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1. Introduction: The Evolution from Industry 1.0 to Industry 4.0

Industry 4.0 can be seen as an evolution of the three predecessor industrial revolutions, in which each of these revolutions had its own distinct characteristics and focus. The third industrial revolution, which is marked by the use of electronics and information technology, and began in the mid-1970s, is moving towards a new technological era, the fourth industrial revolution, where the main focus is on the development of cybernetic physical systems (CPS). In the early twentieth century, the second industrial revolution occurs, characterized by the introduction of new means of production and optimization, such as mass production based on the division of labor. Still in the twentieth century, the third industrial revolution emerges in the early 1970s. The third industrial revolution is characterized by the use of electronics and IT (information technology), already aiming at an automation of manufacturing. Finally, the fourth industrial revolution emerges, which is highly complex and technologically advanced.

The need for technological changes has opened space for a new discussion about the future of industries and manufacturing, originating the concept of Industry 4.0. This concept was first presented in 2011 in Germany, focusing on digitization and high-tech strategies. The goal was to transform the management and production of industries through the integration of new technologies, and thus create a fusion of the real and virtual worlds. The German government, together with universities and industry, has bet on Industry 4.0 as a strategy to stay in the leading position and advance further in high technology, mainly because it is a country that is characterized by a strong export of technology and has a leading and competitive industry. The focus of this strategy is industrial information technology, which, according to the German government, is what would revolutionize industrial production.

2. The fourth industrial revolution and how its potential revolutionizes industrial value chains

With the starting point being the German government's strategy in industrial information technology, Industry 4.0 can be defined according to Federal Ministry of Education and Research (2016, p. 20) as the organisation of production processes based on technology and devices autonomously communicating with each other along the value chain: a model of the ‘smart’ factory of the future where computer-driven systems monitor physical processes, create a virtual copy of the physical world and make decentralised decisions based on self-organisation mechanisms.

Also according to Federal Ministry of Education and Research (2016) the most striking main features seen in Industry 4.0 are: I) Interoperability; II) Virtualization; III) Decentralization; IV) Real-time capabilities and V) Modularity. These characteristics are related to the technologies that are considered the pillars of Industry 4.0, creating an identity for it.

The term "intelligent" for factories, products, industry and processes is often used in the definition of Industry 4.0, where an autonomy in technological processes is observed, and thus there is no longer a need for total human control, giving way to intelligent self-control and organization systems. In this context, the characteristic of decentralization is classified, where cyber-physical systems have the ability to make their own decisions. Interoperability also arises in this context, which is described as being a characteristic that allows greater communication and connection between humans and machines, also through cyber-physical systems (FEDERAL MINISTRY OF EDUACATION AND RESEARCH, 2016).

Also according to Federal Ministry of Eduacation and Research (2016) in Industry 4.0 one can observe two integrations simultaneously: vertical and horizontal. The vertical network consists of the integration of intelligent production systems, where all production processes are connected, which by means of cybernetic physical systems create an intelligent network of control and organization of production and a maintenance management. In this way, factories have quick responses to changes in demand and inventory, as well as a quick localization of materials and products. also need a vast integrated database to perform their operations, since production via smart factories has an individualized character for each customer (DELOITTE AG, 2014).

Horizontal integration also occurs through CPS and is similar to vertical integration in that it responds quickly or in real time to sudden changes such as problems and failures. It is an integration through global value chain networks, where they facilitate communication in global terms, from the inbound logistics to the outbound logistics of the products and the production itself. This allows for greater transparency and flexibility in the production chain and its entire process, as it allows for greater interaction between all contributors in the value chain, creating greater global and real-time optimization (DELOITTE AG, 2014).

Also according to Deloitte AG (2014) Industry 4.0 allows for greater flexibility, cost reduction and individualized solutions through exponential technologies, such as artificial intelligence, which is shown to be strongly autonomous and individualized, and 3D printing, which has created greater flexibility in creating new solutions for products.

Modularity is described by Ministry of Education and Research (2016, p. 21) as flexible adaptation of smart factories to changing requirements by replacing or expanding individual modules and according to Balasingham (2016, p. 7) flexibility causes only relevant information related to specific processes to be shared, thus resulting in the rapid production of customized products, a strong feature of Industry 4.0. A flexible CPS network enables processes to become more efficient, as these systems create flexible production through automated process monitoring. This results in problem solutions and responses to sudden changes in real time, thus generating process optimization and higher productivity.

The implementation of Industry 4.0 processes and systems can be costly in its early stages. However, it is expected that with advanced manufacturing a significant cost reduction will occur over time through the more efficient use of resources. According to Balasingham (2016, p. 9) the main means of efficient use of resources in Industry 4.0 are the efficient use of raw materials, energy consumption, and human capital.

Real-time capability, according to Ministry of Education and Research (2016, p. 21) is "the capability to collect and analyze data and provide the derived insights immediately." Smart grids are able to share data between components of the production process, from resources to the final product, which can be located, tracked, and monitored in real time, anywhere. The result of this process is a greater reduction in the costs of the entire production process, because any failure can be detected in real time and through intelligent systems problems are solved before production even begins, resulting in a strong reduction in waste.

According to Deloitte AG (2014) individualized solutions regarding customer needs and requirements can lead to great opportunities in the development and production process. With the individualization of products, there is also greater integration between customers and companies, resulting in greater flexibility in production, where customers can follow the production process from its initial stage.

Virtualization is described according to Federal Ministry of Eduacation and Research (2016) as a linking of sensor data from a virtual copy of the smart factory to virtual factory models and simulations. That is, it is possible to create a digital copy of factories, and through simulations prevent damage, improve and optimize the production process of smart factories by detecting threats and possible problems in the future.

Another defining feature of Industry 4.0 is increased security throughout the production process by means of information technology (IT). A protection of data and processes is essential so that information leakage and undesirable events do not occur. According to Fraunhofer (2016) Industry 4.0 needs a great deal of high-level technological protection and testing against possible attacks and system failures. To keep the system reliable and combat network attacks, information technology is needed as a means of high security. Information technology security is one of the main aspects that ensure the success of Industry 4.0, because it develops strategies to combat possible attacks on the production network, making simulations, examining the implications of attacks and thus preventing them in advance.

The implementation of Industry 4.0 according to the characteristics cited above results in a higher level of competitiveness of industries, in local and global parameters, because it changes the entire process of the value chain, through high quality production, speed, flexibility and cost reduction. As a result, higher productivity and industrial growth occurs, where economies of scale and scope can also be observed, leading to increased competitiveness and a creation of competitive advantages through digitalization (Balasingham, 2016, p. 12).

3. Technological pillars of Industry 4.0

Being a new technological paradigm, the fourth industrial revolution is characterized by having new and different technologies, which are essential for Industry 4.0 to become successful. These technologies have the characteristic of much more autonomous communication and significantly increase the productivity of industrial processes along the entire value chain (MINISTRY OF EDUACATION AND RESEARCH, 2016).

Despite being integrated technologies and used to generate specific and individual solutions for companies, the use of technologies differs according to each client and solution presented, and it is not necessary to use all technologies for all cases. However, what is striking in this new paradigm is the high number of combinations of these distinct technologies that can be made and used to solve problems in industries, accelerating their diffusion and the production process itself.

The classification of the main technologies that underpin the new technological paradigm of Industry 4.0 may differ according to different authors. IEDI's (2017) classification brings nine technologies that are part of Industry 4.0, which are: I) Cyber-physical systems (CPS); II) Big Data Analytics; III) Cloud computing; IV) Internet of Things (IoT) and Internet of Services (IoS); V) 3D printing and other forms of additive manufacturing; VI) Artificial intelligence; VII) Digitalization; VIII) Energy harvesting; and IX) Augmented reality. Although all the technologies mentioned above have great importance for Industry 4.0, Hermann, Pentek & Otto (2015, p. 5) cite four as key technologies for the success of advanced manufacturing. These are: I) Cyber-physical systems; II) Internet of Things; III) Internet of Services and IV) Smart factories.

What is often observed is an integration of these technologies, which despite being independent, connected create new technologies. The analysis of the technological pillars that underpin Industry 4.0 can be done separately, but the integration of these technologies, such as cyber-physical systems, big data, the internet of things, and services, will also be discussed.

3.1 Cyber-Physical Systems (CPS)

Cyber-physical systems are the core technology of Industry 4.0, being the basis and starting point for the other technologies. CPS can be described as the joining of the virtual world with the real world, through the connection between autonomous machines and internet networks, resulting in intelligent machines, storage systems and production facilities that act independently, without requiring full human control (Kagermann et. al, 2013).

Because they are the foundation of other technologies, cyber-physical systems play a key role in advanced manufacturing because they allow areas with little affinity to be integrated, resulting in new end capabilities. For being able to unite several areas and integrate them, the CPS can be seen in several industries and are also applied in various situations, such as: medicine, automotive systems, infrastructure, energy conservation, traffic control systems, robotics, among many others. The SPCs are composed of a control unit, which interacts with the physical world, commanding the sensors and actuators, by identification technologies, by storage mechanisms and by data analysis. All these components work together and enable integration and communication in real time, and thus prevent and identify failures in production, such as a high stock of products or errors in manufacturing, such as damaged or missing parts.

PSCs are connected with internet of things, internet of services, smart factories, among other technologies. According to Nagy et al. (2018, p. 12) production systems in the near future should take into account product individualization, and need to be developed through PSCs for this to occur, resulting in greater flexibility in the production process. In this context, SPCs are incorporated into smart machines, storage systems, and production facilities, where they exchange information and have the autonomy and intelligence needed to command the production process.

3.2 Internet of Things (IoT) and Internet of Services (IoS)

According to Kagermann (2013) IoT and IoS will be present in all key areas in Industry 4.0, considering a fully connected world. This connection occurs through horizontal integration and vertical networking throughout the value chain, generating intelligent products and processes.

The internet of things is the network of physical objects, systems, platforms and applications with embedded technology to communicate, sense or interact with internal and external environments. This is nothing more than an integration of networked technologies, specifically the internet, with mostly concrete objects of frequent human use. It can be stated that IoT is the progressive automation of entire sectors of the economy and social life based on machine-to-machine communication: logistics, agriculture, human transportation, healthcare, industrial production, and many others.

IoT can already be seen in everyday life, mainly through micro-sensors in different physical objects and products, providing relevant information and facilitating daily life and work routines. One of the most common examples of IoT are "connected homes", where smart appliances through sensors identify the needs of the residents, and thus autonomously make the necessary changes such as house temperature, lighting and sound systems, etc.

The amount of internet-connected objects that generate data about reality is increasing due to a cheapening of sensor costs and miniaturization of electronic components, and thus give a greater space and facilitate the incorporation of the internet of things. When we talk about IoT we must attribute the concept of hyperconnectivity. For the author, the term hyperconnectivity is related to communication and at first was created to characterize the state of availability of people to connect at any time. The most recent explanation of the term can be related to a large amount of information and data production, and what is observed is not only communication between individuals, but also between individuals and machines and between machine-to-machine.

The internet of services follows practically the same idea as the internet of things, but differs in that it is connected through an internet network with services rather than physical objects. IoS is the digital means by which companies, people, or intelligent systems can communicate in order to provide and obtain services. IoS is used in value chain service processes through external and internal communication and information exchanges, thus creating efficient process control through a flexible and adaptive planning network.

3.3 Smart Factories

Smart factories can be considered Industry 4.0 itself, facing challenges of complexity, speed, and flexible production. Smart factories are the factories of the future, where the production process and the products themselves communicate intelligently, such as self-control of tasks in the production process by means of cyber-physical systems. The SPCs in smart factories allow a communication between humans, machines and products, through the collection and processing of a massive database, and in this way manage to create autonomy and intelligence in the production process, resulting in a more economical and productive process (Brettel et al, 2014, p. 39).

Furthermore, according to Deloitte AG (2014) the massive database along with intelligent sensors in the factories of the future are also used to enable individualized and customer-specific production and to respond quickly to changes within the factories. All these processes occur through cyber-physical systems that are embedded in the vertical network.

Through cyber-physical systems within smart factories, it is possible to create smart processes and products, such as mobility, logistics, buildings, and electrical systems, which are embedded in IoS (logistics, mobility, etc.) and IoT (smart products).

3.4 Big data

Although not classified by authors Hermann, Pentek and Otto (2015, p. 7) as one of the four key technologies of Industry 4.0, what is observed is Big data behind the key technologies, being a technology of paramount importance in the new advanced manufacturing paradigm. Big data can be described as an evolving term that describes any voluminous amount of structured, semi-structured, or unstructured data that has the potential to be exploited for information.

Big data in its essence is people, as every movement, purchase, internet search is stored and used as a database. What characterizes big data in the new technological paradigm is the increasing volume of the database used, as well as the high speed at which this data is processed. The data can have a variety of formats, with different devices collecting different data in different situations. This variety of data can be considered an additional challenge, as the information can be quite distinct and must also be analyzed distinctly.

The old techniques for data collection and analysis can no longer keep up with the accelerated growth of the database. This growth is so high that it is expected that in the next few years gigabytes will disappear, to be replaced by zettabytes. The large volume of data can be generated not only by the internet but also by the application of SPCs and other connected equipment in the production system.

4. The fifth industrial revolution – an excurse

Policies to support technology development are of utmost importance for a country/region to be able to increasingly expand and strengthen its technological potential. Within the new technological paradigm of Industry 4.0, industrial policies to support the development of technologies are indispensable and it is through them that the success of leading countries in Industry 4.0 can be observed. Eight countries are in a prominent position in advanced manufacturing: Germany, Japan, South Korea, USA, UK, France, China, and India.

An important concept to be highlighted in this sense is the National Innovation System (NIS). The NIS provides learning as its main activity, through interactions and partnerships between the actors. This interaction promotes and influences the development and use of innovations within a country. The actors of a NIS may differ according to countries, but they are often classified as private and public companies (whether large or small), universities, and government agencies, aiming at the production of science and technology within national borders (NIOSI et al., 1993). Also, the actors are influenced by several factors that are specific to each country, such as: regulations, financial and governmental system, labor relations, etc.

In this sense, the policies to support technology development also differ according to each country among those considered leaders in advanced manufacturing, because each country has its own industrial characteristics, traditions and technological priorities. These issues are evaluated along with the strengths of each economy, thus emerging specific strategies in order to achieve goals for the development of industry in priority sectors in these countries, according to the individual technological facilities and advantages they have.

According to an analysis on the industrial and technological development strategies in the leading countries in Industry 4.0, the conclusion was reached that all eight countries analyzed have partnerships between industrial companies (not only large companies, but also small and medium-sized companies and technology-based startups), academia, and government. These partnerships are intended to foster innovation and technology and ensure a supply of skilled labor within industries. Despite their differences, it can be stated that there are a set of themes that are considered priorities for the development of Industry 4.0 through policies. They are: Support for the diffusion of these technologies with companies to modernize the production apparatus and development and the adaptation of workers' competencies and skills to the new technologies adopted by companies.

One policy that is relatively recent and widely seen in these countries is the promotion of startups and small technology companies, where technological products and solutions are commissioned by the government, a measure that stimulates the production of national technology and can also be found within universities. Alongside this is seen an encouragement of technology developers, skills training, and supply chain development. These incentives trigger an increase in investment in research and innovation spaces, and thus enable greater distribution of new technologies in industry.

Also according to the study a high participation of governments in the role of industrial incentive and financing in the leading economies in Industry 4.0 is remarkable. All eight countries have governmentfunded technology incentive plans, and only the United Kingdom and India do not have a concrete strategic plan for Industry 4.0. Inspired by Germany, the other countries have created their own strategic plans, such as New Industrial France in France and Manufacturing USA in the United States. What is also seen in all the countries observed is a strong public-private partnership, connecting the government with companies (from startups to large companies with high technological potential) and academia. These partnerships make room for the creation of councils (as in the case of Japan, the Artificial Intelligence Technology Strategy Council), research institutes (such as the Fraunhofer Institute in Germany), and technology development headquarters.

The main objectives of policies to encourage the development of industry in leading countries are to spread high technology in domestic companies, with the support of large companies with high technological potential, to offer more and more technology to the industry in order to create a modernization of it, and to create a generation of workers prepared, skilled and able to better adapt to advanced manufacturing. These goals are summarized in the strategy of maintaining technological leadership and continuing to advance in technologies that already have advantages.

Policies to encourage industry development are not exclusive to the leading countries of the technological paradigm, but are also seen in several countries that seek to deepen their technologies in industry. The contrast is observed by the level of knowledge of the actors of a NIS regarding Industry 4.0. While in technologically developed countries Industry 4.0 is already a reality and there are several policies to support the development of the industry, as shown in Table 3, it is observed in economies with lower technological potential (as in the case of Brazil) a greater ignorance on the subject, and as a consequence a lower incentive to create industry development policies, in addition to a greater expected slowness in the process, because the Brazilian industry is highly heterogeneous, making it difficult an equal diffusion in all sectors.

Moreover, the policies were divided according to the main actors of a NIS: Public and private companies, universities (academia) and government. The importance of the integration between these actors is emphasized so that the policies are successful and results appear.

Although the compilation of policies describes the main policies seen for the promotion of technology and innovation, it can be stated that the degree of effectiveness of industrial and technological policies is not the same for all segments, and depends on an adequacy to the specificities of each segment. Therefore, policies should be formulated according to the potential of their effectiveness and the level of technological competencies/learning capabilities of the agents. The authors describe four dimensions that should be taken into consideration for the formulation of industrial and technological policies: Technological, institutional, business conditioning and degree of systemic and local competitiveness.

There are several policies to support technological and industrial development in developed and technologically developing countries, and the government stands out as being the agent that has more influence and incentives to create policies, especially for the financing of projects and plans. Although the policies created by the government have a greater impact, the policies made by other agents such as academia and companies are also extremely important for the technological development of the industry, because the entire process of technological and industrial learning depends on the integration between the agents.

In the technological dimension, policies are effective when there is not a high degree of generality, where sector specificities are an important determinant of competitiveness. In the institutional dimension, what should be considered is the capacity to design and implement these policies, that is, the capacity of institutional infrastructure, and policies become effective when there is a real capacity to influence the decisions of economic agents. The dimension of business conditions takes into account mainly the level and learning capacity of the agents. In this case, segments concentrated in the national market such as multinationals do not present much efficiency in industrial and technological policies. The efficiency of the policies can be seen through the national market only in national companies. Finally, the fourth dimension addresses the degree of systemic and local competitiveness. This dimension should always be compared to the international level, such as the degree of competitiveness of the productive structure and the development of the national innovation system of a given country, for example. The efficiency of policies is high if both degrees are also relevant.

In segments that have a high degree of effectiveness of the policies, combined with a high technological competence, it is viable that the policies be efforts for the development of local technological solutions. In segments with a high degree of effectiveness, but with low technological competence, the suggestion are policies focused on the demands of the national productive structure, in activities of medium aggregate value and local business models. In segments where there is a low degree of effectiveness of policies but high technological competence, it is suggested that a strategy be created to foster systemic competitiveness, such as the SNI. In contrast, in segments where both policy effectiveness and degree of technological competence are low, it is suggested that the creation of policies that contribute to technological diffusion, so that the technological potential increases, and consequently, the productivity of the productive structures.

Finally, PWC (2014) states that international industry standards and regulations are very important, and that policies can provide support by promoting uniform industry standards at global levels. These international standards and regulations enable an integrated exchange of data and information in machines, systems, and software, and are the basis for vertical and horizontal connections in value chains.

5. Opportunities and challenges

Every revolution undergoes significant changes, bringing with it not only new opportunities but also some challenges. PWC (2014, p. 7) states that "the various opportunities, the large extent of change and the elevated need for investments make the industrial internet one of the most important topics for corporate management. However, the numerous challenges that the transition entails are also not to be underestimated". In this sense, space opens up for a greater understanding of the challenges that appear behind the opportunities in Industry 4.0.

The challenges begin with the difficulty of implementing new technologies for the industry, mainly because it is a topic that is still little known and debated in several economies around the world. It can be stated that few companies will be prepared to face all these changes at once. There are, on the other hand, thousands of companies that should participate in the diffusion process of these new technologies gradually. In addition to a lack of knowledge on the subject, there is also a resistance on the part of some companies due to the uncertainty of the results on the implementation of Industry 4.0, because besides being something relatively unknown, it requires a high investment for its implementation, such as the replacement of machinery, equipment, and materials.

According to the study done by PWC (2014) about half of the companies interviewed are still resistant to Industry 4.0 and have no program for implementing the new technologies, as well as not making the investments considered necessary. These measures are a consequence of two reasons, considered as the most important challenges for the implementation of Industry 4.0: I) Uncertainty in the economic benefits and II) Need for high investments.

The uncertainty in the economic benefits from the implementation of Industry 4.0 technologies is a case often seen in companies that are resistant to the new paradigm. As the level of knowledge is low, it becomes even more difficult to make a prediction for the future, making it difficult for companies to see whether the implementation of Industry 4.0 will be beneficial for them. Because it is a relatively recent theme, the idea has not yet been completely disseminated, and the results are starting to appear gradually, especially in companies already consolidated in the market, with high technological potential. In a survey conducted by Deloitte AG (2014) with Swiss companies, more than half said they did not feel a great impact in the transformations to Industry 4.0, although most believed that Industry 4.0 could boost the country's economy, but they are still resistant due to uncertainty.

The need for high investments can be considered one of the biggest barriers to the implementation of Industry 4.0 technologies in companies. Consolidated companies with high technological potential have a higher level of adherence to the technologies, because besides having a greater knowledge of the subject, they can replace their machines, equipment, etc., more easily, due to their high level of capital. Startups, small and medium-sized companies need greater financial support to be able to implement new technologies, often depending on the government or larger companies for this to happen. There are policies that enable this implementation, but they are not always applied.

The issue of workers can also be classified as a challenge, because in the future a larger skilled and specialized workforce will be required for Industry 4.0 operations, and thus it will be essential for companies to hire qualified workers who have great skills for operations in both vertical and horizontal connections. According to the study, it is noted that most countries that are leaders in Industry 4.0 technologies are already focusing on skilled labor in the near future, with the help of policies to support industry development. However, it is considered a challenge in countries that have not yet reached technological maturity, where workers do not have the necessary skills and qualifications for the demands of Industry 4.0.

Still on the issue of workers, following the idea of a need for skilled labor, Deloitte AG (2014, p. 14) states that

"digitalisation increases also the importance of new technical skills, notabily in the case of operating activities and mechanical working processes in production, purchsasing and warehousing all logistics.

New, process-dependent systems making greater use of technology may prove to be a major challenge for existing employees”

That is, high-level technical skills will be increasingly required by companies, and companies will have to invest in the skills development of their employees in order to create a base of workers prepared for future changes. Through the research done by Deloitte AG (2014) companies state that they still have doubts about the issue of workers, due to the uncertainty of the areas that require more skilled workers, resulting in a low level of skill development of their workers.

Since the presentation of the Industry 4.0 concept by the German government, several opportunities have been presented, showing the benefits of implementing new technologies for world economies. The German government has been very optimistic about the topic, causing other powers to be inspired by the idea and follow the German plan, but creating their own strategies.

The opportunity that stands out the most in Industry 4.0 is to achieve a higher level of productivity and adaptation, and as a consequence of this a higher cost reduction is expected, an innovation in production, making it mass-customized (flexible production) and a higher quality and efficiency production. All these factors are related to at least one technological pillar of Industry 4.0, highlighting the importance of technologies for production efficiency. Another striking opportunity is for an increase in competitiveness (in the case of non-leading countries) and a maintenance of leadership in countries considered leaders (FEDERAL MINISTRY OF EDUCATION AND RESEARCH, 2016; DELOITTE AG, 2014).

Balashingam (2016) states that greater flexibility in production in Industry 4.0 will bring several benefits, such as better resource allocation and product customization. The complexity of production processes should be reduced as greater flexibility increases, thus facilitating and optimizing production. Furthermore, there is greater autonomy and efficiency in production processes through SPC networks, where failures and problems are expected to be detected at early stages through automated systems, avoiding waste and losses of raw materials and damaged objects.

Following in the idea of flexibility in production, Balashingam (2016) relates the impacts of higher quality and efficiency in production. Quality and efficiency in production are factors that stand out in Industry 4.0, since they ensure a better allocation of resources and logistics of the production system through intelligent machines that communicate with each other. This communication is autonomous and allows the production process to become more efficient, so that it will be difficult to find faults, as one would find with human work. This is expected to significantly improve resource utilization, especially in the early stages of production. As a consequence, further cost reduction is expected in the entire production process through digitalization.

Greater cost reduction is another notable feature in Industry 4.0, which despite initially having a high implementation cost, in the long run production costs are expected to reduce significantly, especially due to higher quality and efficiency in production. Balanshigam (2016, p. 6) states that "resource efficiency considers not only the responsible use of natural resources without harming the environment, but also the efficient utilization of human capital and raw materials." That is, efficiency appears in a whole, from natural resources to the utilization of human capital. This efficiency only becomes possible through the implementation of Industry 4.0 technologies, such as SPC. Cost reduction is seen mainly in the significant reduction of waste (such as product failures, production), in the early identification of problems, and in energy savings.

Maintaining leadership or increasing competitiveness in non-leading countries is another opportunity that stands out in Industry 4.0. Leading countries want to maintain their leadership and improve on the key technologies they possess. Countries in technological development seek a greater space in the new technological paradigm, in order to catch up with the leading countries or get closer to their technologies. In this sense, there is an increase in competitiveness among all countries in the race for Industry 4.0, where each country seeks to improve its leading technologies, always incorporating sophisticated strategies, such as lean manufacturing and mass customization. Competitiveness among countries tends to increase over time as Industry 4.0 technologies become better known and used, generating high benefits for all countries, such as a significant increase in GDP due to higher productivity and generation of additional jobs (BALASHINGAM, 2016).

Another important opportunity to highlight is the facilitation of the entry of some small and medium-sized companies in Industry 4.0. Although the efficiency gains are much higher in large companies, the entry barriers for SMEs are lower, and they enter in a way that collaborates with these large companies, supporting them with research and new ideas, and thus acquiring new competencies and skills. SMEs usually absorb knowledge quickly, and are thus able to create the conditions for a quick mastery of the use of technology in production. Facilitating the entry of these SMEs results in higher productivity in the industry, as well as accelerating the development of new technologies.

A study by Unido (2018) states that Industry 4.0 is still a new concept, but that countries and several companies are already adopting Industry 4.0 technologies, especially large multinational companies. Despite being a new concept, a difference between some challenges described by the study done by PWC (2014) is notable. As it is a more recent study than the one presented by PWC (2014), a change in the challenges is observed, where previously they were summarized in two main ones: Uncertainty in the economic benefits and the need for high investments, and today it is noted that different challenges were presented, such as inequality and exclusion and privacy, transparency, ethics, and security. The lack of knowledge is still noted, as in the case of Brazil, according to the study, but in more advanced economies one can already notice the reduction of uncertainty in economic benefits, making room for the choice to adopt advanced manufacturing technologies because several benefits have been proven.

The opportunities, in turn, do not have great differences and have remained practically the same since the initial idea of Industry 4.0, according to the studies analyzed. As time goes by more opportunities tend to arise, with the appearance of new possible technologies.

Based on the studies conducted by Unido (2018) and Ministry of Education and Research (2016), the main opportunities and challenges of the first study, which is more recent, were merged with the strengths and weaknesses described in a SWOT analysis presented by the second study, thus creating a new SWOT analysis adapted to the strengths, weaknesses, opportunities, and threats of Industry 4.0.

6. Conclusion

The idea of Industry 4.0 is presented, from its emergence to the opportunities and challenges foreseen with the implementation of new technologies in industry. The use of different studies, done in different countries, at different times proved to be efficient because one can notice the evolution of knowledge on the subject by companies and government, and as a result of this one can also notice a change in the challenges, which according to PWC (2014) were strongly linked to uncertainty about the future of industry 4.0 in developed countries. The most recent study used in this chapter made by Unido (2018) showed different challenges, proving the satisfactory results about industry 4.0.

Advanced manufacturing can be briefly described by the implementation of innovative new technologies. Cyber-physical systems are the technology that is considered the basis for other technologies, such as IoT, IoS, smart factories, and others. CPSs are the joining of the real and virtual worlds through advanced intelligent connection technology, such as the connection between the internet and machines, the internet and systems, and the internet and people. In addition to SPCs, other technologies are embedded in the context of Industry 4.0, such as big data, artificial intelligence, augmented reality, and others. Despite being technologies connected to each other, they are not necessarily present in all production processes, and may vary according to their specificities.

Nine technologies are considered the main ones, and each of them has its own characteristics. The classification of technologies differs according to different authors, but Hermann, Pentek, and Otto (2015, p. 9) cite CPS, IoT, IoS, and Smart Factories as the base technologies of Industry 4.0. The characteristics (or basic principles), in turn, have been classified into five main ones by Ministry of Eduation and Research (2016): Interoperability, virtualization, decentralization, real-time capabilities, and modularity. Although they have their own characteristics, each technology meets at least one basic principle (as in the case of IoT) of Industry 4.0, and the others meet at least two.

For the implementation of new technologies to be successful, one needs incentives and policies for industry development, which are mainly done by the government, but are also seen in companies and universities. According to a study, the leading countries in Industry 4.0 have strong government incentives and policies for industrial development, mainly through funding and creation of strategic plans. Other policies such as support and incentives for startups, SMEs, and university projects also stand out, characterizing the idea of the National Innovation System. The interaction between the agents of a NIS is extremely important for the development of technologies and innovation in a country or region.

Industrial and technological development policies are different in each country and situation. The degree of effectiveness of policies differs according to the suitability to the specificities of each segment. Policies should be made according to their potential effectiveness and the technological competencies of each segment. Four dimensions are taken into account for the analysis of policy formulation: technological, institutional, business conditions and degree of systemic and local competitiveness. Policy suggestions are made according to the level of potential effectiveness and the level of technological competencies (these two factors are combined to reach a conclusion as to which policies will be the most appropriate for the scenario analyzed).

Industry 4.0 presents not only many opportunities, but also challenges. The challenges have changed over time, where before they were concentrated in two: Uncertainty in the economic benefits and the need for high investments. Currently, through studies, a change in challenges has been noted, due to the change from uncertainty to a confidence in Industry 4.0, and the high investments made by the government. It is necessary to emphasize that this is the case in some developed countries, because in developing countries such as Brazil, a high lack of knowledge about Industry 4.0 and uncertainty about future gains can still be noted. The main opportunities, in turn, are defined by an increase in the level of competitiveness between countries, a greater reduction in costs, greater efficiency and quality in production, and flexible production (Balashingam, 2016).

From the characteristics of Industry 4.0 presented in this chapter, with a view and approach of international authors, we arrive at the case of Brazil, which also has peculiarities and different industrial and technological characteristics, and thus creates its own identity. The Brazilian technological and industrial issue is presented in the following chapter, as well as the CT&I development policies, worldwide comparisons and Industry 4.0 itself.

References

BALASINGHAM, Kajanth. (2016): Industry 4.0: Securing the Future for German Manufacturing Companies. 2016. Dissertation (Master) - Curso de Business Administration, Univeristy Of Twente, Enschede.

BRETTEL, Malte et al. (2014): How Virtualization, Decentralization and Network Building Change the Manufacturing Landscape: An Industry 4.0 Perspective. International Journal of Information and Communication Engineering. p. 37-44.

DELOITTE AG (Zurich). (2014): Manufacturing systems are vertically networked with business processes within factories and enterprises and horizontally connected to spatially dispersed value networks that can be managed in real time – from the moment an order is placed right through to outbound logistics. URL: https://www2.deloitte.com/content/dam/Deloitte/tw/Documents/manufacturing/tw-research-industry4-0-en.pdf

FEDERAL MINISTRY OF EDUCATION AND RESEARCH. (2016): What is Industry 4.0. URL: http://www.europarl.europa.eu/RegData/etudes/STUD/2016/570007/IPOL_STU(2016)570007_EN.pdf

FRAUNHOFER-GESELLSCHAFT. (2016): Trends in Industry 4.0. Alemanha. URL: http://www.fraunhofer.jp/content/dam/japan/ja/documents/media/publication/Trends-in-Industrie-40.pdf

HERMANN, Mario; PENTEK, Tobias; OTTO, Boris. (2015): Design Principles for Industrie 4.0 Scenarios: A Literature Review. Working paper.

KAGERMANN, H et al. (2013): Recommendations for Implementing the Strategic Initiative Industrie 4.0. Frankfurt.

NAGY, Judit et al. (2018): The Role and Impact of Industry 4.0 and the Internet of Things on the Business Strategy of the Value Chain—The Case of Hungary. Sustainability, p.1-25.

PRICEWATERHOUSECOOPERS (PWC). (2014): Industry 4.0 - Opportunities and Challenges of the Industrial Internet. Germany.

UNITED NATIONS INDUSTRIAL DEVELOPMENT ORGANIZATION (UNIDO). (2018): Industry 4.0 – The Opportunities Behind the Challenge. 1-32. Vienna, 2018.