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THE ADVENT OF INDUSTRY 4.0 IN MANUFACTURING INDUSTRY: LITERATURE REVIEW AND GROWTH OPPORTUNITIES

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Abstract

Nowadays, the value creation process is based on management of a large amount of data, the Big Data, which are able to connect businesses and customers from all over the world (Xie et al., 2016). Considering the managerial and industrial points of view, Industry 4.0 is a new economic model for the industrial world (Peressotti, 2016), based on the evolution of production paradigm, technological change and process logic adoption: companies should change their business models, invest in staff training, adopting new managerial tools. As a result, the change of the market (from standardized to diversified) with the production of customized products. Machines and robots are able to communicate each other, to take decisions and to self-update. The production lines are automated: control and maintenance tasks can be performed remotely. As a consequence, the creation of the agile value chain: it allows you to monitor large amounts of data in real time, to track status and location of goods, to control the production process distantly. To study the level of adoption of 4.0 industrialization plans, two global indicators have been analyzed: they identify the placement of the largest industrial powers as

a result of their industrialization policies adoption. Since the literature review shows few academic contributions and the subject is studied from engineering, computer and industrial design points of view, the objective of the work is to provide a theoretical contribution to managerial and industrial studies: the adoption of innovation in economic policy represents an opportunity to improve the country identity and the competitiveness level. So it is essential to encourage companies to adopt innovative tools, making the production automated. The methodology used is the content analysis technique: literature analysis, reports, conference proceedings, publications and websites are consulted. The originality of the work is to investigate a topic developed recently in Italy.

Keywords: Industry 4.0, smart factory, supply chain

1. INTRODUCTION

The globalization era, the programming language development, the new product and process technologies diffusion, the network complexity, the objectives of energy saving, waste and inefficiencies reductions, the requests of customized products and the variability in customer's demand, have been determined the need of change in manufacturing industry.

The manufacturing revolution has begun in 2011, when the German government promoted the Industry 4.0 initiative, in cooperation with industrial and scientific organization. The promotion of the industrial change and the acquisition of a leadership position in manufacturing sector in the world, were the main objectives of the country (Bartodziej, 2017). At the same time, USA developed the Advanced Manufactured Partnership, a re-industrialization plan, aimed at innovating manufacturing through the adoption of intelligent production systems and improving the occupational level of the country. In 2011, the United States launched the "Advanced Manufacturing Partnership" plan, in order to innovate the manufacturing system of the country, increasing productivity and reducing costs. With a greater delay, in 2015, France launched the "Alliance for the Future" program, to implement the digitization process for support innovation, and in 2016, Italy, approved the "Industry 4.0" plan (*http://www.economyup.it*).

The originality of the work is to investigate a topic emerged recently in Italy (December 2016). In fact, the literature review shows a great number of academic contributions from engineering, computer and industrial design points of view and few contributions in economic and managerial fields. In particular, the studies makes reference to the implications of big data on consumer behaviour, the relationship between big data and business models (Rialti *et al*., 2016), the relation between ICT and economic performance, the digitalization process through the usage of 3D printers (Berman, 2012; Cautela *et al*., 2014; Pisano *et al*., 2014). For this reason the goal of the present work is providing a theoretical contribution to managerial and organizational studies, trying to fill this gap.

The application of Industry 4.0 plans and the adoption of *ad hoc* regulations in individual countries, suggest that companies are really working to apply digital policies to their production processes. The research questions of the study are the following: what are the organizational changes of innovative industrial policies adoption? Is it possible to measure whether the countries have been really adopting 4.0 projects? To solve the questions, the methodology used is the content analysis technique, thanks to which it is possible to put together different kinds of managerial and industrial information through the analysis of different contributions: national and international literature, documents, reports, conference proceedings and internet sites. Consulting publications of Deloitte are used to study the level of adoption of 4.0 industrialization plans by countries: the Global Attractiveness Index and the Global Manufacturing Competitiveness Index. The two global indicators allow you to identify the placement of the largest industrial powers as a result of their industrialization policies adoption.

2. INDUSTRY 4.0: THE POSSIBLE CHANGES WITH THE FOURTH INDUSTRIAL REVOLUTION

The interaction, the interdependence and the timely exchange of information, impose for businesses the adoption of innovative systems to meet the complex needs of customers (Aquilani *et al*., 2016). Today's consumers have the opportunity to choose from a multitude of products and services, but they seem to be always unfulfilled. For this reason, to create value, to stay on the market, to retain or increase customers, it is therefore necessary to create personalized products (Prahalad, 2004). With reference to the present period, the "digital transformation" ones, the creation of value is possible through the management of large amounts of data, the Big Data, able to interconnect businesses and customers from all over the world. The development of activities with cooperation view and the use of a large amount of data are the key drivers of the actual continuous change (Xie *et al*., 2016).

The management of large amounts of data, the use of digital technologies to connect the whole value chain, the adoption of a digitization strategy for manufacturing and logistics, the development of cyber-physical systems that allow the collection of a large amounts of data, putting in communication each other machines through the use of the Internet of Things (National Academy of Science and Engineering, 2015) are the most important characteristic of this revolution. The network is the means by which occurs the communication between physical reality and virtual reality: machines and products communicate each other and machines know what is necessary to produce (Cappellin *et al*., 2017).

The Industry 4.0 program is based on the following components:

1) Intelligent factory, in which all resources exchange information in an automatic way and the production processes are autonomous and independent;

2) business activity, based on the integration of communication systems between suppliers, customers, manufacturers, in order to exchange data in real

time and reduce phenomena such as pollution, emissions, raw materials used;

3) intelligent products, that are able to transmit information thanks to integrated sensors and processors;

4) customers, which may require products with any function and modify their order at any time of the production process. Moreover, smart products provide a guide and support to customer, during their use (Qin *et al*., 2016).

The Industry 4.0 program is "a new economic model for the industrial world" (Peressotti, 2016, 44), based on the evolution of the production paradigm, through the technological change and the adoption of processes logics. Many scholars define this type of change as the fourth industrial revolution.

From the first industrial revolution, in the eighteenth century, with the introduction of the mechanical loom and the use of steam energy, it is passed to the second industrial revolution, in the twentieth century, with the mass production and the assembly line. The third industrial revolution in the 70s, has conducted to the spread of computers, electronics and ICT technologies, making the production processes automated. Finally, the fourth revolution, which is the current one, provides the connection between physical and digital systems, with the use of intelligent machines, which are able to communicate each other and with people (*http://www.sviluppoeconomico.gov.it*).

The interaction between man and machines leads to the creation of innovative products: an example could be represented by cars which are able to drive themselves, or robots and drones, or the intelligent systems used in agriculture (Cappellin *et al*., 2017).

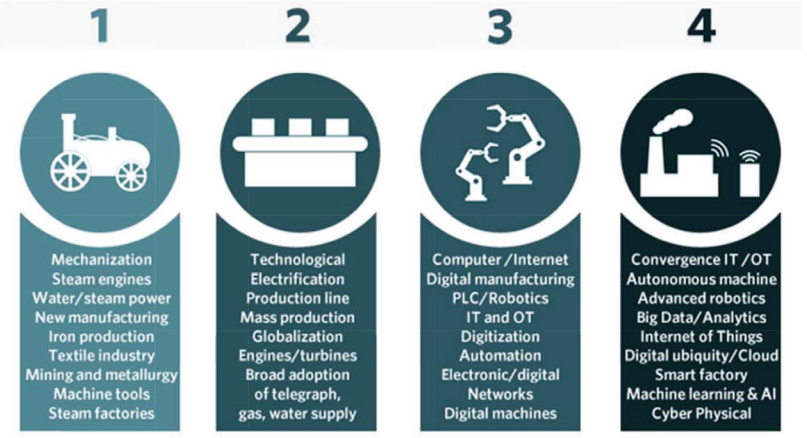

Figure 1 Industry 4.0: from first to fourth industrial revolution
Source: https://www.i-scoop.eu/industry-4-0/

2.1. Organizational perspective: the new concept of supply chain

According to a study conducted by the American firm, the Boston Consulting Group, the enabling technologies of Industry 4.0 are the follows:

- Advanced Manufacturing Solutions, such as collaborative, autonomous and programmable robot, which are able to interact each other and with people;
- Augmented Reality, which is a set of tools that allow you to add information to those really feel;
- Additive Manufacturing, which refers to the creating objects through additive production processes, mainly through 3D printing. Through various basic technologies that differ mainly due to the ability to employ different materials, additive manufacturing allows companies to produce prototypes and finished products directly on the market, or produce individual components that can also value products in terms of design;
- Simulations, which are necessary to optimize products and processes, minimizing the number of errors;
- Vertical and Horizontal Integration of information throughout the entire value chain, from supplier to end-consumer;
- Cybersecurity, which represents the need to protect the computer systems, ensuring a network security;
- Big Data, which represents the collection and analysis of large amounts of data to improve products and production processes;
- The Cloud, which represent the need to share large amounts of data or IT resources, available by the Internet and accessible at all times;
- The Industrial Internet of Things, which represents the set of technologies and sensors that enable communication between artificial world and people, including products and production processes (BCG, 2015; Rüßmann *et al*., 2015).

Figure 2 The nine Smart Manufacturing technologies
Source: The Boston Consulting Group

These kinds of technology are not already in use, such as the 3D printers, the RFID technologies and the augmented reality. The actual change makes reference to the ability to create a new production model, realizing a new relationship between customers and suppliers. The world is becoming more "smart": the advent of the smart factory represents a production solution that makes the process flexible, dynamic, agile and adaptive, thanks to automation, leading optimization production and waste reduction (Radziwon *et al*., 2014).

In the smart factory, one of the most important factor is the communication between machines and robots, which are able to make decisions independently, to self-update, to self-learning and self-adapting to internal and external changes (National Academy of Science and Engineering, 2013; Rüßmann *et al*., 2015). As a consequence, the production process is optimized and the production lines are automated, bringing the reduction of errors, wastes, costs, time-to-market, improving the total quality (Oesterreich *et al.*, 2016).

In this manner, the control activity and the maintenance task can be performed remotely (Lee *et al*., 2014). As a result, the creation of an agile and intelligent value chain (Schumacher *et al*., 2016). Traditionally, the value creation has been considered from a financial point of view.

Today, the value creation is determined by intangible assets such as process improvement, innovation, knowledge and human capital investments (Tonelli *et al*., 2016). The fulfillment of an integrated supply chain allows you to monitor large amounts of data in real time, to track the status and location

of goods and to remotely control the entire production process. In this way, it is possible to ensure the products traceability, managing remotely the assets, thanks to the introduction of new design systems, to the augmented reality, the 3D modelling systems, and the use of new artificial intelligence systems for programming activities (Brettel *et al*., 2014).

In addition, the use of automation involves the need of competent and specialized personnel: planning and problem solving activities, to prevent failures and anomalies in the production process are preferred to technical and manual tasks. The characteristics of the new worker are related to the development of digital skills, creativity, language skills, multitasking, problem solving, decision making. It is necessary to get stronger the education system, implementing the "learning by doing" approach, realizing a cultural change.

The prospect of collaboration and cooperation is another distinctive feature, thanks to which it is possible to create a dynamic organization (Radziwon *et al*., 2014): the horizontal integration, to facilitate collaboration between companies; the vertical integration, to facilitate relationships within the factory subsystems; the value chain integration, to support design, planning and product development (Wang *et al.*, 2016).

As a consequence, the transformation of the entire value chain, from design to post-sales activities, with significant impacts on profitability and investment efficiency. According to preliminary studies (including the Roland Berger ones), the introduction of Industry 4.0 models involve the profitability growth, with a consequent reduction of invested capital (Peressotti, 2016):

ROCE = profitability * IC

The profitability development is due to the high level of personalized products, the increasing in flexibility, the reduction in labour costs and the increase in automation. The invested capital reduction, however, comes from the more flexible asset, the reduction of waiting times and stop machines, the reduction of waste and more sliding flows (Blanchet *et al*., 2016). A complex, advanced and automated system, has different advantages, such as time and cost reduction, a better management of space, the complete customer satisfaction, the smart production; but it has also a disadvantage, connected to the high cyber attacks risks, with the consequent loss of data or production process interruption. For this reason, it is necessary to raise the security level, ensuring the reliability of data, avoiding their dispersion.

2.2. National economy perspective: the Global Attractiveness Index

With the aim of enhancing the competitiveness and productivity levels of our country in an international perspective, it has recently launched the project "The European House Ambrosetti", realized in collaboration with ABB Italy, the Italian leader in energy technologies and automation, Toyota Material Handling Europe and Unilever. The project includes the development of a special attractiveness indicator, the Global Attractiveness Index (*http://www.tecnoedizioni.com*), to evaluate the

attractiveness level of our country. This indicator is calculated by considering different aspects: the degree of innovation, efficiency and assets allocation (*http:// www.industriaitaliana.it*).

Italy ranks fourteenth than other 143 countries. The goal of the project is to improve Italy's strategic positioning and the degree of innovation, stimulating companies to invest in high digitization projects and strengthening the training system. In this context, it is significant the adoption of IoT and Industry 4.0 strategies to support the level of competitiveness of companies in a worldwide perspective (*http://www.internet4things.it*).

The Italian companies, known all over the world for the quality of the manufacturing sector (Italy has about 400,000 manufacturing enterprises) must necessarily increase the level of innovation to ensure sustainable and long-term growth. The implementation of technology solutions and the adoption of new production models, allow the competitiveness and the image of Italian companies improvements in the world, attracting new investments and strengthen the growth and wealth processes.

2.3. Industry perspective: the Global Manufacturing Competitiveness Index

The competitiveness and attractiveness of a country depends on its industrial level: to keep up with the big international companies, it is necessary to implement specific digital integration initiatives and support the industrial automation (The European House-Ambrosetti, 2016). Considering other global indicators, Italy get a much lower score than other countries. An example is represented by the Global Manufacturing Competitiveness Index, which is an indicator calculated by the consulting firm, Deloitte Group, in cooperation with U.S. Council on Competitiveness.

The studies conducted, makes reference to the 2010, 2013 and 2016 years, in order to assess how the manufacturing sector contributes to the growth process in each country. According to Deloitte, in the manufacturing sector the competitiveness drivers are identified in three elements:

- the training activities, to have a high qualified resources for realizing high productivity levels;
- the digital innovation, to ensure high levels of competitiveness;
- the definition of rules and regulations, to protect the technology transfer and intellectual property, as well as to establish incentives and subsidies in support high-tech investments (*https://www.deloitte.com*).

From the ranking below, it is possible to see how Germany and the United States achieve a score improvement through the implementation of Industry 4.0 policies (which adoption takes place in 2011 in both countries), unlike France and Italy which have a much lower positions, having not yet implemented digitization programs. In 2010 France holds the twenty-third position, while Italy the twenty-

first; in 2013 France holds the twenty-fifth and Italy the thirty-second place while in 2016, France the twenty-first and Italy the twenty-eighth place.

Table 1

Table 1: Global Manufacturing Competitiveness Index for the first ten countries

2010		
Rank	**Country**	**Index score**
1	China	100,00%
2	India	81,50%
3	Korea	67,90%
4	USA	58,40%
5	Brazil	54,10%
6	Japan	51,10%
7	Mexico	48,40%
8	Germany	48,00%
9	Singapore	46,90%
10	Poland	44,90%

2013		
Rank	**Country**	**Index score**
1	China	100,00%
2	Germany	79,80%
3	USA	78,40%
4	India	76,50%
5	Korea	75,90%
6	Taiwan	75,70%
7	Canada	72,40%
8	Brazil	71,30%
9	Singapore	66,40%
10	Japan	66,00%

2016		
Rank	**Country**	**Index score**
1	China	100,00%
2	USA	99,50%
3	Germany	93,90%
4	Japan	80,40%
5	Korea	76,70%
6	UK	75,80%
7	Taiwan	72,90%
8	Mexico	69,50%
9	Canada	68,70%
10	Singapore	68,40%

Source: our elaboration.

The variables used for the Global Attractiveness Index and the Global Manufacturing Competitiveness Index calculation (such as the degree of innovation of a country), lead to deduce how the industrialization policies contribute to determine both the competitiveness of the manufacturing sector and attractiveness of a country.

It is possible to come to this conclusion, for example, looking for the Germany position, which in 2010 obtained a performance for the 48%, while following the implementation of Industry 4.0, (introduced in 2011) it obtained an indicator of the 94%, in 2016. It is reasonable that countries with high score, could adopt behaviours conform to digitization plans.

3. CONCLUSIONS

The work provides a starting point to manage better the transition from the old to the new paradigm: the adoption of innovation policies is essential to obtain an improvement in manufacturing performance. The new paradigm is characterized by the ability to connect objects, guaranteeing control and traceability through sensors, applied directly to machines.

Machine linkage, robots replacing man, availability of large amounts of data, flexibility in production and customization of products, optimization of production through automatic control operations are the most important features of the phenomenon. The most disruptive technological effects is connected to the possibility to realize customized products, by overcoming the traditional constraints of the standardized assembly line and mass production.

Companies must change their business models, invest in staff training, improve internal processes, invest in management tools and activities. As a result,

the change of the market, from standardized to diversified (Case & Massarotto, 2016): as a consequence the realization of customized products, whose value added is represented by the intelligence of products and services and the ability to create relationships throughout the entire value chain, in order to exchange knowledge and information (Carrus, 2014).

This work faces an issue which is widespread in our country, in Europe and generally in the world; it is provided a conceptual input, which is the result of a literature review: the absence of empirical analysis could be considered the main limit of the work. This study contributes to improve the knowledge of phenomenon and it could be a guide for those companies who are adopting new business models for implementing an innovative and competitive environment.

Disclosure of these topics represents a growth opportunity not only for the individual firm, which can create shared value through the digitization of production, but for the entire Country, which may attract more investment and strengthen the brand of Made in Italy all over the world.

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