

Innovation through Industry 4.0 – Driving Economic Growth and Building Skills for Better Jobs

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Abstract

Novel technologies are quickly reshaping the industrial environment as well as the labor market in what has been called The Fourth Industrial Revolution or Industry 4.0. As digitalization and robotization quickly become industry standards in many fields of manufacturing, businesses, both big and small companies need to quickly adapt their strategies, workforce and operations to this new reality in order to remain competitive and relevant. Being able to adopt and integrate new technologies quickly will make the difference between being a trend setter or a follower in an increasingly more globalized and more digitalized economy. And there are not just the businesses that need to adapt to this rapid change. The workers themselves will be required to master new skills and be able to operate new machines quickly and proficiently or risk being replaced by one in the near future. This paper aims to look at the new, emerging technologies in the industrial sector, their rate of adoption and their impact on workers, production processes and businesses.

Keywords: Industry 4.0; digitalization; innovation.

JEL Classification: E24; L23; O14; O33.

Introduction

The global economy is becoming ever more reliant on novel technologies and digitalization plays a key role in modern business. The worker, as well as the entrepreneur both face new challenges and are forced to adapt quickly to an ever changing, ever more technologically complex environment. Industry 4.0 and the changes that accompany it leave many wondering about the future of their business or career (Surugiu et al., 2018; Rehman et al., 2020; Bănescu

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et al., 2021; Gigauri & Djakeli, 2021; Grigorescu et al., 2021; Tetik & Akkaya, 2021; Akkaya & Ahmed, 2022). But it is not the first time when humans have felt that their livelihoods were threatened by machines. The Ludites of 19th century England were secretly destroying textile machines, believing that it was worthless trying to learn new skills as technology was eventually going to replace them completely. Yet today, the textile industry employs over 1.5 million people in the European Union alone. Humans are resistant to change, and often hesitant to look for the benefits it offers. Increased reliance on technology and digitalization will bring about a plethora of novel jobs that require new skills, new mindset and new approaches to work (Zhan et al., 2020; Liviu et al., 2021; Vasile et al., 2021; Elena et al., 2022).

Technology has always represented a primary driver of change in the labor market. Ever since the first industrial revolution, powered by the steam engine, the worker has been forced to adapt to novel circumstances, acquire new skills, learn how to operate machinery as well as master new processes. The current digital revolution is identical in nature, though different through the skills and abilities required. The essence of Industry 4.0 is digitalization, the creation of the Internet of Things (IoT), the implementation of smart technologies and automation of many business and industrial processes. And though it may seem that this digital transition will make the human laborer obsolete, this new industrial revolution will bring about a plethora of novel high paying jobs in all sectors of business and industry. But the worker is not the only one who will have to face change. Organizations will be required to adapt quickly to a fast-changing business environment, in an age of globalization in which competition can come from every corner of the world and clients will choose providers that can integrate in their own technological framework. Organizations will be forced to migrate from legacy technology to the digital environment while at the same time trying to minimize the impact on their processes, workforce and clients (Smuts et. al. 2020). In order to remain competitive, businesses will not be required to merely adapt to change but redesign their operations in order to seamlessly integrate their business models in a global market driven by digital technology and processes.

The purpose of this paper is to identify the best solutions for implementing new technologies into the workplace that will stimulate growth as well as help workers adapt quickly and develop skills for the future.

Bibliometric Analysis regarding Innovation through Industry 4.0

For analyzing the literature on innovation through industry, we used the association of following words: “innovation”, ”Industry 4.0”, the results being represented by 2096 papers for the period 2006-2022. According to Figure 1 the number of published papers and citations register an ascending trend, highlighting an increased interest in the field starting with 2016.

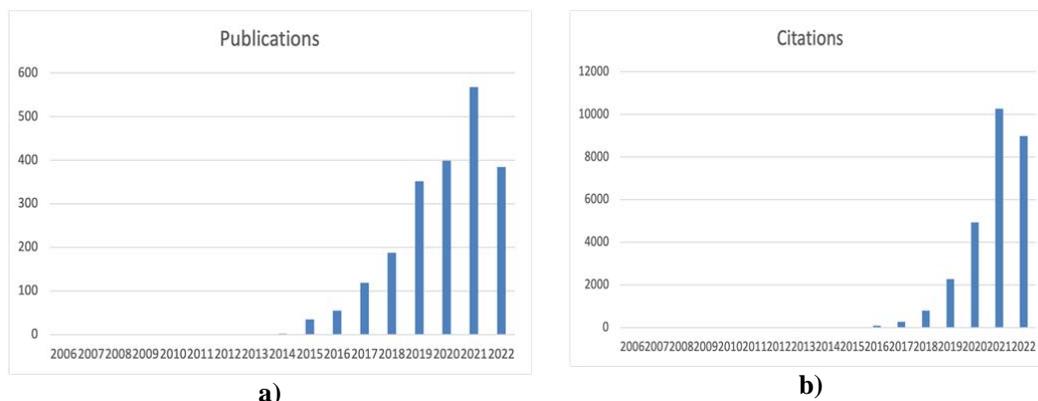


Fig. 1. Dynamics on (a) publications, and (b) citations in the field of innovation through Industry 4.0.

Source: authors own work.

In order to analyze the most common words regarding innovation through Industry 4.0, we performed bibliometric analysis, identifying the literature content in this field. For this, we used the word clouds considering the most common words. For determine the relationships between words it was investigated which words follow other words or occur together. Thus, the word network reflects the word pairs which co-occur most often, and the correlation network reflects the words appearing more often. For this, we used the 2096 papers on innovation through Industry 4.0 provided by the platform Web of Science for the period 2006-2022. For inspecting the most common words and the relationship between words, the content analysis was used and for co-occurrences network was considered a frequency of at least three time and a correlation degree greater than 0.5. The analysis has been done using the Vos programme. The empirical results reflects that the words with the highest frequency of appearance encountered on the content of selected articles are: “technology”, “knowledge”, “revolution”, “business”, “challenge”, “capability”, “process” (Figure 2). Thus, in the literature, innovation through Industry 4.0 is associated with technology and knowledge, being encountered in business.



Fig. 2. Most common words in scientific publications regarding innovation through Industry 4.0.

Source: authors own work.

The most encountered combination of words was explored within the selection of articles. The empirical results, presented in Figure 3, highlighted five important clusters of the most common combinations in the selected 2096 studies in the field. These are:

Cluster 1: ability, adoption, application, barrier, capability, challenge, confrontation, cyber physical system, digitalization, environment, industrial company, information technology, internet, manufacturing, value innovation;

Cluster 2: business model, digital transformation, impact, implementation, innovation performance, interview, practical implication, perspective, value;

Cluster 3: attention, competitive advantage, competitiveness, development, implication, innovation, manufacturing industry, opportunity, sustainability, technological innovation;

Cluster 4: business, improvement, influence, information, knowledge, leadership, learning, process innovation, revolution, roadmap;

Cluster 5: actor, collaboration, contribution, cost, customer, effect, enterprise, integration, open innovation, policy, provision, SME, technology, solution.

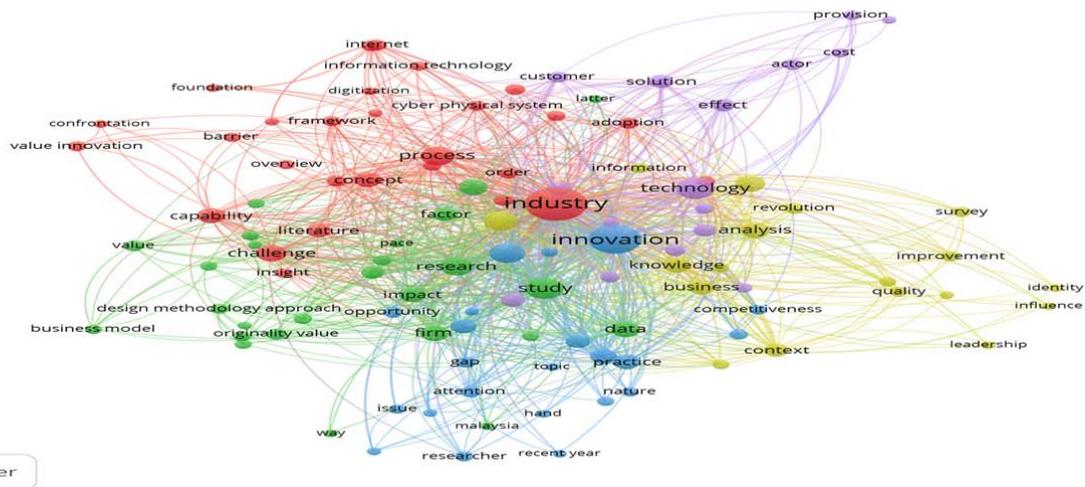


Fig. 3. Most common words and word network in scientific publications' content on innovation through Industry 4.0.

Source: authors own work.

These results indicate that innovation through Industry 4.0 has implications most on environment, industrial company, cyber physical system, and manufacturing, implying challenge, barrier, and confrontation (cluster 1). Regarding business model, innovation through Industry 4.0 presents digital transformation which has an impact on performance (Cluster 2). For manufacturing, it is reflected through attention, competitiveness, representing an opportunity to achieve sustainability (Cluster 3). In the field of business and leadership, it represents a revolution, a learning pathway in order to improvement and information (Cluster 4). For SMEs, innovation through Industry 4.0 generates cost and collaboration, representing a solution towards innovation.

Industry 4.0 – New Technologies and Vital Skills

Smart factories and smart workplaces are powered by a set of novel technologies that allow machines to better communicate with each other as well as with their human operators and supervisors, streamlining processes, reducing downtime as well as being as energy and resource efficient as possible. Some of the most important technologies that define Industry 4.0 are:

1. The Internet of Things (IoT) and Industrial Internet of Things (IIoT) – representing a key component of the smart factory, this technology allows seamless connectivity between a wide range of machines, sensors and other connected devices and their human operators via an easy to interpret visual interface. Live data collection and analysis allow workers to monitor a multitude of processes and operations in real time, without having to shut down machines or interfere with the production process. This generates a more efficient and uninterrupted operation of a factory (Li et al., 2015, Beier et al., 2018).
2. Artificial intelligence (AI) is the ability of a machine to perform tasks that require human intelligence. Frequent, complex processes and large amounts of data can often overwhelm even the most skilled and experienced human operators. Machine learning gives computers the ability to foresee problems in the production process and alert the worker to the possibility of a future malfunction, identify parts that will need to be replaced in the near future as well as identify the optimal times for performing maintenance in order to minimize downtime. Predictability in production will not only maximize efficiency and

- profits but will also alleviate the stress brought about by uncertainty for the workers (Sharma et al., 2020a).
3. Cloud computing – a crucial part of any Industry 4.0 operation, cloud computing allows data to be shared in real time, not only inside the workplace but also with other entities that are important to the operations: customers, suppliers, warehouses, the sales force, distribution services, etc. Cloud computing is decisive to integrating a business in the modern global economy (Dincă et al., 2019, Sharma et al., 2020b).
 4. Analytics and big data – as industrial processes generate a large amount of data, it is practically impossible for human workers to analyze and interpret it in a timeframe that is relevant to the business. Machine learning allows for this data to be quickly processed and offer insights to the entire production process in order for the best decisions to be made when it comes to plant operation (Ardito et al., 2018, Dai et al., 2021).
 5. Cybersecurity – cyber-physical systems can become a target for malicious attacks and robust cybersecurity systems and practices are a must for any modern, interconnected workplace. Cyber protection should encompass the entire operation: data and data streams, machinery, sensors and analytics, computer systems and the cloud.

Most of the work in the smart factories is done by machines and the high level of automation only requires a human supervisor. Given the high level of technical complexity in the workplace as well as the novel technologies and machines used for production, the human operator requires a high level of understanding. Employability in an Industry 4.0 environment will highly depend on the skills and abilities an individual has or is able to acquire quickly. There will be a high demand for employees who will be able to demonstrate both soft skills and technical skills simultaneously. A paper by Beier et. al., 2022 found that companies from Germany, Brazil and China have much higher expectations from workers in an Industry 4.0 environment (Beier et. al. 2022). The most important ones are listed in the table 1.

Table 1. Crucial skills for an Industry 4.0 environment

Soft (business) skills	Technical skills
Communication	Programming
Leadership	Database management
Adaptability	Computer modeling
Flexibility	Computer aided design
Logical thinking	Cyber security
Delegation	Data interpretation
Monitoring	Knowledge of robotics and Artificial Intelligence

Source: authors own work.

Technological Trends, Pressures and Developments

The Fourth Industrial Revolution will focus heavily on interconnections between digital systems and rely on a data driven, digital infrastructure, robotics and Artificial Intelligence. The impact for the job market will be significant. Many human laborers in manufacturing, warehousing and logistics, agriculture and construction will be replaced by robots and machines. Those with low levels of technical skills, lack of desire to adapt and learn new things will be particularly at risk of job loss. The most significant market pressures driving digitalization in manufacturing are:

1. Cost reduction. Cost reduction is a key factor for maintaining a competitive edge and increasing profitability. Preventive maintenance, enabled by AI algorithms that analyze the machines helps reduce downtime, lower repair costs and ensure smooth, uninterrupted and efficient operation of the plant.

2. Improved efficiency. Analyzing data collected automatically helps managers gain an insight into various processes and make decisions that improve the efficiency of certain operations or the business as a whole.
3. Customization. Mass producing custom products and designs while maintaining production costs low has long been looked at as the holy grail of manufacturing. Thanks to the IoT and smart machines, producing on demand has become a reality of modern manufacturing.
4. Faster time to market. Modern demand is highly flexible and susceptible to trends. Being able to offer a thought after product quicker than the competition puts businesses in a significant advantage. A quick flow of information and interconnected pieces of the manufacturing and supply chain allow for much quicker acquisition of materials, parts and technologies in order to satisfy customers demand quicker than ever before.

In order to remain competitive on the global markets, companies in the European Union should strive to adopt novel digital technologies at a faster pace. According to the European Investment Bank's Investment Survey on Digitalization in Europe in 2021-2022, the EU lags behind the United States when it comes to the adoption of advanced digital technologies (EIB 2021). The country breakdown is presented in the figure 4.

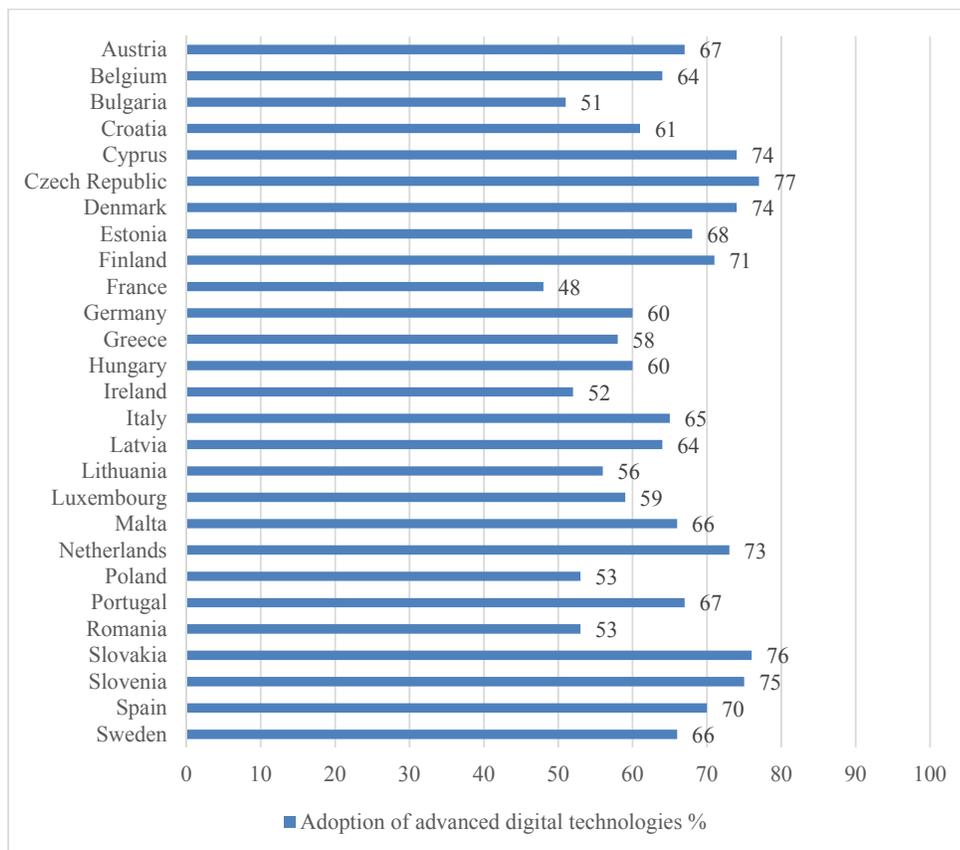


Fig. 4. Degree of adoption of advanced digital technologies by European Union firms

Source: authors own work based on data from the European Investment Bank.

The results of an online survey conducted from 29 October to 14 November 2021 by the market research institute YouGov on behalf of the Handelsblatt Research Institute and TeamViewer of 4531 corporate decision makers representing 1452 companies from ten European countries (Denmark, Germany, France, Italy, the Netherlands, Norway, Poland, Sweden, Spain and the United Kingdom) shed light on the digitalization of the production process and the adoption of

novel technologies. When it comes to technologies decision makers deem important for the future of production, cybersecurity ranks on top, not surprisingly as a digital factory, where everything is interconnected and computers control most of the production process is particularly vulnerable to cybersecurity threats (table 2).

Table 2. Important future technologies in production – country comparison.
Proportion of surveyed corporate decision-makers.

	DE	UK	FR	ES	IT	DK	SE	NO	NL	PL
Cybersecurity	25%	14%	24%	28%	32%	25%	19%	23%	35%	34%
Digital platforms	26%	20%	17%	29%	27%	29%	24%	23%	32%	29%
Internet of Things	22%	24%	23%	30%	31%	17%	21%	23%	28%	25%
Cloud services	23%	16%	21%	27%	24%	16%	24%	19%	31%	33%
Mobile robots	17%	14%	21%	25%	19%	11%	19%	19%	17%	26%
AI-based machine learning	19%	17%	19%	26%	22%	9%	14%	23%	13%	18%
Big data/(predictive) analytics	22%	18%	18%	24%	21%	11%	5%	14%	17%	18%
Cloud computing	15%	18%	17%	26%	19%	10%	12%	18%	21%	19%
3D printing	20%	15%	16%	25%	14%	9%	16%	11%	12%	16%
Augmented reality	17%	10%	19%	22%	20%	9%	14%	11%	10%	17%
Image and object recognition	21%	12%	14%	17%	21%	15%	20%	7%	13%	15%
Collaborative robots	16%	8%	21%	22%	17%	10%	12%	14%	16%	13%
Self-learning systems	19%	11%	14%	19%	20%	14%	15%	12%	17%	15%
Voice and character recognition	18%	9%	18%	14%	15%	3%	11%	14%	15%	16%
Smart containers	14%	14%	16%	18%	15%	6%	13%	12%	14%	14%
Autonomous driving	14%	7%	13%	19%	16%	6%	15%	19%	8%	19%
Wearables	10%	8%	14%	19%	17%	2%	5%	25%	9%	16%
Chatbots	13%	8%	15%	18%	11%	7%	8%	7%	13%	12%
Blockchain	13%	10%	9%	18%	11%	6%	11%	9%	14%	16%

Source: authors own work based on data from the “Industry 4.0 How digital technology is changing companies’ production processes” of the Handelsblatt Research Institute

The survey revealed that when selecting a provider for new production technologies, most decision makers consider that pricing policy is the most important criteria, followed by security and the availability of technical support. This suggest that although having access to the latest technologies is important, cost will still be a major factor and the companies that manage to offer the most competitive prices for their products and services will definitely be at an advantage. The table 3 reveals the most important criteria decision makers consider important when picking a technology provider.

Table 3. Important decision criteria in the selection of technology providers – country comparison.
Proportion of surveyed corporate decision-makers.

	DE	UK	FR	ES	IT	DK	SE	NO	NL	PL
Clear and flexible pricing	16%	18%	19%	18%	20%	32%	22%	32%	29%	20%
Security (‘Security by design’)	21%	15%	23%	17%	19%	34%	21%	21%	23%	18%
Availability of advice, support and profession- al services	18%	11%	21%	24%	23%	17%	14%	14%	9%	24%
Expertise in process integration	14%	15%	17%	15%	26%	14%	13%	26%	19%	19%
Expertise in automation	11%	15%	15%	21%	19%	17%	12%	19%	27%	21%
Full service provider – holistic Industry 4.0 concept/solution	20%	15%	15%	21%	19%	9%	9%	11%	12%	21%
Excellent flexibility with project implementation	17%	15%	10%	16%	21%	13%	19%	16%	21%	18%
Clearly defined Industry 4.0 strategy	16%	9%	14%	20%	18%	6%	9%	16%	17%	18%

Open standards (interoperability, scalability, security)	17%	15%	14%	16%	13%	17%	14%	11%	12%	16%
Business relationships with traders	18%	13%	15%	15%	10%	3%	12%	18%	17%	22%
Large network of partners for Industry 4.0 projects	16%	2%	19%	18%	15%	1%	9%	16%	11%	14%
Available references and case studies	14%	9%	13%	19%	13%	7%	8%	14%	8%	15%
Vertical industry solutions/industry knowledge	12%	8%	12%	15%	14%	5%	6%	4%	15%	16%
Expertise in edge computing	13%	5%	15%	11%	15%	5%	7%	11%	6%	9%

Source: authors own work based on data from the “Industry 4.0 How digital technology is changing companies’ production processes” of the Handelsblatt Research Institute

Conclusions

Economic activity is in a complex process of metamorphosis under the action of factors with different influences. On the one hand, technical progress generates radical changes in the production process and in the way of doing business. Digitization and industry 4.0 are the watchwords that reconfigure the activity of companies and implicitly of employees but also of other categories of stakeholders. On the other hand, the acceptance of new technologies is not a simple process, there is a certain resistance to the new on the part of employees and consumers and the problems generated by their unethical use are at the center of attention of the public authorities that are trying to create and consolidate the legal and institutional frameworks. In this context, cyber security is a constant concern considering the negative externalities that cyber-attacks can generate on critical sectors of the economy such as energy production. The authors are aware of the limits of the research carried out, which is why they are considering initiating additional studies to analyze the specific situation of European countries that are involved in a complex process of twin transition, considering the challenges generated by climate change.

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