part in the correct position and start the line again".* (TS 1 CEO & IM)

The third situation is related to the qualification of specific workers (e.g. team leaders, project managers, maintenance workers) who may need to make changes in the robot's programming and therefore are trained to do so by the integrators or robot suppliers. But normally, there are only 1 or 2 workers in each company, in this situation. According to the technology providers interviewed, very often the user company receives the robot already programmed by the integrator that does the installation and the workers only need to press one or two buttons to make the machine work. (TS 2P TC; TS 2P TC)

Organizations from the research and technology system, have similar perceptions of what is happening or can happen in respect to qualification.

Technology experts have the perception that in technologically advanced companies, the employees are more qualified people, with bachelor's degrees, master's degrees, doctorates, and there is more talk about AI and AI solutions.

According to the technology center for metalworking, family-owned companies, small, without a professional management, usually they don't look for AI solutions but automation technologies (e.g. IoT). Why? Is it that a more qualified workforce is able to deal with AI technologies? Or is it a consequence of the need to upskill the workforce due to the adoption of AI technologies? According to the expert on social sciences:

*"Qualification is both a condition (increase on qualifications, improvement of skills, new learning processes) and a result of industry 4.0 (de-qualification, or re-qualification). The*

*outcomes depend on the design of the technology to be implemented and on the organizational model adopted"*. (A3SR)

From the interviews to end-users, it was possible to see that some of them (EU1SPC, EU4RID, EU4VID) have been changing their qualification profile from a workforce with basic level to a workforce with, at least, the secondary level of schooling. This is also in line with the statistical analysis performed. Therefore, their level of formal qualifications is not only higher than before but also gives them the possibility to perform added value tasks. For example:

*"We have qualified workers that work in engineering and maintenance (3 people), and they are in charge of all the maintenance of the robots and the machines, of programming the machines, of finding solutions when there is a problem with the machinery, you have engineers and technicians in the control room and then we have less qualified workers that work on the shop floor."* (EU4RID)

And,

" *We have workers who do the programming internally. It is not any worker because it requires some training, but is done, for example, by a team leader or other qualified worker. We also have someone inside the company who does the maintenance of the welding robots, takes care of the wire power source, contact tube, cleaning, parts replacement; all the basic tasks but which require some qualification are done in production area, always. These are done by workers which are employees to whom training was given by the integrators or by the robots' supplier. For example, ABB gives training and we also have maintenance contracts with them, but we also have robots form FANUC and, in this case, the training is given by the integrators."* (EU1SPC)

This also means that, according to Autor, et al (2003), workers of a given skill level can perform a variety of tasks and change the set of tasks that they perform in response to changes in labor market conditions and technology.

According to EU4VID, the porcelain tableware production company, their workers are high qualified workers with very specific competences and experience on the porcelain production process. They have around 650 workers working in the company and the problem is that training on the competences needed is scarce and they are facing a lack of qualified workers for their production needs. According to EU4VID manager, they are trying to recruit new workers to learn from the experienced workers at the factory before these workers get retired.

*"We have here workers with 40 years on the job, whose families work here, they parents worked here and this is the only way we have been able to have access to workers. It is very difficult to attract the young generations to this kind of activities. Moreover, designers are also difficult to find. We have launched internships, trainings so young designers with fresh ideas come here and spend some time with us. Just near the factory we have what we call the "designers village". We have small cottages where the designers can stay while they are here in their internship."* (EU4VID)

According to EU4VID, there is still no AI-enabled system able to replace the knowledge and experience of workers for the type of products (customized, complex geometries, many different colours, hand painted) they produce nor there are workers available.

**Therefore, the adoption of automation and AI technologies can have different effects on the qualification of the workforce that depend on the technology design and organizational model adopted. If the technology is designed to substitute the worker (ex. TS 1 CEO & IM) he will face a de-qualification, if it will be designed to support the worker (ex. TS 2P TC) he will face a re-qualification, in line with Autor, et al (2003) claims.**

When introducing a new element to the process and keeping the same organization model, most likely it will result in a de-qualification of the workforce because jobs are the same, workstations are the same and an inevitable substitution of the worker will be witnessed. When there is change in the organization model to accommodate the new element (technology) and take advantage of all the resources available in the organization, it will most likely improve productivity and efficiency, as argued by Acemoglu and Autor (2011). According to these authors, which skills (embodied in labor), technologies (embodied in capital), and trade or offshoring as offering competing inputs for accomplishing various tasks, which input (labor, capital, or foreign inputs supplied via trade) is applied in equilibrium to accomplish which tasks depends in a rich but intuitive manner on cost and comparative advantage" (Acemoglu & Autor, 2011).

In the opinion of the researcher on AI, that is why there has been a conscious refocusing of European investment policy towards skills and Industry 5.0 which puts the human at the center of the technology. (A2IR)

### 5.2.6. Human-machine interaction

Organizations from science and technology system have the perception that company's motivation to invest in automation and AI is to increase productivity.

*"The argument is always productivity, but they also reach to us to re-skill workers. Companies want training, but even training is to increase productivity. The re-skilling of the worker is so that he can keep his job even though he has other functions."* (A1ED)

A1ED also claims that he has never seen dismissal of workers because of technology in the metalworking sector but he acknowledges that the criterion used, when looking for a solution, is not taking advantage of the existing resources, including the workforce. For example, when process of orders, or stocks, or maintenance are streamlined or automated it results in an increase of efficiency of the manufacturing process itself, rather than substitution of a worker because the machine will do it.

For A3SR it is obvious the importance of analysing the organizational dimensions of work in complex environments when automation and AI technologies are adopted because only with that knowledge can someone take informed decisions on how, when and in what conditions adoption of automation and AI technology is the best option for the business, the worker and society.

*"Most of our studies have been with automated systems in manufacturing industry. We have studied both the human-machine interaction in such environments and the potential impacts on the labour market and on employment in general."* (A3SR).

According to the technology suppliers, Human-machine interaction is still a research area with very few examples on the shop floor.

*"For example, in an automotive manufacturer, the gearbox is a heavy part, and it is easier to use a robotic arm. TS2P robotic arm is full of sensors, not every brand has it, and the worker only guides the payload and the robot deals with the heavy load. This is human-robot interaction."* (TS2PTC)

According to the technology supplier, TS2PTC, although robots work in a collaborative way with humans most of the time it is not a human-machine interaction. Moreover, according to him, most of the end-users do not know exactly what collaborative robots are for. They have incentives to buy them, they have heard about them, and it is more like a "trendy thing". He reported that, once, when visiting a client, he saw a collaborative robot behind a fence. According to him, collaborative robots are not supposed to be behind fences, they are designed and programmed to be in the same space as the worker and to interact with him.

**In summary,** and based on the evidence collected through the interviews, it seems that in the manufacturing industries, in Portugal, **visions of new forms of interaction between AI-enabled systems and humans are rather limited.** The idea of an "Industry 5.0" (I5.0), centred an anthropocentric technology, with technology, organisations, and working places adapted to human and societal needs, have not yet materialise in Portugal. According to evidence collected through the interviews and group discussion with workers representatives from the automotive sector, and also on some findings from industry 4.0 implementation reports (Chap 3), in Portugal, **manufacturing industries are in different stages of modernization, from industry 3.0 (EU1SPC, EU3TED) and industry 4.0 (S2W, EU4RID, EU2MPM).**

### 5.2.7. Industry 4.0 Strategy

In the case of a strategy for Industry 4.0, the technology suppliers interviewed all have one strategy to Implement this industrial transformation, the sectoral association for moulds (S1A) also have a strategy for the digital transition of the moulds sector and some of the end-users (EU2MPM, EU3TED and EU4RID) also have a strategy for digital transformation of its production processes. Moreover, S2W also has a strategy for industry 4.0 at the level of the company's group but the representative for the worker's committee does not know it nor its committee has a strategy of its own.

The most highlighted aspects from the different strategies were:

i) <u>Investment in Industry 4.0</u>

According to TS1CEO&IM, they have been investing in new Industry 4.0 technologies (e.g. computer vision, predictive algorithms, human-machine interaction, AI):

*"We (the integrator) identified computer vision inspection systems as a trend and so we created this new business area. In addition to this bet, we have also made strong investments in other areas. All contracts with industry include a mechanical part and a computer vision part, of the 12/13 M€ that we have under negotiation, around 3 M€ are for computer vision inspection systems".* (TS 1 CEO & IM)

The organizations from the science and technology system also have the perception that technological investment is not a problem since there are public incentives to do it. However, other important dimensions, such as incentives for re-skilling or upskilling the workforce and **funding for research studies on management and organization of work seem to be not covered**. (A1ED, A2IR, A3SR).

In the perspective of end-users' companies, in order to keep their competitiveness, they must keep a technological level more and more associated with computation, digitalization, robotization. In their case, investments have been mobilized from the public and own funding in a structured way (EU2MPM, EU4RID, EU3TED) and, in other cases, from own funding in a case-by-case scenario (EU1SPC).

According to EU2MPM, their investment capacity is limited because of difficulties in justifying more serious automation, but they have a strategy called factory of the future, designed in 2018, with internal budget associated. Moreover, the justification of the investments is always linked to the production volume, payback time and return on investment.

*"In this segment, having a unit working only one shift with a little more than 10 thousand units/year, it is difficult for us to justify some investments with returns equal to or less than 3 years.*

*But of course, then we have other opportunities, we can make some investments related to ergonomic issues, related to safety issues*" EU2MPM

According to the porcelain tableware production company (EU4VID) their investments in industry 4.0 are due to the lack of skilled people.

*"We have a strategy. Due to the lack of skilled workforce we are trying to search for adequate technologies. We have bought a 3D printing machine for decoration but it colours set is limited."* (EU4VID)

ii) Access to Skills

Technology providers usually sell their products ready to use or with aftersales services that cover assistance to the machinery. They also heave trainings for workers and for programmers. Industrial managers, engineers, administration, and consultants training is covered by the organizations of the science and technology system which also have 3 types of trainings that cover industry 4.0.

End-users report difficulties in keeping and attracting a skilled workforce. Some strategies have been designed to overcome this issue. For example, EU1SPC, recruits only workers with, at least a secondary level of schooling because, his perception is that these profiles are able to learn new competences and learn faster.

iii) Focus on People

In order to reply to the strategy of introducing new human-machine interaction systems with a focus on people and society (industry 5.0), according to technology suppliers, especially in big brands there have been some actions in this regard (TS2SSE). Social experts have been hired and some technological challenges are being pursued but this kind of systems are still in their infancy stage:

*"We are still very far from scenarios with collaborative robots with human-machine interaction. And now is the time to show people that robots can be trusted or under what circumstances they can be trusted. (...) For TS 2S it is an investment in the future, basically to make sure*

*that we have an ethical solution development. If you ask VW, BMW or others, they would tell you about the quality of the robots from TS 2S. Quality is important and we want to continue to sell high quality robots, but it is not everything. People will have to trust the brand and this trust will consist of more than just high-quality products and services. That is why TS 2S is considering ethical, legal, and social aspects (ELS)"* (TS 2S SE)

The motivation of technology providers seems to be the market demand for automation solutions and the potential for innovation, although safety is always a primary requisite. Even in the case of the world-leading robot supplier for the automotive sector, from the perspective of the software engineer working on the development of solutions, what motivates him is the challenge and the potential for innovation:

"*We are here to test, to discover new solutions, and then try to describe what the benefits can be, the pros and cons of the developments, and what the possible ways of using that technology are. Or what things you should not do with it"* (TS 2S D).

In the case of the integrator, many innovations result from internal innovation processes. His perception is that companies are more open to Industry 4.0 technologies.

"*We (integrator) see industry more open to invest in this kind of technologies (e.g. automation solutions, AI solutions, robots, human-machine interaction, computer vision) because they are concerned about efficiency and productivity; they perceive that it is practically inevitable to go down this path (Industry 4.0)"* (TS 1 CEO & IM)

From the training coordinator's perspective, he believes that companies are still afraid of a smart, interconnected, data-driven industry:

*"I think industry in general is still not convinced. There is a lot of information about Industry 4.0, but people are afraid. Industry 4.0 is a smart industry where data is collected and stored in the cloud and this makes a lot of confusion for companies. Today, there are still companies that don't have their machines connected to the internet."* (TS2PTC)

A fear which is based on economics rather than on social effects.

Organizations from science and technology system have the perception that company's motivation to invest in automation and AI is to increase productivity.

" *The argument is always productivity but they also reach to us to re-skill workers. Companies want training, but even training is to increase productivity. The re-skilling of the worker is so that he can keep his job even though he has other functions."* (A1ED)

A1ED also claims that he has never seen dismissal of workers because of technology in the metalworking sector but he acknowledges that the criterion used when looking for a solution is not keeping the workforce employed. For example, when process of orders, or stocks, or maintenance are streamlined or automated it results in an increase of efficiency of the manufacturing process itself, rather than substitution of a worker because the machine will do it.

For A3SR it is obvious the importance of analysing the organizational dimensions of work in complex environments when automation and AI technologies are adopted because only with that knowledge can someone take informed decisions on how, when and in what conditions adoption of automation and AI technology is the best option for the business, the worker and society. (A3SR)

iv) Infrastructure

Organizations of the science and technology system have facilities open to companies to use and test technologies.

*"We have activities to support Industry 4.0, even more than in AI. One and a half years ago we created a FAB LAB, a laboratory with pilot equipment that companies can use, which also serves for awareness actions, namely in IoT, prototyping, ML, additive manufacturing, AI, etc*" (A1ED).

Very often, end-users and technology suppliers use infrastructures available at the organizations from the science and technology Portuguese system to test and validate technologies. However, there is still a need for modernization and create the right conditions for companies to be able to rip the full benefits of AI-enabled systems.

In summary, from a theoretical perspective, the **impact of AI** on employment **is ambiguous**, it may strongly depend on the type of AI that is being **developed and implemented**, **how it is developed and implemented**, and on the **market conditions and policies**. Figure 33, shows the main results for each dimension.

| | | Main Results |
|---|---|---|
| Dimensions | AI-enabled systems Adoption and Applications | Several applications of automation and AI technologies, such as, transportation (e.g., conveyors, AGVs), handling (e.g., and collaborative robots), welding, machining, painting, assembling (e.g., conventional robots), quality inspection (e.g., computer vision and AI), predictive maintenance (eg., Big data and AI), mass customization (e.g., AI).<br><br>Main **motivations** for adopting AI-enabled systems is **increase on the competitiveness**, through **increased productivity, efficiency**, **quality, predictably, exports and cost reduction**; Although some concerns around social dimensions, safety and ergonomics exist, the first criteria to adopt an AI-enabled system is, still, competitiveness.<br><br>Although **employment** have been following the positive trend of investment in AI-enabled systems, its **growth is much lower than the productivity** generated by the automation systems.<br><br>Although AI is capable of performing some non-routine cognitive tasks, some difficulties persist in its adoption, and **many tasks still require humans** to perform them. |
| | Public Incentives and Financial Incentives | **General awareness** about the public policies for digital transformation and financial incentives.<br><br>Most of the companies have **used public financial incentives to adopt specific AI-based automation systems;** in its majority, to **support research, development and transfer to market** of emergent technologies and on the **adoption of technological apparatus**.<br><br>Incentives for **regulatory policies** in matters of AI and automation because of the risks associated with data and of authorized/ non-authorized usages of AI technology; investment policies towards **education and training** to complement technology development, research studies on **effects of automation and AI technologies** in the society and on **organisational design and innovation research studies**, are **rather limited and need to be increased**. |
| | Organization of work | The majority of the companies did **not involve their workforce in the process of adoption of AI-enabled systems**, with very few exceptions. Even these exceptions are **not really having a decisive role** but are only involved for information.<br><br>Empirical evidence based on AI applications adopted in the last 10 years does **not support the idea of a decline in employment in occupations exposed to AI-enabled systems,** though there is not much possibility for reallocating the dismissed workers due to their low qualifications.<br><br>Current policies, financing incentives, strategies and management decision is still based only on efficiency, **thus changes to the organisation of work are not expected**.<br><br>Until now, in the sectors studied, **AI is still not able to replace most of the human skills and thinking** but can replace humans operating simple tasks, in line with the framework explained by Autor (2003, 2015). |

Figure 33 - Summary of main results obtained for each dimension analysed.

Source: Author's compilation

| | | |
|---|---|---|
| Dimensions | Competences | The schooling level of the workforce, in the manufacturing industries, have been changing from a workforce mainly with the basic, primary schooling level to a **majority of the workforce with a secondary schooling level.** Since, and according to Autor, et al (2003), workers of a given skill level can perform a variety of tasks they can **adapt better to changes in the set of tasks that they perform** in response to changes in labor market conditions and technology.<br><br>**Training on industry 4.0 and emergent technologies** like AI, advanced computing, Big Data., etc**, is available**. However, until know, it was **oriented to the managers and engineers** and not so much to the workers that have to deal with these technologies in their professional activity.<br><br>Expectation that in the future, **programming language and installation will be simpler** due to the trend for frequent changes (products change every two years) and the **training will be more accessible for everyone in the workforce**.<br><br>Recently (2023), outcomes of public policies on increasing the digital competences of the workforce are starting its operations. The expectation is that it will contribute to a **more efficient, productive, qualified workforce and competitive industries**. |
| | Qualification | Although the schooling level of the workforce has been increasing, the **level of low-qualified and semi-skilled workforce is still relatively high** in the manufacturing Industries in Portugal. Usually the **workers dismissed are low-qualified workers** due to the difficulty in accommodating to other workstations.<br><br>The adoption of automation and AI technologies can have **different effects on the qualification of the workforce** that **depend on the technology design and organizational model** adopted. If the technology is designed to substitute the worker he will face a de-qualification, if it will be designed to support the worker he will face a re-qualification, in line with Autor, et al (2003) claims. |
| | HMI | In Portugal, manufacturing industries are in different stages of modernization, from industry 3.0 to industry 4.0 and visions of **new forms of interaction between AI-enabled systems and humans are rather limited.** |
| | Industry 4.0 Strategy | Most **SMEs do not have a specific digital transformation strategy**. Some of the large enterprises do have some objectives related with the Industry 4.0 model.<br><br>Several dimensions included: the adoption of technologies of Industry 4.0, training and access to skills, infrastructure, production model, HR.<br><br>**Difficulties** in implementation at companies, seem to be from the association of investment in new technologies to the production volume, payback time, high quality standards; keeping and attracting a skilled workforce; investment and conditions for re-skilling and upskilling the workforce, investment for studies on management and organization of work and access to facilities to test and use the new technologies previously to the investment decision.<br><br>**Actions** used **to overcome some of the above-mentioned issues**: recruitment of workers with, at least a secondary level of schooling because, these profiles are able to learn new competences and faster; access to the few testing facilities available at the research and technological ecosystem and participation in research and demonstration projects to convince management on the benefits of the adoption of AI-based automation systems. |

Figure 33 (continuation)- Summary of main results obtained for each dimension analysed.

## 5.3. Scenarios

Scenarios are a description of possible future states taking into consideration several characteristics or variables, based on internal (e.g. company, region, etc.) and external (e.g. statistical data, economic projections, etc.).

Taking in consideration that:

- from a theoretical perspective, the impact of AI on employment and wages is ambiguous, it may strongly depend on the type of AI that is being developed and implemented, how it is developed and implemented, and on the market conditions and policies;
- Empirical evidence based on AI applications adopted in the last 10 years does not support the idea of a decline in employment and wages in occupations exposed to AI-enabled systems and that;
- Although AI is capable of performing some non-routine cognitive tasks, some difficulties persist in its adoption, and many tasks still require humans to perform them;
- Main motivations for adopting AI-enabled systems is increase on the competitiveness, through increased production, efficiency, cost reduction, increased predictably;
- Investment decision is based on labour costs, productivity, quality of products;
- Effects that improve working conditions (work organization, Human-Machine interaction)
- Social effects (employment, qualification, training)

Based on these findings, the following **exploratory scenarios** were designed.

### 5.3.1. Scenario 1 - Focus on Substitution

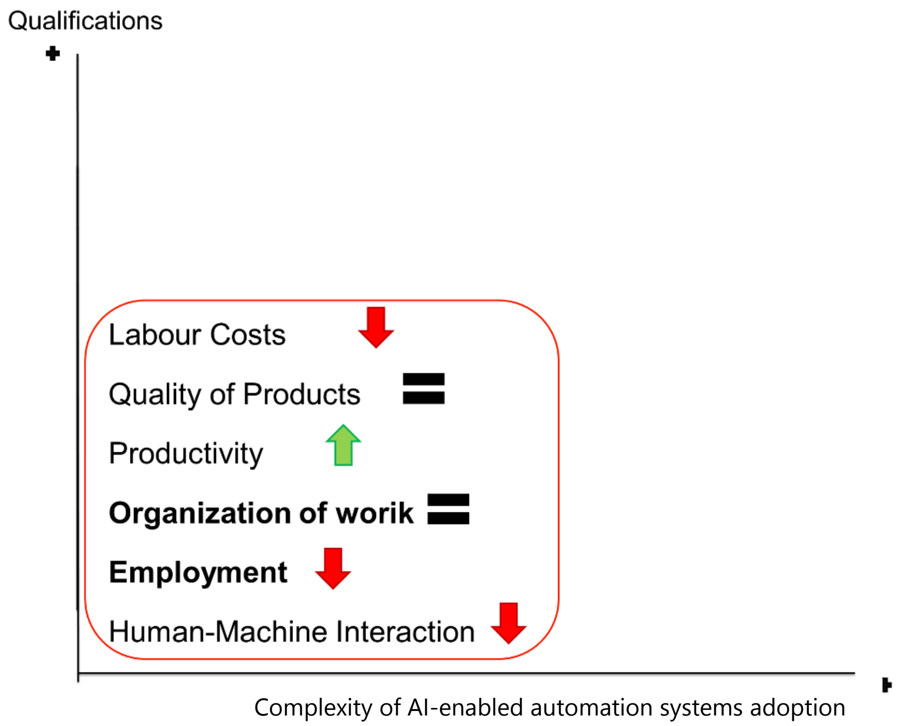


Figure 34 – Scenario with a focus on Substitution of Work.
Source: Author's analysis

This scenario (figure 34) translates what might happen to companies with a **low qualified workforce**, with a motivation to, at least, keep company's competitiveness with **adoption of existing automation technologies** which focuses, mainly, **in replacing manual, routine, and non-cognitive tasks.**

In this situation, there is no alternative to **increase productivity** through the adoption of automation technologies that substitute human factor since the workforce has not the capacity to contribute to add value to the competitiveness of the company.

Consequently, the labour costs would rise unless there is **dismissal of workers with negative consequences on employment (substitution effect).** Human-machine interaction is expected to be decreased and, over time, it is expected that qualifications of the workforce will also decrease. Therefore, the focus of this scenario is on **substitution of the human factor**. This scenario might become a possible future for **companies with simple products, with little variability, large series, standardised products, low quality and a low qualified workforce (e.g. EU1SPC, S2W).** Typically, this would be the Industry 3.0 model (automation and "electronic taylorism").

*"(...) productivity increases with the inclusion of automation; (...) greater predictability, determined time, reduces costs and all this is important to be competitive and get more contracts in the future. It has a disadvantage, in automatic welding there is no flexibility while in manual welding, if the piece doesn't turn out well, the operator can do something about it."* EU1SPC

*"(....) layout change, in the factory space, where a new robot will be placed (...). The reduction of occupational diseases is one of the causes of the introduction of robots, but on the other hand the robot will take away 3 jobs, in 3 shifts."* S2W

### 5.3.2. Scenario 2 - Focus on re-organization of work

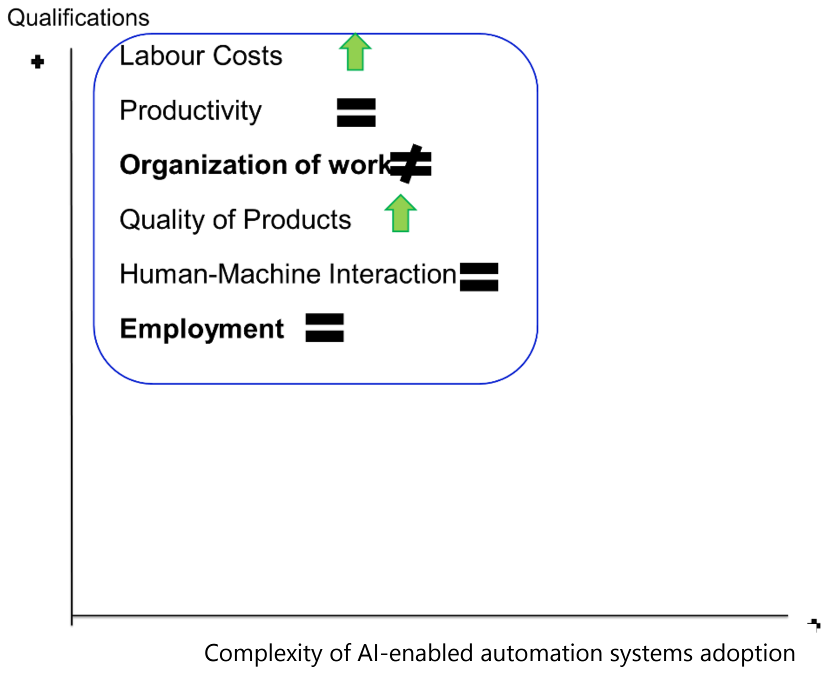


Figure 35 – Scenario with a focus on Re-organization of Work.
Source: Author's analysis

This scenario (figure 35) translates what might happen to companies with a **high qualified workforce**, highly experienced and knowledgeable of its production activity with a motivation to keep company's competitiveness with **adoption of existing automation technologies** which focuses, mainly in replacing manual, routine, and non-cognitive tasks.

In this situation, expected effect is an **increase of the labour costs**, due to the costs of automation technologies adoption, maintaining highly qualified jobs become critical to perform complex tasks. With the increase of labour costs, productivity can decrease. Therefore, in order this to be prevented, there is a **need to re-organise the work to take advantage of the highly qualified workforce and to increase the products' quality.** This means the company would introduce innovations in products or processes.

With worker involvement in more creative tasks, the working conditions are expected to improve. Finally, and since the systems adopted are automation technologies (with AI-enabled features), the human-machine interaction and employment are not expected to change. However, under this scenario, the **production process and the product characteristics do not depend on technology but on the skill and competences of all employees**.

Therefore, the focus of this scenario is on the **re-organization of work**. This scenario might become a possible future for **companies with complex, variable, small series, customized products** (e.g. EU3TED, EU4RID).

*"There are meticulous, complex pieces that can only be worked by hand, with the knowledge of many years of experience".* EU4RID

### 5.3.3. Scenario 3 - Focus on People

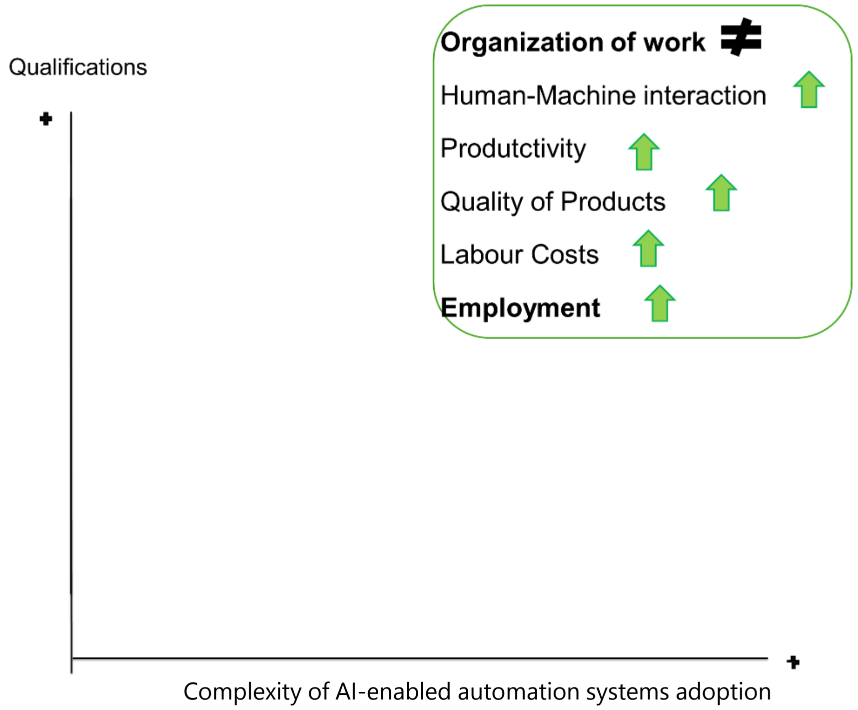


Figure 36 – Scenario with a focus on People.
Source: Author's analysis

This scenario (figure 36) translates what might happen to companies with a **high qualified workforce**, highly experienced and knowledgeable of its production activity and with a motivation to increase company's competitiveness with **adoption of AI-enabled systems which are designed to enhance the human factor.**

In this situation, expected effects are of **changes in the organization of work** to take advantage of the human-machine relationship, which, through the potential of AI (data analysis, learning, forecasting) **is expected to increase productivity and product quality**. The probability of labour costs to increase is also high. This can happen via technology and training of people for new tasks, or new hires. However, the gains in competitiveness are higher contributing to **increased employment.** It can be expected that qualifications will continue to increase over time, and functions will be more creative.

Therefore, the focus of this scenario is **on people**. This scenario might become a possible future for **companies with complex products, high quality, large series, high variability and**

**competitive in the global market.** For example, it could be the case of Bosch or Autoeuropa, if they develop the concept towards Industry 5.0.

#### 5.3.4. Scenario 4 - Focus on Efficiency

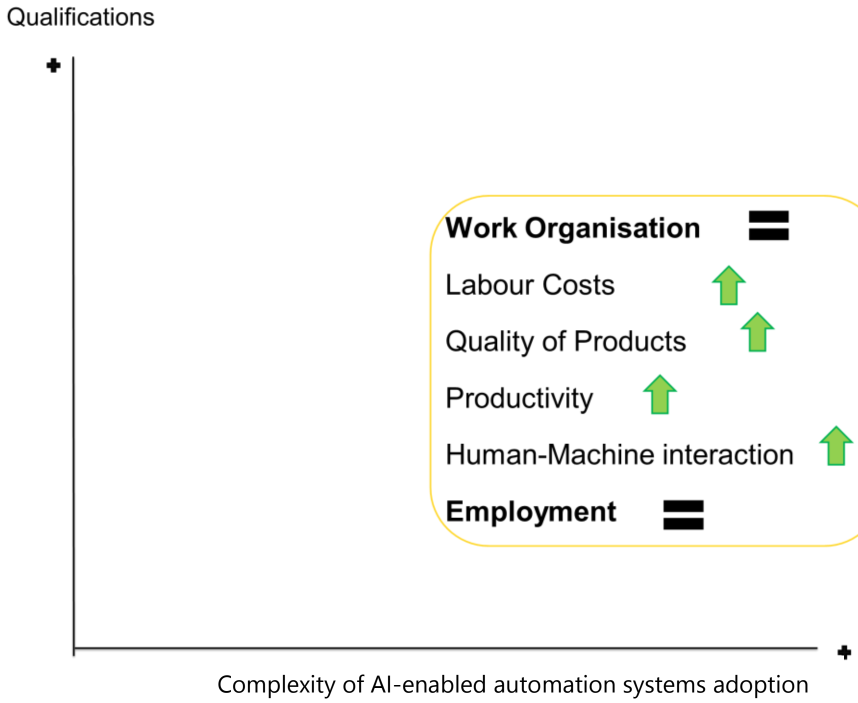


Figure 37 – Scenario with a focus on Efficiency.
Source: Author's analysis

This scenario (figure 37) translates what might happen to companies with a **low to medium-qualified workforce** and with a motivation to increase company's competitiveness with **adoption of AI-enabled systems**.

In this situation, expected effects are off **no changes to the organization of work**, increase on Labour costs and on the quality of products contributing to an **increase in productivity**. The Human-Machine interaction is expected to increase initially and, over time, to be decreasing with a de-qualification of work. **No changes are expected to the employment**. However, possibilities of "technological unemployment" can be created.

Therefore, the focus of this scenario is on **Efficiency and typical of the application of the Industry 4.0 model.** This scenario might become a possible future for **companies with complex**

**products, high quality, large series, high variability and competitive in the global market**. Some examples are EU4RID or EU2MPM.

## 5.4. Scenario assessment of AI implications for employment in Portugal [31]

The debate around the relationship between Artificial Intelligence (AI) and work is very recent in Portugal. Since the 1980s, several studies have been carried out in Portugal on the relationship between employment and automation in industry and, since then, research has been applied to cases where the relationship between technology and work is analysed at a micro level. There have been few studies on this relationship in sectors or regions, or in professional groups, and even less on the impact at national level or at the level of the job market.

The analytical approach was almost exclusively limited to the analysis of labor relations, and the economic approach, especially the economy of labor markets, is almost non-existent in Portugal. Thus, although the tradition of research on the relationship between technology and employment is important at an international level, in Portugal it was and still is very limited.

Considering this context, the difficulty can be increased because the development of technology in work environments has evolved a lot in recent decades. Not only the diffusion of production automation technologies (robotics, numerical control, mobile systems, etc.) can be witnessed, but these technologies have come to have new characteristics that interfere with conventional models of human interaction with machines. And, in particular, this happens in the labour sphere, with clear implications for **employment**. However, regarding the Portuguese reality, there are no reliable data on the volume of installation of these technologies. Neither in general, nor by sector. Even less is known on reliable statistical series on the investment in this equipment.

[31] Based in the presentation made together with A. Moniz for the Portuguese Congress of Sociology, April 2023, APS, Coimbra, with the title "Inteligência Artificial e seu impacto no emprego: avaliação de cenários para Portugal".

At the same time, data on the qualifications of the workforce in Portuguese industry is still very limited. The information on **qualification** does not correspond to what is currently understood by this concept. The classification is left to the companies themselves considering sectorial collective agreement systems that are already very outdated. The only variable that could be feasible would then be the one related to the acquired formal educational level. But the "training" or "competence" component is not integrated by the Ministry of Labour's statistics in the "Quadros de Pessoal".

The implications of digitalisation are crucial for current jobs for which development of new skills will be needed, and also for those new jobs that will be created based on new skill requirements. New areas of training that consider these new technological domains are vital. In fact, **these new processes require scenarios that allow anticipating trends in technological areas, as well as qualification needs, and therefore training**. **The existence of different scenarios makes it possible to establish a diversity of options promoting informed choices, whether by entrepreneurs, workers' representatives or public policy agents.**

# CHAPTER 6 CONCLUSIONS AND RECOMMENDATIONS

## 6.1. Outcomes on the scenario exercise

From the scenario exercise, and in line with the framework of Acemoglu and Restrepo (2018), four exploratory futures have been Identified: 1. Focus on **substitution of the human factor**, 2. Focus on **re-organization of work**, 3. Focus on **People** and 4. Focus on **Efficiency**.

As a conclusion, the replacement of human labour by machine with cognitive functions is not always going to happen. There are still technological limitations. Moreover, if half of all jobs were eliminated in ten years, social conflicts may become "wild cards", in addition to the ones already identified like the energy crisis and electrification which can lead to the scenarios with less adoption of technological systems (Focus on substitution of the human factor and Focus on re-organization of work).

The determinist perspective also forgets that the pure replacement of humans by automated AI-based systems is not the only solution: human-machine collaboration makes it possible to considerably reduce arduous work tasks. Close complementarities between human labour and AI, is an equally likely option.

Finally, the trends observed for **each scenario depend on the various initial conditions** and, above all, **on the motivations and orientations of business strategy** and the **on main social actors in presence**.

As it is, **incentives to adoption of technology without orientations to the organization of work, public policies and financial incentives would lead to a scenario focused on substitution of the human factor or to the scenario focused on efficiency**. However, with the recently initiative announced that promotes organizational and process innovation it might be an incentive for the scenario focused on people.

## 6.2. Outcomes on AI, automation and jobs

The research developed shed some light on the implications of automation and AI in the Portuguese manufacturing industry. Some findings point to the idea that productivity increases have a direct relation with the capital investments (proxy for automation, including AI). The main argument that relates productivity with labour costs seems not to be central. The present strategies towards improvements to productive capacity are derived from automation efforts, including the development of artificial intelligence.

However, though automation affects productivity in a positive way, it is only one of several factors that weigh in the investment decision to adopt automation and/or AI. Many factors can be considered, as the return on investment, the existent lack of competences on the labour market, the skills to operate the new automated systems and on the type of products and production models in place. Obstacles can also come from the resistance of managers to adopt new technological solutions in larger companies, which may imply job displacement or dismissal.

Findings suggest that employment has not been affected with recent automation trends in Portugal. Although automation affects productivity in a positive way, it requires an adequate infrastructure to integrate automation technologies and skilled workers to operate it.

AI has further challenges such as technological limitations and need for specific knowledge associated with the development, understanding and recompute new algorithms, control of the AI system and production, immateriality of software and increase complexity at management level, among others.

AI presents further obstacles related to industrial mass production. There are questions related to the lack of flexibility to respond to variation in production and also the wide dissemination of automation and AI appears to be a challenge.

The transfer of these technologies inside the value chain or outside the analysed sectors requires companies with high levels of modernization. Thus, there can be asymmetric social and economic implications because different dynamics (delay or an acceleration) can occur when trying to implement automation and AI solutions across companies. In other words, **this may lead to polarization within sectors and/or value chains when the majority of companies are not able to cope with these solutions, and only a few are better connected in the global production system and have resources to adopt it.**

A reduction of the weight of low qualified workers in the employment structure in the Portuguese automotive sector is also indicating that skilled workers are better prepared to deal with these technologies. If this impacts on the action of social partners, is still not clear.

Some companies studied in this research activity are classified as a medium-high-technology industry. However, those firms still have most tasks done by humans that could be automated, for example in the final assembly line. In other cases, the motivation for investments in automation and AI seems to be linked to the lack of workers to perform physically intensive and/or repetitive tasks. In fact, until now, in the sectors studied, it seems AI is still **not able to replace most of the human skills and cognitive capacities** but **can replace humans simple tasks**, in line with the framework explained by Autor (2003, 2015). Therefore, **in a short to medium term, automation will not replace workers but augment their capacity to perform their tasks and alleviate their burden.**

Although some research and innovation projects may already have some results, there are still technological challenges that remain unsolved. On one hand, these systems, in essence, assist operators as they manage to make a detailed analysis that is more adequate to the objectives of the task, increasing the efficiency of the process. On the other hand, these technologies seem to lead to a displacement of the operator to conduct control and supervision tasks.

In the cases of AI-enabled automation assessed it could not be concluded that there are implications in employment, but findings, in this research study, suggest there may be implications for the organization of work. In other words, investments in AI and automation can be done by firms without substituting operators but rather by changing work organization **(Scenario 1 - Focus on re-organisation)**. **Furthermore, and according to the results of the scenario exercise, there are four different possible situations, according to the various initial conditions, company's motivation, business strategy, public policies in place and main social actors involved.**

Thus, the debates and social anxiety about automation and AI are not totally substantiated by the results of this research study.

In any case, a lower level of intensification of automation has implications mainly in the organisation of work and may imply job displacement. The technology costs may not be able to compete with labour costs resulting in a delay of industrial transformation unless large production volumes or high-quality products are needed. The delay itself can lead to the decrease of competitivity, decay on the value chain and need for job restructuring.

The expectations for many social actors about the recent automation trend, including AI, in Portugal is that it can produce an increase in productivity. Besides these high expectations, it is also foreseen an increase in complexity of the technological apparatus and in management by companies. The intensification of the dependency on new automation and AI artefacts, calls for preparation of the company to deal with technical problems, maintenance, health and safety, and security regarding its investment.

Although several implications of Industry 4.0 need to be addressed, nothing is being proposed by the government about the digitalisation of manufacturing, even after many robots have been introduced. Social partners have no concrete proposals on the impact of the process of digitalisation on employment – apart from the need for further training, that algorithms should be regulated, and that further legislation should be issued on autonomous AI behaviour. Besides these topics, unions propose the need for stable jobs in the context of digitalisation, and employers the need for further legislation and incentives for investment.

**Evidence suggests that automation can have widespread adoption in the short-term, but AI technologies are still in their initial phase of implementation and will take more time to be adopted**. In an automation or AI project designed to improve productivity, **it should be taken into consideration the developments in work organisation**, otherwise the projects can have limited implementation and be postponed (or even forgotten).

Findings clearly suggest that there is a need to **support a balance of investment and regulatory policies** in matters of AI due to the **risks** related with **data** and of authorized/ non-authorized **usages of AI technology**; investment policies towards **education** and **training** and **organizational innovation** to complement with technology development.

Several dimensions influence the adoption of AI-enabled automation systems and their effects at societal level. AI-based systems design and implementation should take in consideration not only the technological dimension but also social dimensions, such as, competences and qualifications of the workforce, organisation of work, and human behaviour, especially relevant for human-machine collaboration. Ethics, legal and safety aspects should become a must in every AI-based system design in order to increase confidence and trust to use AI based artifacts.

Importance of scenarios on new processes were highlighted to understand and evaluate possible changes that will allow **anticipating trends.** The existence of different scenarios makes it possible to **establish a diversity of options promoting informed choices**, whether by entrepreneurs, workers' representatives or public policy agents.

Only by taking a socio-technical approach when designing and implementing AI-based automation systems and anticipate strategies and incentives to achieve the best possible scenario, will the digital transformation of the shop floor be successful.

## 6.3. Will AI in the automotive sector be a challenge to the product electrification? Which consequences for labour in Portugal? [32]

Besides the restructuring process transition to the electric vehicle, it is necessary to consider the transition as well towards intelligent automation. The Portuguese sector is characterised by a strong dependency on the value chain as high-end supplier. Thus, the restructuring transition in the automotive sector (electrification and automation) has a strong impact on the whole employment sectoral structure. In fact, intelligent automation will require data from the whole automotive value chain, which means a sophistication of both suppliers and OEMs will be needed.

The transformation of the structures and systems that underpin the automotive industry are mostly related to the **following factors:**

a) **the rapid technological developments leading to improvements in design and manufacturing,**
b) **increases in digital driving systems,**
c) **the changing of consumer preferences,**
d) **the growing concern about sustainability and climate change and finally**
e) **the regulatory pressures and measures.**

An example of such transformation is the rapid rise in the global supply and demand for electric vehicles (EV). In terms of technological developments, these are being integrated into already highly advanced manufacturing in order to reduce lead times and increase customization. Furthermore, digitalization is disrupting the entire automotive supply chain, from product design to the sale of automobiles. As Portugal has a main expertise on the supply level, these changes will affect deeply the labour market structure in the sector. For the whole global value

[32] Based on the presentation by Candeias and Moniz, with the same title as this sub-chapter, to be presented the *31st International GERPISA Colloquium*, Brussels, Free University of Brussels, Parallel session No 19, June 29th, 2023

chain, the advances are also enabling manufacturers to offer new products and services, such as EVs and (in less extend) automated vehicles (AVs).

Antonialli et al. (2022) refers that AI is opening the door for significant changes by activating essential innovations. And they focus on three of them: "Firstly, AI is orchestrating 'mobility-as-a-service' (MaaS), allowing a user-centred customized multimodal sustainable mobility. Secondly, AI is pushing forward the market introduction of autonomous vehicles (AVs), enabling them to drive on open roads towards safer and cheaper mobility. Thirdly, AI is renewing public transport with on-demand automated collective services for better coverage and connection with isolated areas, offering more inclusive and flexible mobility choices" (Antonialli et al., 2022: 325-326). However, these are changes in the product and in the market shape. One, of highly significance, could also be added: the innovation on the manufacturing production system.

The digitalization process in this sector is set to revolutionize the entire automotive supply chain. Interconnected supply chains improve end-to-end management of the production process and drive down costs and lead times through partner system integration and advanced data and analytics.

This can be done together with increase of efficiency of the process from design to manufacture and distribution. As the ILO report underlines, "digitalization is further altering the automotive value chain through the predictive maintenance of vehicles. (…) Continuous data analysis enables a system of preventive maintenance that reduces critical failures of vehicles, enhances driver safety and lowers the frequency and severity of recalls" (ILO, 2020: 18). AI applied through the concept of Industry 4.0 accelerates the digitalization process of the whole value chain and enables the production capacities for new products. Autonomous vehicles were already mentioned, but the electrification of engines will become a major factor of change.

There are still several contradictions and tensions in the transition process. As Pardi underlines, "the transition towards carbon free transports cannot be left to technological roadmaps and market coordination alone as highlighted by the past failure of this regulatory approach. It requires a comprehensive policy that the EC does not seem to be able to conceive" (Pardi, 2021: 177). In his study, Pardi proves that the electrification process is increasing a market shape in Europe that provides larger and heavier electric vehicles which are much more expensive than the conventional ones. This can refrain the renewal of fleet and the sustainability of the market in the future once it is very socially unbalanced. However, most European OEM still prevail with the same strategy of the last decades. "The parameter by which the CO2 target for each carmaker is based on the average weight of the vehicles sold, meaning that if the vehicles are heavier the targets are less demanding than for lighter vehicles" (Pardi, 2021: 163), continues the coordinator of the GERPISA network.

The challenges of digitalization, their readiness and capability to adapt to the challenges of digitalization depends upon the size of companies: the smaller the SME, the more likely it is to suffer rather than benefit from the industry-wide changes brought about by digitalization. As it has been seen, with the electrification of vehicles in Europe, the legislation is also promoting the premium carmakers, which are the larger OEM. This also puts a large pressure over the supply chain. In terms of sectors, in the German automotive supplier industry, about 54% of the companies report strongly or predominantly automated production; in 36% of the firms the production is characterized as mixed, i.e. it consists of automated and predominantly manual areas; only 10% of firms still have predominantly manual production (Krzywdzinski, Jürgens, and Pfeiffer 2016). It is probable that, with the increase of electric vehicle production, these figures will intensify. **In other words, the predominantly automated companies will even be increasing in number, and the manual production will become almost residual.**

The Portuguese report for ILO mentioned that "interviewees have stated that Industry 4.0 applications and automation are a reality, including robots, cobots and AI. For example, technological development continues to advance at Mitsubishi Fuso, as evidenced by the November 2020 announcement of a new tool using machine learning and advanced language processing techniques to improve quality management processes. Yet, there is a visible gradient in technology adoption between large firms and SMEs. The current focus is on digitalization rather than automation, as automation levels in the industry are traditionally high" (ILO, 2022: 50) in the automotive sector.

From other research activity in the scope of this research study, "therefore, the expectation is not for automation to replace workers but augment their capacity to perform their tasks and/or alleviate burden, in the short time. Robotics, automation, and computational vision will have widespread adoption in one to two years. However, cloud, plug and produce, blockchain and AI will take longer to be implemented as they involve connectivity, monitoring, data collection and automated decision making with implications at management level" (Moniz, Candeias and Boavida, 2022: 236).

But, if it is expected a job substitution at OEM due to the electrification of powertrain, the impact of this transformation will also impact the supplier's industry. This may have an increased impact on the Portuguese labour market of the sector. Just to have an idea about the recent technology investment changes, considering OEM and suppliers, a study from G. Anzolin et al. (2020) suggests "that it is difficult to claim strong correlation between inward

FDIs and industrial robots' adoption in the automotive sector, especially when we look for patterns across different segments of the value chain – assembling and components production – and for different types of components. However, there exist some interesting FDI related patterns that characterise the adoption of new technologies. That is, the heterogeneity of FDIs-led robotisation especially when comparing the automotive OEM with automotive components" (Anzolin et al., 2020: 230-231). They also confirm that automotive OEMs clearly are the main drivers of robotisation. "This is largely expected because OEMs are large in size, have a high market power and have the capacity to invest in new technologies and because of the operations they perform" (Anzolin et al., 2020: 231).

As it has also been confirmed in this research study empirical analysis, these authors also refer that the automotive OEM "are the first adopters of industrial robots in their new facilities, and this is increasingly the case with the increase in quality standards and safety issues that led to the introduction of, for instance, electrostatic coating in the paint shop and different types of new laser and spot welding robotic cells in the press shop and body shop. On the other hand, they could also activate foreign capital inflows involving components suppliers, especially big international Tier 1 suppliers which are closely linked to OEM operations (Anzolin et al., 2020: 231).

However, and in line with Pardi, Krzywdzinski and Luethje "even in routine based standardized jobs in the assembly line, when product complexity and variability is high, human work and tacit collective skills remain central in order to cope with uncertainties and non-standard work situations.

Trade unions should pay attention to the status of this 'real' collaborative work, the recognition of the tacit skills involved, as well as the conditions under which these skills are integrated (or not) in new digital manufacturing system. Trade unions should try notably to be actively involved in the design and implementation of these technologies whenever possible. They should challenge in particular the top-down revival of the 'high technology drive for automation for the sake of automation pushed by consultants and technology providers and engage with local engineers and factory managers in bottom-up 'human fitting and motivating' automation strategies" (Pardi, Krzywdzinski and Luethje, 2020: 22).

**This process to technological transition towards electrification and digitalisation in the automotive industry, will imply a large impact on the employment structures of countries where the supply of components plays an important role. The impact will be especially important in terms of new qualification needs for the workers that remain working in the sector, and on the substitution based on the product automation features.**

The challenges will demand a strong participation of workers representatives (unions and workers committees) in the negotiation of technology development and application modalities. The competences for such negotiation will become critical for the success of the industry in Portugal. This success involves all social partners and not only workers. In this regard, public policies supportive of these initiatives may be critical.

## 6.4. Recommendations

Based on the evidence collected and analysed under this research study, all research questions and respective hypotheses were confirmed.

Empiric evidence on motivations from the manufacturing industry did confirm hypothesis one (Motivation for investment in AI-enabled automation is due to the association of these technologies with cost reduction, increased product quality, increased productivity, increased exports to the global markets). Several testimonials supported this hypothesis as competitiveness driven by cost reduction, increased product quality, productivity, exports, bigger predictability and efficiency. Although there are signs of some concerns around social dimensions, safety and ergonomics, the first criteria to adopt an AI-enabled system is, still, competitiveness.

The knowledge on the public policies for digital transformation and respective financial incentives as well cases of how these were used by some companies confirm hypothesis two (Motivation for investment in AI-enabled automation is due to the availability of financial incentives, from public policies, for digital transformation). No only, but also because, although some companies did not use the public incentives they became aware of the digital transformation topic and all its issues. From the scenario exercise and also from the empirical evidence it was possible to confirm hypothesis three (There is no involvement of the workforce in the AI-enabled automation adoption process led by its employers). The majority of the companies did not involve their workforce in the process of adoption of AI-enabled systems, with very few exceptions. Even these exceptions are not really having a decisive role but are only involved for information and awareness.

Investment in AI adoption and the impact of AI-enabled automation on productivity and employment through the statistical analysis, evidence on the concerns and attitudes of the workers to the implementation of AI-based automation and the scenario focused on efficiency, all contribute to findings that confirm hypothesis four (The implementation of AI-enabled automation technologies in the manufacturing industry results in an immediate productivity increase which, in turn, increases the company's competitiveness generating additional business opportunities and thus, increasing employment. However, since there are no changes in the work organization, the employment growth is not sustainable). Although employment have been following the positive trend of investment in AI-enabled systems, its growth is much lower than the productivity generated by the automation systems. Moreover, scenario "Focus on Efficiency" describes exactly this situation and according to the interviews is already happening in some companies In Portugal and Spain.

Evidence on the perceptions on what might occur to the organisation of work with the AI-enabled automation adoption derived from the interviews but also from the four exploratory scenarios identified, confirm the hypothesis five (There are no changes on the work organization due to the AI-enabled automation adoption). Specifically, in two of the scenarios (focus on substitution and focus on efficiency), which are the most probable ones for manufacturing companies in Portugal, if the current policies, financing incentives, strategies and management decision are kept, changes to the organisation of work are not expected.

From the statistical analysis and from empirical analysis, some insights on the level of qualifications of the workforce, directly or indirectly, working with AI-enabled automation systems were identified, which confirms hypothesis six (The implementation of AI-enabled automation technologies, in the manufacturing industry, does not increase the qualifications of the workforce working directly with these AI-enabled automation systems). Although one of the scenarios (Focus on People) foresees that qualification can be expected when dealing with AI-enabled systems, from the statistical analysis it was possible to conclude that low-skilled or semi-skilled workers are decreasing, in most of the cases, this is not what will happen. Most of the cases assessed included displacement of workers to functions of supervision and intervention only when the system had a problem, or dismissal of the workers. Few cases reported qualification due to AI-enabled systems and are limited to the maintenance workstations.

Finally, knowledge on different roles of the human when interacting with AI systems are translated in the scenarios exercise and confirm hypothesis seven (There are multiple visions about the role of humans on the interaction with AI-enabled automation.). From the four scenarios identified derives the vision of no interaction, low-Interaction and collaborative interaction. However, new forms of collaborative interaction between human and machines are still far from being reached.

According to this research study and based on the literature review, there is a role for society to play in the definition of what kind of work we want for our future. Given the important role of work for human life this is a discussion that should not be ignored and should be enlarged to the workplace of manufacturing Industries. Scenario focusing on substitution of the human factor should be avoided and Scenario focusing on People should be promoted.

Therefore, **three main recommendations** are here presented to contribute to this outcome:

1) Set-up a TA working group that could follow-up on impacts of technologies and anticipate future threats and opportunities. Such working group could contribute to increase the access to data, information and knowledge upon which better decisions can be made. In this case, and as an example, it could be considered the AI-enabled automation systems adoption that should be followed closely to make sure the "right kind of AI" is being implemented and the scenario Focus on People to be promoted;

2) Adapt public policies and financial incentives to focus, not only on technological adoption but also on organisational, innovation and foresight processes;

3) Organise debates and discussions around the issues of digital transition oriented to the social groups that might be affected (eg., low-skilled and semi-skilled workers, workers with routine and repetitive tasks) by that transition.

This research activity had some limitations. The time to develop this study was shorten by the restrictions originated by the pandemics in 2020 and by the termination of the PhD program. There was not enough time to go through all the evidence collected and some of the visits to factories were not performed.

An extensive study, resulting in a framework to guide the companies in the adoption of AI-enabled systems, should be considered in future research activities. Furthermore, sectoral case studies research, anticipatory studies and new models for the organisation of work should also be part of future research in this field.

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A

# ANNEX 1 SEMI-STRUCTURED INTERVIEWS

## A1.1. Interview Protocol

- Interview Protocol for Sectoral Associations
- Interview Protocol for Research and Technological Organizations
- Interview Protocol for Technology Suppliers
- Interview Protocol for Academia
- Interview Protocol for Workers' Representatives
- Interview Protocol for End-User Companies

# Impact assessment of AI-enabled automation on the workplace and employment

## Interview Protocol

---

Interviewed profile:

Name:

Date:

Place:

---

Introduction to the research activity

Information about the usage of the data collected

Getting Consent

# Questions to Sectoral Associations

1. Do you have or have been developing a **strategy for Industry 4.0?**

Yes [_]

No [_]

2. Why?

   1. **Public incentives**? [_]
   2. Topic **Information/ awareness**? [_]
   3. Workers' **qualification**? [_]
   4. Workers' **skills**? [_]
   5. Other? [_] ______________________________

3. If answer to 2. a)

Do you know how many of your associated companies tried to get information about **public incentives** to develop Industry 4.0 projects? Please, provide examples: __________

Do you have been in contact with the Ministry of Economy and Digital Transition, or through its public organizations (IAPMEI, Investment Bank, secretaries of state), to get information about **public incentives**?

Yes [_]

No [_]

4. If answer to 2. b)

Where have you got **information** from/ How do you have been creating awareness on the subject? ____________

5. If answer to 2. c)

How many **qualified workers** are there in your sector? [___]

How many **qualified workers** are needed today in your sector [___]

How many **qualified workers** would be needed in 5 years' time? [___]

6. If answer to 2. d)

Are there studies on the **impact of Industry 4.0** on your sector?

Yes [_]

No [_]

If yes, can you give some examples? ___________

7. In your perspective, what would be needed for Portuguese companies to **adopt Industry 4.0**?
________________________________________________________________

8) Have companies asked you for information regarding Industry 4.0?

Yes [_]

No [_]

9. What is your perspective on your sector in 5 years' time?

1. Labour Market:
2. Available Technology:
3. Competitiveness of Portuguese products:
4. Foreign Investment:

# Questions to Research and Technological Organizations

1. Do you have or have been developing a **strategy for Industry 4.0?**

Yes [_]

No [_]

2. Why?

**a. Public incentives**? [_]

**b**. Topic **Information/ awareness**? [_]

**c**. Workers' **qualification**? [_]

**d**. Worker's **skills**? [_]

**e**. Other? [_] ______________________

3. If answer to 2. a)

How many companies tried to get information about **public incentives** to develop Industry 4.0 projects from you? Please, provide examples: ___________________________

Have you been in contact with the Ministry of Economy and Digital Transition, or through its public organizations (IAPMEI, Investment Bank, secretaries of state), to get information about **public incentives**?

Yes [_]

No [_]

4. If answer to 2. b)

Where have you got **information** from/ How do you have been creating awareness on the subject? ____________

5. If answer to 2. c)

How many **qualified workers** are there in your sector? [___]

How many **qualified workers** are needed today in your sector [___]

How many **qualified workers** would be needed in 5 years' time? [___]

6. If answer to 2. d)

Are there studies on the **impact of Industry 4.0** on your sector?

Yes [_]

No [_]

If yes, can you give some examples? __________

7. In your perspective, what would be needed for Portuguese companies to **adopt Industry 4.0**?
______________________________________________________________

8. Have companies asked you for information regarding Industry 4.0?

Yes [_]

No [_]

If yes, at what level?

1. **Technological** [_]
2. **Training** [_]
3. **Organisation of work** [_]
4. Other: [_] ____________
5. Examples:__________________

If you gave examples, where there **impacts** and what were its effect at the level of:

6. **Productivity** [_] ____________________________

7. **Organisation of work** [_] ____________________________

8. **Qualifications** [_] ____________________________

# Questions to Technology Suppliers

1. How **many robots** are there in companies in Portugal? In what sectors? How many of those were installed by your company and what were the main sectors? ___________________

2. Which of your products requires **specific skills** from the workers? Why? _________________________________________________________________

3. How many of your products do not need workers/ are able to work automatically? _______

4. Who does the installation of your products? Is it done directly by you to your clients or is it done by software companies? Is there a preference? Why? _________________________

5. Are there **suggestions** given directly by the workers during the installation process of your products?

Yes [_]

No [_]

6. Are there **suggestions** from the client's engineers during the installation process of your products?

Yes [_]

No [_]

7. Is there usually a **dialogue between all interested parties in the process** or are usually the requirements specific enough to not have this into consideration?

Dialogue [_]

Specific Requirements [_]

8. Does the **programming leve**l have become more complex in the last years?

Yes [_]

No [_]

9. Des the programming have become more intuitive and therefore easier to use without **specific training**?

Yes [_]

No [_]

10. Do you have/ have been developing a **strategy for Industry 4.0**?

Yes [_]

No [_]

11. If yes, what kind of strategy? ______________________________________________

12. If not, why?

a. lack of **public incentives** [_]

b. lack of **information** [_]

c. Other [_] ________________________________

13. Are there already new concepts of **Human Machine Interaction** on the shop floor?

14. Did **technology development have social and organizational dimensions** in consideration?

Yes [_]

No [_]

15. Why? _________________________________________________________________________

16. About the **responsibility of operation**, is it usually responsibility of:

a. workers [_]

b. team coordinators [_]

c. engineers/ technical personnel [_]

d. autonomous decision systems (algorithm) [_]

17. When an unexpected event occurs may the worker stop the system? Is it self-regulated?

Worker [_]

Self-Regulated [_]

18. Why? ___________________________________________________

19. In your perspective, what would be needed for Portuguese companies to **adopt Industry 4.0?** ___________________________________________________

20. What is your perspective for your sector in 5 years' time?

1. Labour Market:

___________________________________________________

2. Available Technology:

___________________________________________________

3. Competitiveness of Portuguese products:

___________________________________________________

4. Foreign Investment:

___________________________________________________

# Questions to Academia

1. Your research is related to Industry 4.0. Which are the main **research topics/projects** developed in your group? ______________________________________________

2. How are they financed?

   a. **Public incentives** [_]

   b. Own funds [_]

   c. Private funds [_]

   d. Other [_]

3. By whom? Examples: ____________________________________________

4. Do you usually have **stakeholders** involved in the research process?

   Yes [_], Which?

   1. Unions [_]
   2. Professional associations [_]
   3. Employers associations [_]
   4. Academics [_]

   No [_], Why? _____________________________________________

5. Do your research projects also integrate **concepts of human-machine interaction**?

   Yes [_]

   No [_]

6. And do they approach the **social and organizational dimensions**?

   Yes [_]

   No [_]

7. Why?_______________

8. What do you think is needed to implement Industry 4.0?

1. **Technology** [_]
2. **Training** [_]
3. **Organisation of work** [_]
4. Other: [_] ____________
5. Examples:__________________

9. What do you think the social effects of Industry 4.0 will be? At the level of:

6. **Productivity** [_] __________________________
7. **Organisation of work** [_] __________________________
8. **Qualifications** [_] ___________________________

10.What is your perspective on your sector in 5 years' time?

1. Labour Market:

______________________________________________________________________

2. Available Technology:

______________________________________________________________________

3. Competitiveness of Portuguese products:

______________________________________________________________________

4. Foreign Investment:

______________________________________________________________________

# Questions to Workers Representatives

1. Do you have/ have been developing a **strategy for Industry 4.0?**

   Yes [_]

   No [_]

2. Why?

   **a. Public incentives?** [_]

   **b**. Topic **Information/ awareness**? [_]

   **c**. Workers' **qualification**? [_]

   **d**. Worker's **skills?** [_]

   **e**. Other? [_] ________________________

3. If answer to 2. a)

   Are you aware of any **public incentives** to develop Industry 4.0 projects? ____________

   Are you in contact with the Ministry of Economy and Digital Transition, or through its public organizations (IAPMEI, Investment Bank, secretaries of state), to get information about **public incentives**? ___________

4. If answer to b)

   Where have you got **information** from/ How do you have been creating awareness on the subject? ____________

5. If answer to c)

   How many **qualified workers** are there in your company? [___]

   How many **qualified workers** are needed today in your company? [___]

   How many **qualified workers** would be needed in 5 years' time? [___]

6. If answer to 2. d)

Are there studies on the **impact of Industry 4.0** on your company/ sector?

Yes [_]

No [_]

If yes, can you give some examples? ___________

7. How long are there, in your company, **industrial robots/ automation systems**? _____

8. Can you give some examples? _________________

9. As a **worker representative**, have you been **involved in the choice and installation** process of those systems?

Yes [_]

No [_]

10. In the installation process of robots/ automation technologies is there:

a. **Dialogue with the workers representatives** previously to the installation process about technical requirements [_]

**b. Training to workers** to use those systems [_]

**c. Training to maintenance workers** to perform maintenance to those systems [_]

**d. Training to engineers and technical personnel** and articulation afterwards with the workers of those systems [_]

**e.** System's performance assessment with **the involvement of the workers' representatives** [_]

**f. Definition of work teams** to use the system [_]

**g. Workers were not involved** in any stages of the process [_]

11. Did the installation of robots/ automation systems have effects on the **organisation of work**?

Yes [_]

No [_]

12. If yes, where at the level of:

a. Workplace substitution by robots/ automation/ AI [ ]

b. Job requalification [ ]

c. Building work teams with job rotation [ ]

d. Building work teams with job enlargement [ ]

If yes (12. d), was it :

- Horizontal – integration of several tasks in the same workplace [ ]
- Vertical – integration of distinct functions in the same workplace [_]

Examples:______________________________________________

13. As a workers' representative, are you interested in being involved in the negotiation of future robots/ automation/ AI installations?

Yes [_]

No [_]

14. In your perspective, what would be needed for Portuguese companies to **adopt Industry 4.0**? _________

15. What is your perspective on your sector in 5 years' time?

5. Labour Market:

____________________________________________________________________

6. Available Technology:

____________________________________________________________________

7. Competitiveness of Portuguese products:

____________________________________________________________________

8. Foreign Investment:

# Questions to End-user Companies

1. How **many robots** are there in your company? In what applications?

2. What have been the gains and/or limitations of those robots?

3. Do you have or have been developing a **strategy for Industry 4.0?**

Yes [_]

No [_]

4. Why?

6. **Public incentives**? [_]
7. Topic **Information/ awareness**? [_]
8. Workers' **qualification**? [_]
9. Worker's **skills**? [_]
10. Other? [_] ____________________________

5. If answer to 2. a)

Are you aware of any **public incentives** to develop Industry 4.0 projects? ____________

Are you in contact with the Ministry of Economy and Digital Transition, or through its public organizations (IAPMEI, Investment Bank, secretaries of state), to get information about **public incentives**? ___________

6. If answer to 2. b)

Where have you got **information** from/ How do you have been creating awareness on the subject? ____________

7. If answer to 2. c)

How many **qualified workers** are there in your company? [___]

How many **qualified workers** are needed today in your company? [___]

How many **qualified workers** would be needed in 5 years' time? [___]

8. If answer to 2. d)

Are there studies on the **impact of Industry 4.0** on your company/ sector?

Yes [_]

No [_]

If yes, can you give some examples?

______________________________________________________________

9. Is there usually a **dialogue between all interested parties in the process** or usually the requirements are specific enough to not have this in consideration?

Dialogue [_]

Specific Requirements [_]

10. Did **technology development have social and organizational dimensions** in consideration?

Yes [_]

No [_]

11. In your perspective, what would be needed for Portuguese companies to **adopt Industry 4.0**? ______________________________________________________________

12. What is your perspective on your sector in 5 years' time?

5. Labour Market:

______________________________________________________________

6. Available Technology:

______________________________________________________________

7. Competitiveness of Portuguese products:

______________________________________________________________

8. Foreign Investment:

# A1.2. Coding

## A1.2.1. Interviewees and their organizations

List of coding associated with identity of interviewees and their organizations

TS 1 – [redacted]
TS 2P - [redacted]
TS 2S – [redacted]
TS 1CEO & IM– [redacted] CEO & [redacted] Inovation Manager
TS 2PTC – [redacted] Portugal Training Coordinator
TS 2SD – [redacted] Developer
TS 2SSE – [redacted] Social Sciences Expert
EU 1S PC – [redacted] Production Team Coordinator
EU 2M PM – [redacted] Industry Director
EU 3T ED – [redacted] Executive Director
EU 4R ID – [redacted] Industry Director & Maitenance Coordinator
EU 5V ED – [redacted] Executive Director
A1ED – [redacted] Executive Director
A2IR – [redacted] Member of the Board & AI Researcher
A3SR – [redacted] Social Sciences Researcher
S1A – [redacted] President
S2W – [redacted] Workers' Representative
FG Auto – Focus Group with Workers' Representatives, Unions, of the automotive sector

### A1.2.2.Colour coding for the topics

List of coding associated with identity of interviewees and their organizations

Sectors

Competences

Products/ areas

Level of automation

Applications

Effects

**Examples**

Dialogue

Social dimension in design of automation and AI technologies

Strategy for Industry 4.0

Human-Machine Interaction

Qualifications

Limitations

Public incentives

Adoption needs for Automation and AI

B

# Annex 2 Group Discussion

## A2.1. Group Discussion Report

Notes from the group discussion between Workers' Representantives and Unions from the Automotive Sector in Portugal.

2023

MARTA S. G. S. CANDEIAS

IMPACT ASSESSMENT OF AI-ENABLED AUTOMATION ON THE WORKPLACE AND EMPLOYMENT: The case of Portugal