Chapter 8
From Industry 4.0 to Industry 5.0—An Overview of European Union Enterprises

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Abstract Industry 4.0 refers to the transformation of industry through the adoption of techniques and processes based on information and communication technologies (ICT) to manage and optimize all aspects of the manufacturing processes and supply chain. Even if Industry 4.0 adoption has significant advantages for companies in terms of increased productivity and decreased costs, it also raises various challenges for companies. At the same time, more and more experts start to voice their concerns regarding Industry 4.0 and discuss the advent of Industry 5.0 with a focus on sustainability as opposed to productivity. During the discussions regarding Industry 5.0 and the necessity of an improved collaboration between humans and technological systems, it is relevant to evaluate the way companies from the manufacturing sector are adopting Industry 4.0, considering all the challenges and costs imposed by the process. The present study aims at providing an overview regarding the presence of the Industry 4.0 elements in European Union manufacturing companies using publicly available data from the European Statistical Office.

Keywords Industry 4.0 · Industry 5.0 · Digitalization · Manufacturing · Sustainability · European enterprises

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1 Introduction

In an increasingly dynamic and complex world, manufacturing companies are constantly under pressure to innovate and become more competitive, and technological competitiveness has become a strategic element for organizations to differentiate themselves and improve their organizational performance both in terms of productivity and sustainability. We are currently living in an increased competitive environment that is constantly evolving into being customer-centric and demand-driven and so, in order to remain relevant, companies need to be able to make a precise, real-time decision while considering multiple ambiguous targets [29] and so, traditional approaches are no longer seen as an appropriate control tool [34].

So regardless if companies are ready or prepared to integrate new technologies and processes in their business models, the market forces them to adapt in order to remain relevant. Added to the general trend, the COVID-19 pandemic put extra pressure on companies that faced the need to rethink existing working methods and approaches and sped the adoption of digital technologies and practices.

2 Industry 4.0

Industry 4.0 refers to all the latest technological advances based on the Internet and supporting technologies that create the environment in which to integrate human actors, physical objects, smart machines, production lines, and processes throughout organizations in order to "create a new kind of intelligent, networked, and agile value chain" [35].

The term itself has been coined by the German Federal Government which considers Industry 4.0 to be the developing configuration through which logistics and manufacturing systems access the global information and communication network to automatically exchange information and match business and production processes [5]. Thus, Industry 4.0 has a significant impact over all industries, bringing disruptive changes in various business areas from supply chain management to business processes, business models, and market positioning [8, 33].

Among the new disruptive elements introduced by Industry 4.0 are "Big data and Analytics, Autonomous robots, Simulation, System Integration (Horizontal and Vertical), IoT (Internet of Things), Cybersecurity and Cyber Physical Systems (CPS), the Cloud, Additive Manufacturing, and Augmented Reality" [31].

Big data and Analytics refer to the practice of collecting and analyzing data from different sources as a means to provide support in the real-time decision-making processes [31]. According to Forrester's definition, there are four dimensions for big data, namely data volume, data variety, data velocity in terms of both generation and analysis, and data value Witkowski [39]. One of the main challenges with respect to big data refers to the fact that manufacturing companies need viable and up-to-date

solutions that gather, analyze, and produce valuable and practical data from various sources and combine it in order to deliver around-the-clock real-time analytics.

Autonomous robots have a vital role in the modern manufacturing industry. According to a report published in 2014, the total number of multiuse industrial robots used in European Industry 4.0 companies has almost doubled from 2004 Roland Berger [1].

According to World Robotics 2020 Report, in 2019, almost 2.7 million industrial robots were functioning worldwide. Compared to 2018, there are 12% more industrial robots functioning in companies around the world and 68% more in comparison with 2016. In 2019, Europe reached an operational stock of industrial robots of 580,000 units (+7%). The European countries which leveraged most of the production advantages offered by industrial robots were Germany which had an operational stock of around 221,500 units, Italy with almost 74,400 units, France with 42,000 units, and the UK with 21,700 units [19].

These robots can carry out independent production methods and can finish specific tasks accurately and judiciously while also focusing on flexibility, safety, versatility, and collaboration [5]. With all these advantages, autonomous robots have a significant impact on the job market structure, as many jobs become obsolete, and companies need workers with a different set of competences and skills.

Simulations are using concurrent data to emulate the real world in a virtual model, which can incorporate machineries, goods, and persons [31]. Simulations' main advantage comes from the fact that it allows workers to assess and improve all the system's settings for future products inline with the virtual reality before the material switch, thus decreasing machine setup times and improving the end-product attributes. Thus, virtual engineering teams have been key elements of the successful application of these approaches and the decision-making processes of these types of teams should be an interdisciplinary approach [2].

System Integration: Horizontal and Vertical System Integration. "The two main mechanisms used in an industrial organization rely on integration and self-optimization" [34]. The entire Industry 4.0 theory is fundamentally outlined through three types of integration: (a) "horizontal integration across the complete value creation network", (b) "vertical integration and networked manufacturing systems", and (c) "end-to-end engineering throughout the entire product life cycle" Stock & Seliger [37].

Internet of Things refers to a "worldwide network of interconnected and uniform addressed objects that communicate via standard protocols" Hozdić [18]. Smart factories are all about intelligent planning, agility, and networking with all elements of the process interconnected and in constant real-time communication.

Cybersecurity and Cyber Physical Systems (CPS). Considering the value of information in Industry 4.0, cybersecurity has become instrumental to "safeguard important industrial systems and manufacturing lines from cybersecurity risks" Vaidyaa et al. [38]. CPS refers to the systems in which the physical space consisting of natural and human-made systems is closely integrated with the cyberspace formed out of computation, communication, and control systems Bagheri et al. [35] and is characterized by the decentralization and autonomy of the production process.

The Cloud. Industry 4.0 implementation requires fast and reliable data sharing and so IT platforms are based on cloud function as a structure for communication and connection Landherr et al. [21].

Additive Manufacturing methods are also extensively used in Industry 4.0 to manufacture small lots of custom-made products, reducing time to market, and increasing customer satisfaction by proving products and services that better respond to the consumers' needs and expectations.

Augmented Reality systems support a variety of facilities meant to both increase productivity and decrease errors, such as providing employees real-time data to perform procedures and make decisions [31].

Regardless of the technological complexity of Industry 4.0, the main design principles of the transitional process from Industry 3.0 to Industry 4.0 refer to [17]: decentralization, interoperability, virtualization, real-time capability, modularity, and service orientation.

3 Industry 5.0

After more than 10 years of practice and research, many scholars have begun to vocally criticize Industry 4.0 due to the fact that its main goal focused solely on increased mass production and decreased costs which led to a perceived disregard toward environmental considerations [7] and human costs resulting from the optimization of processes [22].

In this context, there is a wide consensus in the literature that the next natural step in this evolution, namely Industry 5.0, should be focused on sustainability and waste prevention [30]. This vision is correlated with the fact that the bioeconomy vision of the European Commission is also centered around sustainability and bioeconomy is predicted to have a deep impact on businesses and industries [7, 32].

Considering that it is a relatively new term, there are a plethora of different visions for Industry 5.0: if Industry 4.0 was centered around technology and connecting devices together, Industry 5.0 brings back the human touch into the equation [20, 24] to leverage the synergy between humans and autonomous machines [22].

Østergaard also points that there is a significant shift in consumers behavior, and to meet consumers' increased demand for customized products, the next industrial revolution must rely on human involvement-human engagement Østergaard [25]. Furthermore, according to Atwell, Industry 5.0 focus is "increased collaboration between humans and intelligent systems" as more and more manufacturers are increasing the human component not only for customization purposes, but also for increased efficiency on the production line Atwell [3].

These discussions come to highlight that there is no clear demarcation line between Industry 4.0 and 5.0 and the two industrial revolutions are fundamentally connected and could actually be treated as one natural evolution. In Schwab's opinion [36], "to fully take advantage of the fourth industrial revolution, promising technologies should not be considered as simple tools that are entirely under human conscious

control, or as external forces that cannot be controlled. The best solution is to try to understand how and where human values are embedded in new technologies, and how these technologies can be applied for the common good, environmental protection, and human rights".

3.1 Industry 4.0 Adoption, Opportunities, and Challenges

In this volatile context, manufacturing enterprises are currently confronted with considerable challenges in implementing the elements of Industry 4.0 and Industry 5.0 as it is becoming "more and more obvious that such a far-reaching vision will inevitably lead to an amplified complexity of all industrial processes, both on the micro and macro level" (Schuh et al. 2014).

Despite the clear advantages and opportunities provided, extensive research on companies' perspective over Industry 4.0 [10] has shown that enterprises face serious difficulties in grasping both the general idea and specific concepts related to Industry 4.0, among which we can enumerate the fact that:

- Most companies consider Industry 4.0 concepts to be extremely complex with limited to no strategic assistance provided;
- Most companies prove to be unable to relate Industry 4.0 to their specific area or their specific business strategy;
- Companies face serious difficulties in evaluating their Industry 4.0 development status and, therefore, are unable to establish a specific area for action or create plans and projects.

Another relevant aspect refers to the substantial costs implied by Industry 4.0 adoption process which significantly impact manufacturing SMEs (small and medium-sized enterprises). A study conducted in 2019 [27] highlights that, in terms of impediments for Industry 4.0 adoption, most companies are struggling with the lack of digital competences, lack of technology and infrastructure, and lack of skills and guidance for transformation. Ideas related to the needs for changes and transformations are being already announced by previous studies [28, 26].

4 Industry 4.0 Adoption Among EU Enterprises

The European Union understands the potential of advanced technologies to transform EU industries and so there are several European level policies aimed at encouraging and supporting the adoption of digital technologies.

The EU Commission began to implement a Digital Single Market Strategy in May 2015. This was one of the EU's top 10 political priorities for 2015–2019. This Digital Single Market Strategy consisted of sixteen plans aimed at covering three wide-ranging areas, namely "promoting improved online access for products and

services across Europe, designing an optimal environment for digital networks and services, and providing support for companies to take full advantage of the digital economy as a potential driver for growth" [11].

In the same spirit, most EU governments have included Industry 4.0 among their priorities by adopting extensive strategies and programs to improve efficiency and competitiveness and improve the digital skills of their workforce.

Within this strategy, the European [11] has been working on measuring and characterizing the EU digital society by identifying and gathering relevant data, incorporating information connected with the digitization of the industrial processes. The EU has also constantly developed measures to provide support for cooperation between national research initiatives in the field of "Digital Manufacturing" and to provide various lines of funding within Horizon 2020 [6].

In February 2020, the Commission launched its vision for digital transformation: "Shaping Europe's digital future". Through this, the Commission plans to deliver a comprehensive use of technology "that works for people and respects EU's fundamental values" [13]. The first two pillars of the Commission's innovative digitalization strategy are the White Paper regarding Artificial Intelligence [14] and the European data strategy [15].

Data covering Industry 4.0 Adoption in EU

Most of the data used throughout this study are founded on the Digital Economy and Society Index (DESI) [12], which is a compound guide that condenses all significant indicators regarding Europe's digital development and evaluates the expansion of digitalization of Member States and Eurostat database which assesses periodically the status of ICT usage and e-commerce processes implementation in companies [9].

According to the DESI report [12], the most progressive digital economies in the European Union belong to Finland, Sweden, Denmark, and the Netherlands followed by Malta, Ireland, and Estonia. At the other end of the spectrum, Bulgaria, Greece, Romania, and Italy registered the lowest numbers according to the DESI index.

In terms of **Internet access**, according to Eurostat data, in 2019, 91% of EU companies employing at least 10 persons declared that they are using a fixed broadband connection for Internet access. This number went up 3% compared with 2011, suggesting that the adoption of this technology has reached saturation at the EU level. Considering that nearly all EU enterprises have an Internet connection, the policymakers' focus has shifted lately toward Internet speed, as this is a key aspect for both Industry 4.0 and Industry 5.0.

Internet connection speed. In Industry 4.0 context, speed is equally important to access, and so, between 2011 and 2019, the number of companies accessing fast Internet connections tripled. In 2018, 20% of EU companies declared that their Internet connection ranges between 2 Mb/s and 10 Mb/s. 24% of enterprises declared their Internet connection speed ranges between 10 and 30 Mb/s. 25% of enterprises stated that their connection ranges between 30 and 100 Mb/s, and 18% of EU companies have Internet connections of more than 100 Mb/s.

In 2019, 16% of companies included in the study declared that their Internet connection speed ranges between 2 and 10 Mb/s. 23% were having a connection

ranging between 10 and 30 Mb/s. Over 27% stated that their Internet connection was ranging between 30 and 100 Mb/s, while 23% of companies were using an Internet connection of more than 100 Mb/s [9].

Considering the importance of data and information in Industry 4.0, cybersecurity is an important element to consider. According to the DESI report, in 2019, 34% of EU enterprises declared that they have a focus on cybersecurity and have ICT safety protocols establishing specific procedures that need to be followed by employees. 93% of companies stated that they have implemented at least one cyber safety protocol. The implementation of cybersecurity measures is extensive among large companies and small and medium enterprises alike: as almost 99% of large companies and 92% of small and medium enterprises declared that they employ several cybersecurity measures, but the security measures taken are very diverse. Most enterprises included in the study have set out simple cybersecurity measures such as constantly updating software (87%), device authentication using a strong password (77%), and constantly doing back-ups in separate locations including using cloud solutions (76%). Only a few companies declared that they have in place more sophisticated cybersecurity measures such as security tests (36%) or risk assessments (34%) and only 9.5% of companies implemented biometric methods for user identification and authentication.

In terms of **Cloud computing**, the Eurostat data showed that in 2018, 26% of EU companies declared that they have accessed cloud computing services. In 2020, the number went up by 12%, reaching 36% of EU enterprises using cloud computing. Most companies declared that they commonly use the cloud for e-email and storing files in electronic form.

At the same time, there are important variations that can still be observed across EU countries. In northern countries such as Finland (75%), Sweden (70%), and Denmark (67%), over 60% of enterprises declared that they constantly used cloud computing. At the other end of the spectrum, in Greece (17%), Romania (16%), and Bulgaria (11%), less than 20% of companies regularly employ cloud-based services.

Most companies employing cloud computing services are active in the information and communication sector (71%). For all the other economic sectors, the percentage of enterprises using cloud computing ranges from 27 to 43%. However, the manufacturing sector had the highest increase (+19%) in the use of cloud computing compared with 2018.

Another relevant element refers to the significant differences between large enterprises and small ones when cloud computing use is discussed: 65% of companies employing 250 persons or more use **cloud computing**, representing a rise of 12% compared with 2018 while only around 50% of SMEs declared that they used cloud computing in 2020. However, both small and medium-sized enterprises recorded an increase of 12% compared with 2018, reaching 33% and 46%, respectively.

3D printing or "additive layer manufacturing", refers to utilizing special printers either in-house, by the company itself, or through outsourcing, using 3D printing services offered by other companies to create three-dimensional physical objects employing digital technology.

In 2020, 5% of European companies employing at least 10 persons declared that they utilized 3D printing (in-house or outsourcing). This number represents an increase of 1% compared with 2018 [9]. The highest number of companies using 3D printing in 2020 was from Denmark (9%) and Malta (8%) while the smallest shares were reported by enterprises in Romania (2%).

There is a significant discrepancy in using 3D printing between large enterprises and SMEs: 13% of large enterprises use 3D printing as part of their manufacturing process and only 4% of SMEs access this technology. The technology was mostly employed by companies from the manufacturing sector (9%), followed by companies in activating in the professional, scientific, and technical activities (6%) and in information and communication (5%).

Big data usage. In the last years, due to the ICT advances, the quantity of digital data created, stored, and processed worldwide has been constantly growing exponentially, because every online activity leads to the generation of a series of digital marks which, due to their size, diversity, and speed, are referred to as big data.

According to the data gathered from EU companies, in 2018, 12% of companies employing at least 10 persons reported analyzing big data. The trend for big data analysis is like the other elements measured, being mostly done by large enterprises (33%) and medium-sized enterprises (19%). When evaluating the status of EU Member States, the highest number of companies employing big data analysis is based in Malta (24%), the Netherlands (22%), Belgium (20%), and Ireland (20%). Companies from Italy (7%), Bulgaria (7%), Hungary (6%), Austria (6%), and Cyprus (5%) declared in significantly lower numbers the use of big data analysis.

Enterprises that analyzed big data declared that they use a variety of data sources, the most popular ones used to be geolocation and social media data. Almost 50% of companies stated that they use for their big data analysis geolocation data from portable devices (49%) and data from social media networks (45%). Only 29% of companies analyzed big data from smart devices and 26% used data from other sources. For large enterprises, the analysis was done mostly by employees (90%) and 75% declared that they employ an external service provider for this activity. 42% of the SMEs included in the study declared that they rely on external service providers to analyze big data and 40% stated that the activity is performed by their own employees.

The DESI report (2020) also analyzes the **workforce** and its role in developing the digital economy in the European Union. According to the data, in 2018, a little over 9 million persons were working as ICT specialists all over the European Union. Companies from UK and Germany were employing each around 1.6 million ICT specialists, while companies from France had over 1.1 million ICT specialists. According to the data from 2019, almost 20% of companies declared that they hired experts to create, manage, or maintain ICT systems and applications. Here, there is also a significant difference between large enterprises (75%) and small and medium enterprises (19%). Another aspect related to the specifics of the ICT labor refers to the companies' abilities to recruit personnel, and in 2018, almost 57% of the companies which employed or attempted to employ ICT experts declared having problems in filling such positions. These difficulties were experienced by over 64% of large enterprises

and 56% of small and medium enterprises. Companies from Romania and Czechia are reporting having even more difficulties when recruiting or trying to recruit ICT specialists, as 80% of the companies declared that they are unable to find staff to fill these specific vacancies. The aspect of the specialized workforce becomes even more relevant when discussing Industry 5.0, as these specific skillsets represent a central element in the successful evolution toward Industry 5.0.

5 Conclusions

Since the introduction of Industry 4.0 at the beginning of the 2010s, there have been constant discussions and predictions regarding its evolution and impact over all industrial sectors. In terms of efficiency and costs, research shows that by implementing Industry 4.0, companies have registered 10–30% in decreased production costs, 10–30% in decreased logistic costs, and 10–20% in decreased quality management [23].

However, wide-range Industry 4.0 adoption led to generating other types of societal costs and so, more and more voices begun to point out the inadequacies of Industry 4.0 and propose a natural evolution toward Industry 5.0, not in terms of chronology but of approach, because the shift from a machine-centric approach to a human-centric approach is not only desirable but necessary.

We agree with the scholars who consider that the two industrial revolutions are intrinsically connected and should actually be treated as one, because Industry 5.0 supplements and increases the characteristics and advantages of Industry 4.0.

The use of innovative digital technologies, such as IoT or big data analysis, can ensure companies an increase in productivity and efficiency and provide new development opportunities for EU enterprises from all areas of activity. The analysis of the presence of Industry 4.0 elements in European Union manufacturing companies revealed that in terms of Internet access and Internet connection speed, most European enterprises have managed to advance and harness the advantages, and this is correlated with the European and national efforts aimed at ensuring connectivity and Internet access.

Other elements of Industry 4.0, such as cloud computing or big data usage, are less adopted by EU enterprises, with significant differences between large enterprises and small and medium enterprises. This can be explained due to the costs and resources implicated in the process of technology adoption.

Another aspect that needs to be considered is the workforce skills and competences which need to be updated alongside the technology to ensure a successful transition to Industry 5.0.

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