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Automation trends in Portugal: implications in productivity and employment[1]

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Abstract: Recent developments in automation and Artificial Intelligence (AI) are leading to a wave of innovation in organizational design and changes in the workplace. Techno-optimists even named it the 'second machine age', arguing that it now involves the substitution of the human brain. Other authors see this as just a continuation of previous ICT developments. Potentially, automation and AI can have significant technical, economic, and social implications in firms. The paper will answer the question: what are the implications on industrial productivity and employment in the automotive sector with the recent automation trends, including AI, in Portugal? Our approach used mixed methods to conduct statistical analyses of relevant databases and interviews with experts on R&D projects related to automation and AI implementation. Results suggest that automation can have widespread adoption in the short term in the automotive sector, but AI technologies will take more time to be adopted. Findings show that adoption of automation and AI increases productivity in firms and is dephased in time with employment implications. Investments in automation are not substituting operators but rather changing work organization. Thus, negative effects about technology and unemployment were not substantiated by our results.

JEL Classification: L23; L62; 030; 032; 033

Keywords: Artificial Intelligence; automation; productivity; employment; automotive industry

Note: ***This article is sole responsibility of the authors and do not necessarily reflect the positions of GEE or the Portuguese Ministry of Economy and Maritime Affairs*.**

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1. Introduction

The arrival of the first steam-driven machines in factories in the late 18th and early 19th century started waves of passionate discussions about the future of work. There are arguments in favour of the belief that technology will continuously be improved and will lead to an end-of-work scenario. 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, internet and social media (Eurofound 2019; 2018; Degryse 2019). Techno-optimists named this present phase the 'second machine age', arguing that it now involves the substitution of the human brain (Brynjolfsson and McAfee 2014).

On the other hand, the level of present human-machine interaction can also be described as not more than the natural prolongation of the previous ICT macro-trajectories (Cetrulo and Nuvolari 2019). There are many non-automatable tasks that make jobs less vulnerable than suggested by, for example, the study of Frey and Osborne (2013) (Autor 2015; McGuinness, Pouliakas, and Redmond 2019; Bisello et al. 2019). 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 (Arnold et al. 2018) and complementarity instead of substitution might prevail in many workplaces (Autor 2014). Therefore, despite the resurgence of 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 (Frey and Osborne 2017) and tasks (Autor 2015). One way to refine the implications of automation in work and employment is to select a technological innovation (e.g., Artificial Intelligence) and to study its impact in companies of a given society. Thus, the approach selected for this research work is based on mixed methods bringing not only quantitative analysis but also qualitative evidence to support findings in one sector (automotive) for one country (Portugal). As described in more detail in section two and three of this paper, this approach is innovative and allows for a closer examination at company level of ways in which work is being redefined, what are the future expectations and understand the extension of complementarity that might prevail between machines and humans. The automotive sector is a high-tech industry and is leading the investment in R&D projects related to AI, as shown in section 4 (Results and Discussion). The paper will answer the question: What are the implications on industrial productivity and employment in the automotive sector of recent automation trends in Portugal. The paper will focus on Artificial Intelligence (AI) as the most relevant emergent technology to understand the development of automation in areas related to robotics, software, and data communications in Europe (Moniz 2018).

The relevance of intelligent manufacturing in the automotive sector has also been vastly documented in terms of working conditions, qualifications, and skill requirements (Moniz

2018). Furthermore, the article describes the automotive sector in the world and in Portugal. Moreover, evidence from interviews around three cases will be presented approaching the implications of R&D projects in productivity and employment in the Portuguese automotive sector. Last, the implication of these cases in the automation debate will be discussed.

2. Automating our intelligence

Many debates assume that automation –– as the general processes of substitution of labour by software or machines (Autor 2015) –– is one single phenomenon that impacts homogeneously work and employment. However, automation is a process that encompasses different technologies, and each one will impact labour 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. Furthermore, the effects of technological change can be differently distributed, depending on the institutional framework that each society sets for itself (Eurofound 2018). The impacts in work and employment of each technology will vary depending on the national innovation institutions (Geels et al. 2016), industrial relations system (Freeman 1995), and even type of capitalism (Hall and Soskice 2001).

A much-debated form of automation is Artificial Intelligence (AI). It can be defined as being a computer system that performs tasks that normally require human intelligence, such as visual perception, speech recognition, decision making or translation (Pettersen 2019). 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 (Hall and Soskice 2001). 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).

Nevertheless, AI is not one monolithic term but instead needs to be seen in a more nuanced way (Nova SBE and CIP 2019): 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). Furthermore, AI is an umbrella that includes several technologies, such as Technology Expert Systems, Recommender Systems Apprentices by Demonstration, Machine Translation Speech Recognition, Facial Recognition, Text Recognition, Transport & Scheduling Systems, Self-Driving Cars, Home Cleaning Robots and Negotiation Agents and Virtual Assistants (Koski and Husso 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. In fact, it is expectable 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 (Hall and

Soskice 2001, Autor 2014, Fine et al. 2018). These developments are leading to a wave of innovation in organizational design and changes to institutionalized norms of the workplace (Schildt 2017). The advanced algorithms which 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. But, to avoid speculations, these systems have to be at least in a development phase seven of the European Technology Readiness Levels (i.e. have a system prototype demonstration in an operational environment).

Most reports estimating the impact of AI are based on quantitative modelling of employment by occupations or tasks. 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, change the nature of work in a considerably larger proportion of tasks and the country should be prepared to retrain one million Finnish workers (Koski and Husso 2018). In Portugal, a study reported that AI can reduce 1.1 million workplaces and suppress 50% of the work hours by 2030 (Nova SBE and CIP 2019). In Hungary, 49 per cent of work hours can be automated based on existing technologies, which is equivalent to the work of about 2.2 million people (Hall and Soskice 2001, Autor 2014, Fine et al. 2018).

Research about AI and improved productivity or performance in organizations is scarce, most probably because it is an emergent technology. But there are some reports based on qualitative data analysis of the impact of AI. In two recent European projects[5,6] –– about virtual work and digital platforms –– we have identified significant difficulties of social partners to deal with the broad effects of automation phenomena (Boavida and Moniz 2019, 2020). Nevertheless, this difficulty can be bypassed by conducting interviews on cases from the automotive and components sector selected by using keywords that signal intelligence automation developments and AI applications in Portuguese R&D projects. The technology effects of each AI project can be validated by innovation experts and technology managers. Experts on organizational change and labour processes can also provide details about the effects on work organisation, skills and qualifications required.

[5] Project Deep View. Link: https://www.deepview-eu.org/

[6] Project CrowdWork21. Link: https://crowd-work.eu/

3. Methodological approach

The methodology consisted in literature review, international database analysis, Portuguese databases of R&D projects and fieldwork with experts in the field of R&D related to automation projects in the automotive sector to investigate the implications of AI in productivity and employment. Desk research included not only systematic literature review, grey literature (reports, official documents, newspapers), as well as exploratory interviews with three experts in industrial productivity and employment. Fieldwork included in-depth interviews that lasted for more than one hour with the executive manager as well as with the innovation manager of an experienced and recognised technology company developing many R&D projects for the automotive sector. Last, three non-structured interviews were conducted with work organization and labour experts. In section four many insights and citations are referred to these interviews. The work was carried out from September 2020 to April 2021. For the Portuguese landscape, we were confronted with a lack of data about the investment and adoption of AI by the Portuguese industry. To overcome this constraint, we performed a data analysis in the Portuguese databases of R&D projects, funded by the European Regional Development Fund Database (ERDF). Through the analysis of funded R&D projects from this database we have an indication of the investment done in AI in Portugal, at the pilot level. It also enabled us to identify experts with specific AI cases on the automotive industry. To select cases at the factory floor, rather than in other departments of a company (e.g., sales, management, customer support, etc), the concept of industrial AI previously mentioned was used (Peres et al. 2020).

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) as presented in Group 1 of table 1. From this search resulted 543 R&D projects related with AI. Projects were classified according with a specific NACE code. Through the analys of the number and investment of projects related to AI by NACE code, we obtained a distribution of the sectors that invested the most from 2008 to 2020. As expected, one of the sectors that invested the most was the automotive sector. Next step was conduct a search string based in keywords related with manufacturing and the automotive sector, as other constraines as presented in table 1, in Group 2. These constraines were three extra criteria: search by the names of the eight car manufacturers in Portugal, based on the data from the European Automobile Manufacturers' Association - ACEA; select projects from the automotive sector (NACE 29.10 and NACE 29.32); and select projects finished by the end of 2021, to have substantial results applied in real production environment. Table 1 sums up the conditions on which search strings were adopted in the identification of R&D projects related to AI in the Portuguese automotive sector from the R&D projects database, between 2007 and 2020.

Table 1: Search strings adopted in the identification of funded AI projects in the automotive industry with an end date by 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. Keywords: Auto Europa, Volkswagen, Caetano, PSA, Peugeot, Citroen, Renault, Toyota NACE: 29.10 and 29.32

Following the identification of 25 projects resulting from the presence of at least one element of each of the groups listed in Table 1, a first screening process was carried out to assure the projects selected were only from the automotive sector. The results were narrowed to 13 projects. Out of these, three projects were selected for analysis after applying the following eligibility criteria: projects with car manufacturers (NACE: 29.10) as partners or end-users; and different projects with the same beneficiary (company). These criteria allow us to collect data about implications of AI in car manufacturers in those cases and conduct accurate interviews only to very successful and experienced industrial researchers in the field.

According to the company, their research, and development areas are in Artificial Intelligence algorithms, Mechatronics, 3D design and simulation, Artificial Vision and Industry 4.0. Currently, this company also provides training for the automotive industry and related subsidiaries in Germany, Mexico, and China, and has projects in development in several industrial areas around the world. It is an SME, located near an automotive greenfield near Lisbon and with 32 employees, mostly engineers.

The cases on which the experts were interviewed were related to computer vision and predictive analysis, with prototypes developed at industrial level (Technology Readiness Level 7) as presented in table 2. Project A turned out to be not that relevant for the research question of this paper and Project C, because of the pandemics, suffered a delay and did not yet have results to reflect upon. The most interesting findings resulted from the discussion around project B and several other examples from the company's current business. The interviews lasted for one hour. It was possible to identify several implications on productivity and employment from the demonstration of AI in an automotive industry factory floor.

Table 2: Description of R&D projects selected from the Portuguese R&D database according to the methodology described in section 3.

Project	Description*
A	Project A developed an automated robotic system of universal application for different control philosophies to overcome the challenges posed by a new generation of production lines for the automotive: more durable in the face of constant changes, with lower costs and adaptation times, with simple reconfiguration and flexibility for product changes. Results: two demonstration cells at industrial level. The cells were now back to the company's facilities and were used to give training.
B	Project B used computational vision and predictive analysis in the quality inspection of the structural glue bead application in doors. It developed a quality inspection system for the automotive industry to improve its strict level of quality, so that safety of the driver and passengers of vehicles are guaranteed. Results: Industrial prototype, demonstrated at the industrial level, of a non-destructive testing and predictive maintenance system with customizable solutions, covering all parts manufactured in a production line, integrated into the production process and aiming a zero-defect strategy, without neglecting the productive capacity of the current production lines; continuously and systematically evaluation of the quality of parts manufactured on the production line and the condition of the machinery that contributes to their manufacture.
C	Project C, currently being developed, intends to create a generic automation platform, integrating and harmonizing standardized and emerging methods, processes and systems in the world of automation. The project includes open source structures for the introduction and integration of technology in production lines, investing in the reuse of processes and machines, in the reconfiguration and optimization of parameters, in the digitalization and virtual representation of industrial automation equipment and in zero-defect quality manufactured products, allowing the industry to keep up with the customer's needs and expectations, namely in terms of product customization and constant creation of new offers.

*Projects' description from the company's website

4. Results and Discussion

4.1 Productivity

There are many ways to measure productivity, but two remain consensual to understand the factors contributing to increased productivity in industrialized societies: labour productivity and capital productivity. First, labour productivity, measured as Gross Domestic Product (GDP) per hour worked, is one of the most widely used measures of productivity at country level.

Productivity based on hours worked better captures the use of the labour input than productivity based on numbers of persons employed (head counts) (OECD 2019).

Labour productivity in the Portuguese automotive industry increased from 2010 to 2016, according to our calculations based on data from OECD Statistics7. In fact, the average annual growth rate of labour productivity was 4.3% in this period. In 2016, labour productivity was significantly higher in Portugal (261) than in Spain (42), and close to the Slovak republic (286), France (374) and Belgium (422), to name a few countries comparable, referenceable and with available data.

To take account of the role of the capital input in the production process, the preferred measure is the flow of productive services that can be drawn from the cumulative stock of past investments, such as machinery and equipment[8] [25]. Capital productivity shows how efficiently capital is used to generate output. The series of gross fixed capital formation by asset type are used to estimate productive capital stocks and to compute an aggregate measure of total capital services. The gross fixed capital formation may take the form of improvements to existing fixed assets, such as buildings or computer software that increase their productive capacity, extend their service lives, or both. We assume that this indicator is a proxy of the investment in automation, related to ICT, machinery, electronics, and electricity, even though it also includes construction. Relevantly, the gross fixed capital formation in the Portuguese automotive industry increased significantly from 2010 to 2017, according to our calculations based on data from OECD Statistics9. In fact, the average annual growth rate was 7.9% in this period. An observation in more detail shows (table 2) a decrease from 2010 (455 M€) to 2013 (256 M€). The 2013 marks a turning point in this type of investment as, since then, the gross fixed capital formation has been steadily increasing at an average annual growth rate of 32% between 2013 and 2017.

Table 3: Gross fixed capital formation in the Portuguese automotive industry, from 2010 to 2017

Years	2010	2011	2012	2013	2014	2015	2016	2017
Gross fixed capital formation[1] (M€)	455	339	310	256	293	391	557	775

[1]Source: OECD STAN Database

[7] Data collected from STAN in https://stats.oecd.org , 30/4/2021

[8] These services, provided by capital goods to the production process, are known as capital services. Capital services provided by each type of capital goods are estimated by the rate of change of the productive capital stock, taking into account wear and tear, retirements and other sources of reduction in the productive capacity of fixed capital goods. The overall volume measure of capital services (i.e. capital input) is computed by aggregating the volume change of capital services of all individual assets using asset specific user cost shares as weights.

[9] Data collected from STAN in https://stats.oecd.org , 30/4/2021

Also, from data collected through the interviews and in case of project B, we can observe benefits of introducing AI technologies at the factory floor. According to the innovation manager, "*using computational vision and predictive analysis in the quality inspection of the structural glue bead application in doors, one of the most important manufacturing processes in the automotive parts assembly line, it was possible to increase process efficiency, improve product quality and reduce waste resulting in savings and, thus, contributing to an increase in productivity of the car manufacturer*". However, according to her, although with positive effects on productivity the solution was not adopted by the end-user. She stated that "*there are areas within the factory that are more receptive to the introduction of new technologies than others; the decision makers themselves may be more open; contextual conditions can act as a constraint, such as the closure of the activity in which the solution would be implemented*". Furthermore, "*in the specific case of large OEMs, with several factories around the world, there is great resistance to the introduction of solutions that are not absolutely standard or are consistent with other solutions already introduced in other factories*", added the executive manager. According to him "*the project took place during a period in which the solution was developed and demonstrated on one of the most advanced and relevant lines in the factory, at that time, but when negotiating the contract, this production line was being discontinued and did not make sense additional investment*". The executive manager added "*After the project finished and we went to pick up the demonstrator installed in the line they said it was very good if it stayed in the line. This shows its added value was recognized, namely, in the greater efficiency of the process by reducing the number of non-compliant products, reducing waste, and increasing quality of the final product*".

If we analyse the gross fixed capital formation in a comparative manner, in 2017 was lower in Portugal (37) than particularly Germany (892) and, to a lesser extent, Spain (158), but higher than Austria (34), to name those with available data as well as with comparable and referenceable countries. If we analyse this indicator in terms of its evolution from 2010 to 2017 (table 3), Germany grew annually on average rate of (8.6%), Portugal (7.9%), Spain (16.2%) and Austria (10.1%).

Table 4: Growth Annual Rate of Gross fixed capital formation of some OECD countries, from 2010 to 2017.

Countries	Germany	Spain	Portugal	Austria
Average Annual Growth Rate (%) (2010-2017)[1]	15.8	16.2	7.9	10.1

[1]Source: Author's calculations based on data from OECD STAN Database.

In conclusion, capital productivity grew annually on average significantly higher (7.9%) than labour productivity (4.3%) in the Portuguese automotive sector. Thus, capital investments are the main reason for productivity increases in the sector, which translates into improvements of productive capacity by automation efforts. Nevertheless, regardless of the increase in productivity there are a variety of factors, such as low return on investment, competences/knowledge to operate the system not available or accessible, end-user departments' managers not open to technology and OEMs' managers not traditionally open to new, non-standard solutions. that can influence the adoption of a new technology by industries.

4.1.1 Investment in AI in the Automotive sector

In Improvements to raise productivity in a production system can be made in many parts of a factory. Often, upgrades in the manufacturing sector are made through investment in automation, which can be both automation hardware (e.g., mechanical parts, and/or the electrical and electronic parts) and software [26].

As described previously, the gross fixed capital formation may take the form of improvements to existing fixed assets, such as buildings or computer software that increase their productive capacity, extend their service lives, or both [25]. Hence, the share of gross fixed capital formation invested in ICT equipment, software and databases in the total gross fixed capital formation is a proxy of AI investment. In fact, this investment represents the efforts conducted to improve computational power applied in companies.

In Portugal, the investment in ICT in gross fixed capital formation maintained steady from 2010 until 2015 on average 22 M€. Afterwards, the investment grew significantly up to 36 M€ in 2017, which represents an annual average growth rate of 30.3% between 2015 and 2017. The overall increase between 2010 to 2017 (when the data is available) resulted in an annual average growth rate of 6.7%. Furthermore, the OECD data allows limited, but still interesting, comparisons with other countries. Figure 1 presents the evolution of the share of ICT investment in the total gross fixed capital formation in the automotive sector in four countries.

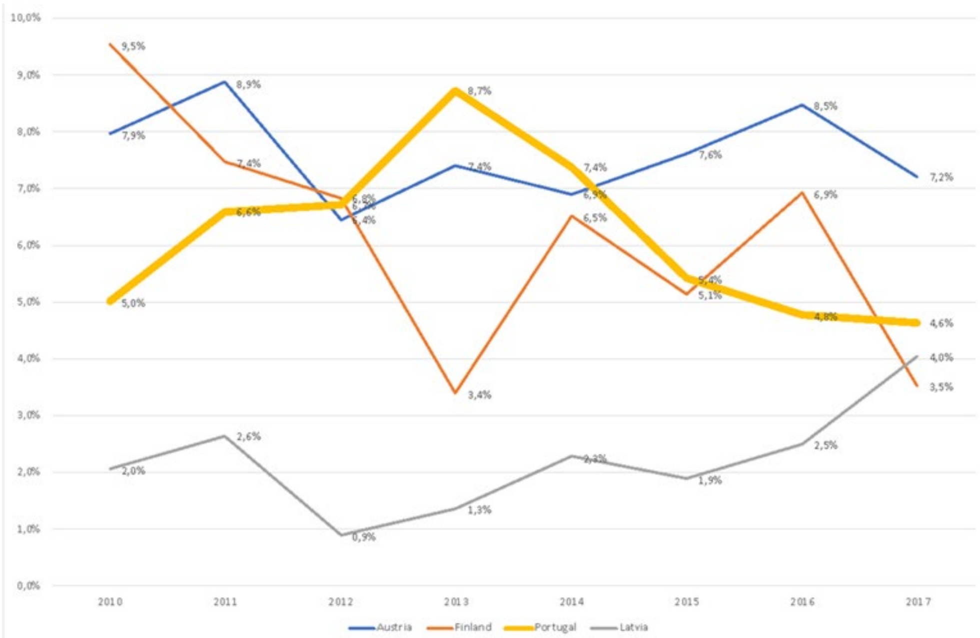

Figure 1. Evolution of the share of Gross fixed capital formation invested in ICT equipment, software, and databases in the total Gross fixed capital formation in the Automotive sector, in a selection of countries, current prices. (Source: OECD STAN Industrial Analysis (2020 ed.)

In figure 1 it can be observed that, in 2017, Portugal had a share of investment in ICT of 4.6% in relation to all the investment made in the automotive sector, which is lower than Austria (7.2%), but higher than Latvia (4.0%) and Finland (3.5%). The Portuguese share of investment in ICT in the total investment had an average annual growth rate -1.1 in the period between 2010 to 2017, compared to -1.4 in Austria, -13.3 in Finland and 10.2 in Latvia. It can be concluded that the automotive sector has seen a slight decrease in ICT related investment in the Portuguese automotive sector similarly.

In summary, there has been a substantial growth of AI investment in the automotive sector of 30.3% between 2015 and 2017. However, the growth in all automation investments was 41% during the same period. Therefore, it should be argued that the recent general automation investments are more significant than those only in AI in the Portuguese automotive sector. The analysis of the national comparative data available also points to the same conclusion.

This conclusion is also supported by empirical data from the interviews. Both the executive manager and the innovation manager agreed and stated that "*Industries in Portugal understand the inevitability of adopting Industry 4.0 technologies if they want to be competitive and increase productivity*". According to them "*Portuguese companies are more open to these new technologies*". Moreover, the innovation manager stated that *"this is true for robotics, automation, and predictive analysis, and we can expect this type of technology to be adopted in a couple of years. However, technologies (e.g., cloud, plug & produce,* *blockchain, artificial intelligence) that may involve connectivity, monitoring, data collection and automated decision making, will take longer to be implemented.*".

Through the analysis of the Portuguese ERDF projects' database, in the period of 2007 to 2020, from the 3151 research and innovation projects 543 AI related projects were identified which were worth 655 M€. AI R&D projects account for 19% of the total investment in R&D projects. This database includes several types of projects from collaborative to individual, research-oriented to industrial application, with an average investment per project ranging from 600 K€ to 27 M€, depending on the type of project. Therefore, AI technologies are expected to be spread across the different development stages. Based on author's calculations from Portuguese R&D projects Database, in the period of 2008 until 2020, the investment of 655 M€ in AI R&D projects corresponds to 19% of the total investment in R&D projects corresponding to an average annual growth rate of 18% demonstrating the hype around this technology. From the distribution of AI R&D projects' investment by NACE group it is observed that the automotive industry (NACE group: 29) is one of the sectors which invested the most, after computer programming, consultancy, and related activities (NACE group: 62) and manufacturing of computer, electronic and optical products (NACE group:26) (Figure 2).

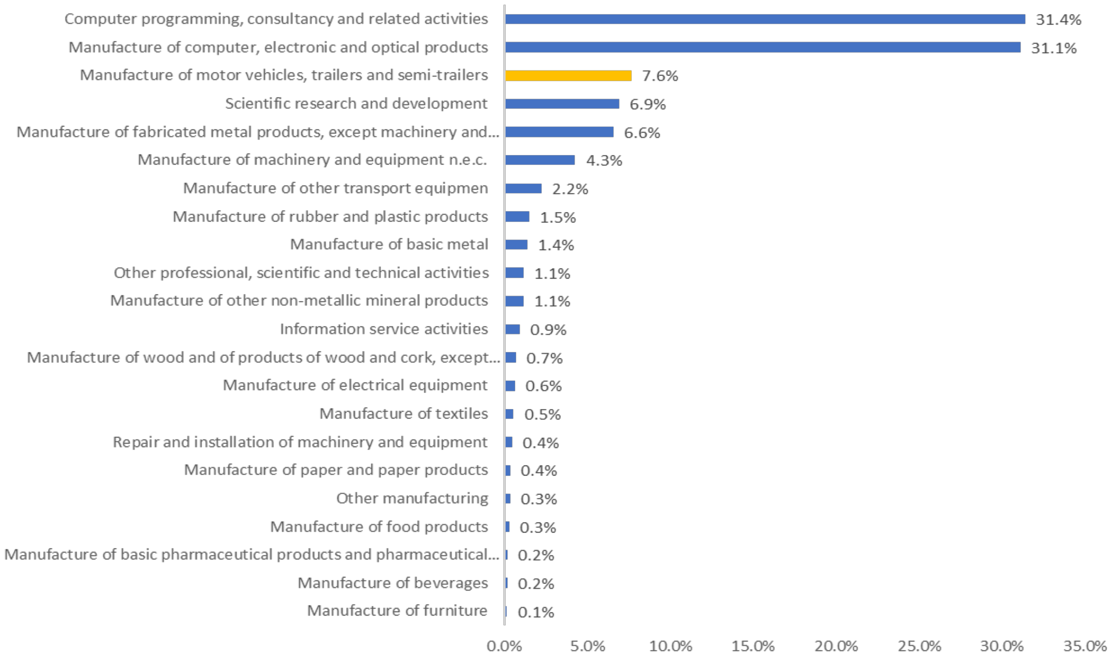

Figure 2 – Distribution of R&D projects related with AI by NACE group. (Source: Author's calculations from Portuguese R&D projects database)

According to author's calculations from Portuguese R&D projects database the automotive sector accounts for 225 M€ of investment in R&D projects related to AI corresponding to 34% from the total investment in R&D projects and for 43% from the total investment in R&D projects of the automotive sector (518M€) (table 5).

Table 5: Portuguese R&D projects data from 2008 to 2020.

2008 - 2020	Total	AI	Automotive sector	AI in automotive sector
Nº of Projects[1]	3151	543	275	50
Projects' Budget (M€)[1]	3 422	655	518	225

[1]Source: Author's calculations from Portugal's R&D projects database.

From 2007 to 2020, investment in AI projects in the automotive sector has been growing (Figure 3) with an average annual growth rate of 15%.

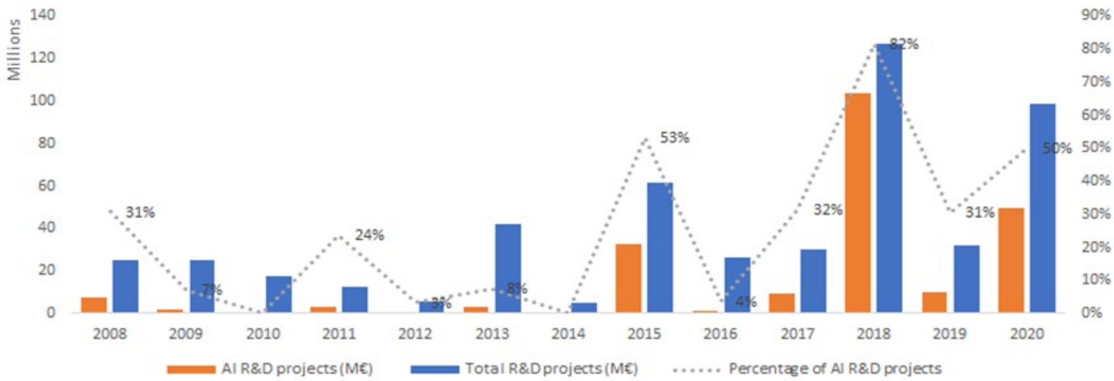

Figure 3. Variation of R&D projects investments in the automotive sector, from 2008 to 2020. (Source: Author's calculations from Portugal's R&D projects database).

There are no studies or evidence to explain this impressive growth. However, the executive manager noted that companies are more open to the adoption of these technologies associated with industry 4.0 and they realize that it is practically inevitable to move along this path if they want to be more productive and more competitive "*I don´t know if this is the result of the excellent work of publicizing the Industry 4.0 initiative, but I can see that companies are very motivated towards these new technologies. The problem is not knowing how to manage them*." In fact, in 2017 the Portuguese Industry 4.0 initiative was launched. According to the Portuguese Agency for Innovation and Small and Medium Enterprises (IAPMEI) website, Industry 4.0 initiative is an initiative, integrated in the National Strategy for the Digitization of the Economy, with the objective to generate 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, 2017-2019, was above all demonstrative and mobilizing and was based on six priority areas of action: human resources training, technological cooperation, creation of the startup I4.0, financing, investment support, internationalization, and legal and regulatory adaptation. Phase II ,2019 – 2021, intends to be transformative and it is estimated that public and private investments will be mobilized in the amount of 600 million euros over the next two years. It is intended to involve 20,000 companies in the various initiatives, train more than 200,000 workers and finance more than 350 transforming projects.

This information seems to be aligned with the executive manager's statement about the awareness of companies for the importance of industrial transformation through digital technologies and might explain the growth of investment in AI R&D projects. According to him, these technologies are a trend, and his company has created a new business area around computer vision to respond to the expected demand from the market "*We see interest from companies in inspection systems with computer vision. We have created computer vision as a new business area, since we have verified the industry's great receptivity for these systems given that the issue of efficiency and productivity is a topic across all industries'*". In addition to computer vision technology, he added that "*We have made strong investments in other areas, some of which are complementary to computer vision. Currently, all projects that are contracted for the industry have a mechanical component and a computer vision part. In the commercial pipeline for a total of 12 to 13 M € under negotiation, 3 M € are for vision systems*."

This evidence seems to corroborate the statistical analysis' data, where the investment in general automation is higher than in ICT, proxy for AI. Even if there is a growth in R&D projects related with AI there is still a lower investment for adopting AI when compared with investments in automation in general.

According to the executive manager of the company, due to the pandemic situation they were faced with the need to diversify their markets. The executive manager indicated that "*Based on the technology of Project B we are now developing several contracted projects with Portuguese companies, in the automotive components industry (exhaust pipes), in the automotive industry (final assembly department), in a textile supplier (zippers) for the automotive industry and in the food industry* ". In this regard, the executive manager also indicated challenges that may influence the integration of AI daily. "*In terms of computer vision, the technological challenge is not in capturing the image (vision system) but in information processing, decision making (AI) and integration with other systems (legacy systems)." Furthermore, he also mentioned a recent assessment on a traditional fishing yarn factory "this company has existed since 1946 with production systems dating from 1970/80. The challenge of integrating new technologies into these systems is as big as it is to introduce a completely new system (stand-alone) on a customer's shop floor*". Although this is not a case in the automotive industry, it can render the situation of other Portuguese low-tech sectors.

In summary, new technologies such as computer vision, predictive analysis and artificial intelligence do have positive productivity effects in the automotive sector. However, these technologies will only have implications in the sector's productivity if they advance from the pilot project to a broader adoption of the technology and this decision is based on several factors beyond technological performance, as described before. The wide dissemination of these technologies appears to be a challenge because of the different levels of modernization needed across sectors.

4.2 Employment

In 2017, the automotive sector represented 1% of the total employment in Portugal. The average annual growth rate from 2010 to 2017 was 3.1%. However, if we analyse these OECD Stan Database figures, from 2013 to 2017, the employment in the automotive sector grew from 32400 to 41300 persons. This growth was significant in this period because the automotive sector had an annual growth average rate of 6.19% compared to an increase of only 1.92% in the total employment. In comparison with other countries, data shows that the volume of employment (adjusted to the population) in Portugal (0.9%) is not very significant. For example, it is comparatively lower in Spain, Italy, France, Belgium, Netherlands, UK, and US. Thus, we can conclude that the automotive sector has a significant volume of the total employment in Portugal, and it has been growing in the period observed (OECD Statistics - STAN).

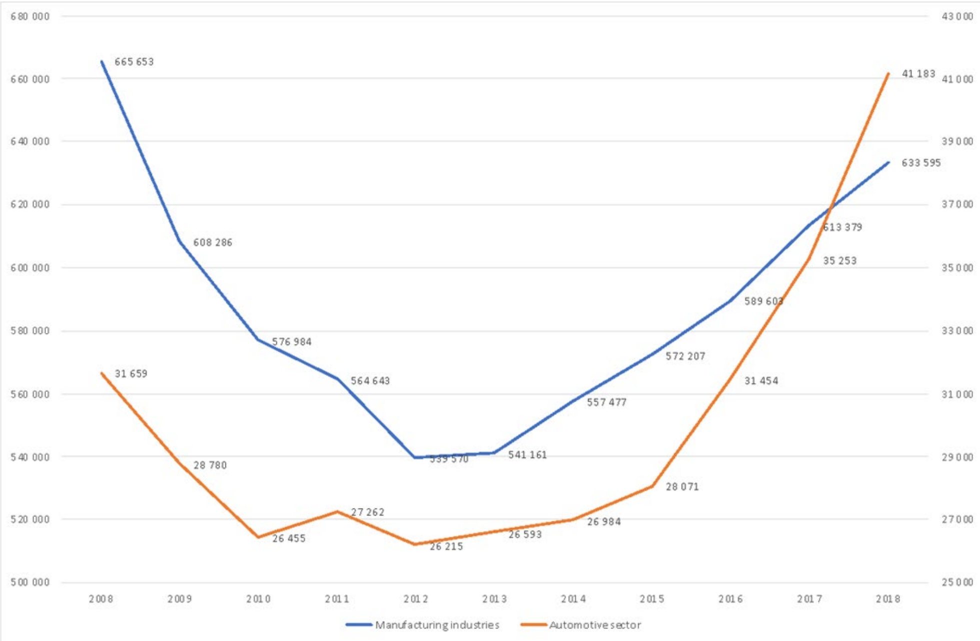

Figure 4. Evolution of employment in the automotive and manufacturing sectors in 2008-18. (Source: Quadros de Pessoal – Séries Cronológicas (2008-2018)10 based on the authors' calculations).

Figure 4 shows that the levels of employment had two different phases. From 2008 until 2013, the employment levels in the automotive sector decreased from 31659 to 26215, an annual average growth rate of -3%. At a similar trend, the levels of employment in other manufacturing industries decreased from 665653 to 541161, an annual average growth rate of -4%. However, from 2014 until 2018, the employment levels started to rise in the automotive sector from 26984 to 41183. The automotive sector grew on average annually at

[10] http://www.gep.mtsss.gov.pt/documents/10182/10928/seriesqp_2008_2018.pdf/cf513838-2724-4195-8763-4d58400df0b9

9%, whereas the manufacturing sector increased only at 3% (Quadros do Pessoal – Séries Cronológicas 2019)[11].

According to table 6, which includes data of Quadros de pessoal (2019)[12], the formal qualification in the automotive structure is very low. It is concentrated at the basic schooling level, which represents 48% of the employment, which is lower than the manufacturing sector with 61%. Employees with the secondary level in the automotive sector also represent 37% of the employment in the sector, which is higher than the manufacturing sector with 27%. Circa 11% have a current graduation degree (B.SC or similar) and 2% have a master's degree.

Table 6 - Distribution of formal qualification in automotive and manufacturing sectors in Portugal, in 2019.

Qualifications[1]	Manufacturing (%)	Automotive (%)
Primary School	61	48
Secondary School	27	37
Technical School	2	2
Graduate	9	10
Master	2	2
PhD	0	0

[1]Source: Quadros de pessoal (2019)[8].

According to table 7, which includes data of Quadros de pessoal (2019)[13], the seniority levels in the automotive structure are more evenly spread than the formal qualifications. Circa 36% of employees have been working from 1 to 4 years in the automotive sector, which is higher than the manufacturing sector with 31%. Employees working for more than 10 years in the automotive sector also represent 38%, which is the same as the manufacturing sector. Circa 13% worked for less than 1 year, which is lower than the 16% in the manufacturing industries. Circa 15% work from 5 to 9 years in the automotive sector, which is equal to the rest of the manufacturing.

Table 7. Distribution of seniority in automotive and manufacturing sectors, in Portugal, in 2019.

Seniority[1]	Manufacturing (%)	Automotive (%)
<1 year	16	13
1-4 years	31	36
5-9 years	15	15
10-14 years	11	9
15-19 years	9	10
20 years or above	18	18

[1]Source: Quadros de pessoal (2019)[9]

[11] http://www.gep.mtsss.gov.pt/documents/10182/10928/seriesqp_2008_2018.pdf/cf513838-2724-4195-8763-4d58400df0b9

[12] http://www.gep.mtsss.gov.pt/documents/10182/10928/qp2019pub.pdf/a4e824a8-3d6c-4c46-b214-1f4a75fa5237

[13] http://www.gep.mtsss.gov.pt/documents/10182/10928/qp2019pub.pdf/a4e824a8-3d6c-4c46-b214-1f4a75fa5237

In subsection 4.1, we have established that productivity in the automotive sector has increased and was mainly due to the adoption of automation technologies. However, we can observe that, for the same period, employment in this sector has also grown suggesting that although automation technologies were adopted it did not affect employment.

Empirical evidence has shown that these investments in automation are not substituting operators but rather changing work organization. According to the description of project B, the quality inspection system developed in the project is completely automated, from detecting the most typical defects in glue beads to automatic diagnosis of the equipment status through historic data processing and automated correction of the correctable bead defects. Although the system can complete its tasks by itself it still needs human intervention to add any additional features or to solve any obstruction that may arise in the production line. For this case, the innovation manager stated that "implications on employment in this specific case are not foreseen to be expressive". Another example happened in a zippers' company, a supplier for the automotive sector. In this case, according to the innovation manager, due to the complexity of the requirements to be inspected, automated artificial vision systems are an added value because they can perform a quality assessment more efficiently than humans. Still, human presence continues to be necessary though in other tasks of the process. "*In the zipper production plant there are many nuances of what is ok or not ok. Especially in the situation where there are many characteristics to be analyzed and difficulty in defining requirements (what is considered a stain, from what size on, different tones, etc.). When there is a lot of data available, as is the case because the factory produces a lot of locks, the AI / ML is a solution. It allows to analyze situations that are too fast for the operator to notice, identifying defects that are not visible to the naked eye and is consistent in the decision to reject a non-conforming product. On the other hand, operator intervention is still necessary. It may have to unlock the system*". Another example shared by the innovation manager was "*In another project, which is based in human-machine interaction (….) to pick and place the parts, the human presence is essential. In case the parts are inaccessible because, for example, they came from logistics in a wrong position and the robot cannot perform its function, the operator must stop the line, put the part in the correct position, and start the line again*."

Data shows that there is an increase in employment despite the increase in capital investments (proxy for automation). Evidence from the interviews also corroborate this fact and seem to indicate that these systems, in essence, assist operators as they manage to make a detailed analysis, 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. Thus, although data have not shown implications in employment in the Portuguese automotive sector empirical findings suggest there may be implications on the organization of work, in line with Autor 2015.

The introduction of automation technologies is also linked to higher levels of complexity at management level. The executive manager stated that "*If they (managers) don't know how to deal with it, it can lead to resistance to adopting the solution despite gains in efficiency and productivity.*" According to him, this additional complexity is related to the knowledge / skills of the client's staff on how to use the new solutions "*For example, in terms of production management, using people is more flexible, if there is less product outflow, instead of having two people checking product quality, the manager will only have one. These are situations known to the manager and which the manager knows how to deal with. Or, if he has three features to check on the product and he needs to add a fourth, he just goes to the people who are doing the inspection and tells them what to look for from that moment on. However, if he is using the vision system, although the system is prepared to be customized and it is possible to add new features, if necessary, there are no people with knowledge to do this at the outset. Even though the systems are designed with easy-to-interact interfaces, being integrated in cyber-physical systems, in a data network through which it is possible to receive support from anywhere in the world, it is nevertheless, a challenge for a person without basic knowledge / training, to program the system to incorporate a new requirement.*" Furthermore, "*Companies want to invest in new solutions, but they do not have people with knowledge / skills to work with the new systems (in their workforce or in the market). Or even if they have one or two people and they get training, there is always a set of unforeseen events (illness, change of job, retirement, etc.) that can affect availability and access to knowledge / skills*.".

In summary, according to the company, computer vision, human-machine interaction, and predictive analysis are changing the operator's tasks but are not resulting in dismissal of workers from the companies. Technologies are more efficient than humans in some tasks, but they still have limitations that maintain humans essential in the overall process performance. Companies perceive the need to automate but, despite being more open to adopting these technologies, they are faced with the lack of available human resources, skills and/or access to knowledge.

In a small foresight exercise, there was a question to both the executive manager and the innovation manager on what their expectations would be, in a range to 2 to 10 years, about implications in productivity and in employment of AI adoption in the automotive industry.

According to the executive manager, the final assembly department of car manufacturers is where there is still a set of technological challenges associated with automation and significant implications can be seen in terms of productivity and employment. In this department tasks continue to be carried out by human resources.

A car factory has 4 large areas: parts' production; glue weld and joining; painting; and final assembly. The executive manager explained that "*The final assembly is the area that creates jobs in a car factory because most of the systems for assembling and assembling components inside a vehicle continue to be executed by people today. For example, at a car manufacturer, about 80% of human resources are allocated to the area of final assembly. So, it is here that* *there is an interest in investing in technologies*." Furthermore, "*Contrary to what one might think, it is not a question of people going out of work, but because it is difficult to attract and retain people to do the functions that are associated with it in the final assembly*.".

The tasks performed by people in the final assembly lines of car manufacturing are boring, repetitive, and physically demanding, and, therefore, he stated that "*often result in several costly health problems, which is a big issue nowadays*". In this sense, the motivation for investments in automation for car assembly lines are linked to the lack of people to perform this work due to physically intensive and repetitive tasks. In addition, according to the innovation manager, human-machine collaboration can help in this area. "*The quality inspection has to be done by a human-machine system in the final assembly, where all the characteristics are inspected before the car is released. At this stage, there is no need for a robot to move around the car because, alone, it does not have enough cycle time to do so and nowadays there are countless people who do it with a set of sensors*". Therefore, the expectation is for automation not to replace workers but augment their capacity to perform their tasks and/or alleviate burden.

The transfer of automation technologies to other less technology intensive sectors faces additional challenges related to labour costs. The adoption of the technology is based on two factors: savings in terms of workers (reduction of health problems, relocation, or dismissal) and gains in productivity / efficiency. The executive manager stated that: "*Do I earn more for doing it automatically or do I have savings from being done automatically? This is the logic that is inherent to the implementation of technology. And this logic may not be competitive in view of labour costs in Portugal. In the country, the minimum salary is very low, and the trend is to continue to be low*".

The innovation manager stated that robotics, automation, and computational vision will have widespread adoption in one to two years. However, cloud, plug & produce, blockchain and artificial intelligence will take longer to be implemented as they involve connectivity, monitoring, data collection and automated decision making.

Based on the evidence analysed four possible scenarios can be identified. First, there is a need to understand how to work with the new solution. For instance, to solve a problem within the new system or to add a new feature to the system. Since there is usually no knowledge or competences in the workforce about a new artifact, the introduction of a new technology may lead to a qualification of work. In adopting the new system, operators that previously did the inspection by sampling, are now only backing the system in case something goes wrong, thus, probably leading to a displacement effect and disqualification of work. Both situations are based in a human-machine interaction that can lead to an augmenting performance of the operator's tasks with implication in work qualification and organization. Third, the adoption of new systems increases productivity and creates the demand for new labour, usually with more qualifications. Last, the investment in automation leads to unemployment of the workers performing the task. This scenario can happen and depend on many internal and external factors, such as time cycle, production line, human resource management, work organization, company, as well as external variables like sector, demand for product, geo-economic context, etc.

5. Conclusions

This paper shed some light around the implications on productivity and on employment by automation and AI in the Portuguese automotive sector. Findings point to the idea that productivity increases are mainly due to capital investments (proxy for automation). These improvements of productive capacity derive 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 in the decision for automation: productivity needs, return on investment, competences, knowledge and/or human resources to operate the new automated systems an end of product life cycle. Obstacles can also come from the resistance of managers to adopt new, non-standard technological solutions in OEM, and they may imply jobs displacement or dismissement.

AI has further obstacles related to industrial mass production. There are questions related to the increased complexity of management when addressing production variability, the need for specific knowledge associated with the development, understanding and recompute new algorithms, control of the AI system and production, and immateriality of software, among others.

The wide dissemination of automation and AI appears to be a challenge. The transfer of these technologies inside the value chain or outside the sector requires companies with high levels of modernization. Thus, there can be asymmetric social and economic implications because different dynamics (delay or 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 most 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.

The automotive sector is classified as a medium-high-technology industry. But this sector still has a lot of tasks done by humans that might be automated in the final assembly line of the OEM. The motivation for investments in automation and AI seem to be linked to the lack of workers to perform physically intensive and/or repetitive tasks. Technologies are more efficient than humans in some tasks, but they still have limitations. Therefore, in a short to medium term, automation will not replace workers but augment their capacity to perform their tasks and alleviate their burden as humans continue to be essential in the overall process performance. Although companies perceive the need to automate and despite being more open to adopting these technologies, they are faced with the lack of available human resources, skills and/or access to knowledge both at the operational and management level.

During the period of analysis, the increase in productivity has not been reflected in employment. The implications are found in the organization of work within the company. Hence, implications regarding increases in productivity and consequent changes in employment will slowly be dephased from each other. It takes time to design the automation and AI system, test, and pilot a technical solution. Furthermore, the decision to invest in such a solution is based in several aspects, as described before. Moreover, the intensification of the dependency on new automation and AI artifacts, requires the company to be prepared to deal with technical problems, maintenance, health and safety, and security regarding its investment, increasing the complexity of management. In the short time, it is expected that automation can be adopted, but AI technologies are still in their initial phase of implementation and will take more time. Thus, one could expect that the debates and social anxiety about automation and AI are not totally substantiated by our results. Implications regarding increases in productivity and consequent changes in employment will be slowly dephased from each other. If an automation or AI project is designed to improve productivity disregarding the developments in work organisation, the projects may face difficulties in their implementation phase and even be postponed (or forgotten). In turn, this may create difficulties for efficient implementation of the technical solutions with low returns on investment.

It can be envisaged that four scenarios are plausible: qualification of work; disqualification of work; augmented work or unemployment. In all scenarios, the expectation is an increase in productivity and an increase in complexity of the technological apparatus and management by the company.

In our research we found some limitations that can be overcome in future research. Although this research found statistics related to AI, interviewees systematically approached AI as part of the automation processes. In fact, these process innovations are difficult to dissociate in the production process of the automotive sector because interviewees saw the technical solution as a whole, including both hardware and software. The R&D cases selected also incorporated automation hardware. Future research should, thus, be extended to other cases and to sectors that do not usually require automation hardware to explore further AI specific implications, such as finance and/or logistics.

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