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The Change in the Traditional Paradigm of Production under the Influence of Industrial Revolution 4.0

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Abstract: The modern history of technical progress is relatively short, as it encompasses merely around 250 years. Within it, we can distinguish four time periods called industrial revolutions. The fourth one of these, which is currently ongoing, is characterized by such ground-breaking inventions as advanced robots, artificial intelligence, Internet of Things, 3D printing, automated guided vehicles, cloud technology, augmented reality, big data, blockchain, nanotechnology, and biotechnology. The author argues that under the influence of these inventions, industrial production is gradually becoming fully digitalized, automated, and autonomous. As a consequence, it will be carried out more speedily, flexibly, effectively, and transparently and will be more environmentally friendly. The quality of products will be higher and the costs of their manufacturing lower, and it will be strictly adjusted to the tastes of the consumers. This means that, contrary to the traditional view, represented by Porter, that companies at a given time can only use one of the basic strategies of competition, i.e., low cost, high quality, and market niche, they are able to implement production that meets all three criteria simultaneously. The emergence of the new production paradigm is stimulated by expected economic and environmental benefits as well as political, social, and natural factors, including the COVID-19 pandemic. These factors contribute to the breakdown of global supply chains, which causes a tendency to insourcing, which is conditioned by the implementation of intelligent production.

Keywords: Industry 4.0; digitalization; automatization; cyber–physical system; smart factory; supply chain

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1. Introduction

Two megatrends visible in the global economy with differing intensities, i.e., globalization and regionalism, cause increased competition between companies and change its character. Nowadays, the key to gaining advantage in the market is to stay ahead of the competitors in terms of technology. In this area, the development proceeds exceedingly fast and the period between the announcements of new inventions is shortened significantly. The current state of their accumulation in industrial production, called Industry 4.0, is a continuation of three previous industrial revolutions [1]:

- The first one, which took place in the second half of the 18th and the first half of the 19th century, whose basis was the use of a steam engine in production and transport;
- The second one, which took place in the years 1870–1914 and which was based on a new source of power—electricity—and automatization, allowing the manufacture of standard goods on a production line;
- The third one, called the digital revolution, which started in the 1980s and is still ongoing. The Internet—its "wonder child"—computers as well as information and communication technologies, including mobile phones, are fundamental devices changing not only the character of production processes but also every other area of societies' functioning.

Industry 4.0 consists in further developing the previous inventions; their increasingly widespread use; and the creation of new ones, such as artificial intelligence, Internet of

Things and Services, 3D printing, blockchain, automated guided vehicles, cloud technology, augmented reality, big data, nanomaterials, artificial biological systems, and modifications of existing systems [2–10]. The aim of the article is to assess the impact of the Industrial Revolution 4.0 inventions on the course of production processes and their effects. Their implementation in the organization of industrial production will allow companies to overcome external and internal challenges of today's economic reality. The challenges include the pressure to lower expenditures; manufacture better and more modern (innovative) products and adjust them to the individual needs and tastes of the consumers; the consumers' increasing demands as to the speed and service of transactions; the increasing complexity of supply chains, business, political, social, and technical risks, and risks resulting from natural causes; the increasing number of vertical and horizontal network links; and the complexity of production analyses and methods. The new paradigm of production will be fundamentally different from the tradition one. In the future, production, carried out in a smart factory, will constitute an essential element of a digital, integrated value chain connected horizontally with the value chains of other organizations. This connection will be based mainly on open, wireless networks of devices functioning without direct participation of people. Personalization and mass customization of production, i.e., the need to strictly and quickly adjust to individual, growing, and changing needs of the consumers, will determine the need and models of cooperation in production. The value chain will become an open, innovative ecosystem in which partners will share their competencies and technologies, which should prove profitable for them as well as their clients.

The structure of the article is as follows: an introduction; a literature review; research methodologies; discussion; and conclusions, which contain the results of the research. In the discussion, issues that are essential for the achievement of the research objective are analyzed, such as the features of the smart factory, smart production and their advantages, factors stimulating the implementation of intelligent production, and barriers and threats related to the new production paradigm. The scope of the research carried out includes determining the features of intelligent factories and devices that determine its functioning. Then, an analysis of factors stimulating intelligent production as well as barriers and threats related to its implementation is performed. Conclusions confirming the hypothesis of a change in the production paradigm are included in the last part of the study.

2. Literature Review

The literature from the Scopus database and Internet sources was of fundamental importance in the conducted research.

The book by Schwab (2016) *The Fourth Industrial Revolution* [11], as well as the studies by Gronau (2014) [12] and Al Zadjali and Ullah (2011) [13], are of the greatest importance for the characteristic of intelligent production and its benefits. The influence of political, social, and natural factors is mainly the result of observation of events and thoughts of the author.In turn the fragments of the article dealing with the barriers and threats of the new production paradigm are based, among others, on Kersten et al. [14], Salt Solutions (2018) [15], UBS (2016) [16], and Smit et al. (2016) [17].

In general, the literature resources on the studied phenomenon are rich, but they require constant supplementing because there are dynamic changes in the macro- and micro-environments of enterprises and in the enterprises themselves.

3. Method and Materials

The paper has a conceptual character and is based on desk research. Research methods such as indirect observation; casual, historical, and predictive analyses; synthesis; induction; and description are used. This allowed for the identification and characterization of most of the inventions of Industrial Revolution 4.0 and their impact on the transformation of production processes. It was found that the essence of Industry 4.0 (in the article, the concept of Industrial Revolution 4.0 is equated with the concept of Industry 4.0/. Its features represent a revolutionary change in manufacturing processes. Their holistic image is made up of the integrated impact of innovative devices that intelligently replace human work. The effects of their implementation bring and will increasingly bring economic, social, and environmental benefits. In particular, they will ensure that production can be realized at the same time at low cost and high quality and be personalized. This means that a shift in the production paradigm will shift the traditional competitive paradigm, which assumed it was impossible. The comprehensiveness of the research also includes findings on factors stimulating the implementation of Industry 4.0, paradoxically including the COVID-19 pandemic and its barriers. The conducted research helped verify the hypothesis about the change in the production paradigm under the influence of Industrial Revolution 4.0 and, consequently, the competition paradigm.

4. Discussion

4.1. Features of a Smart Factory

The essence of Industry 4.0 is a smart factory, also called the factory of the future—for today, it remains only partially realized, but it is estimated that within the next decade, the idea of a production plant with the minimal participation of people will be made a reality. A smart factory can also be defined as a holistic system of production based on cyber–physical devices controlled by computer algorithms, communicating with the Internet and its users, which in an autonomous, harmonious, optimal, and flexible manner of performing the programmed tasks.

The main features of a smart factory include (Figure 1 [7,18–22]):

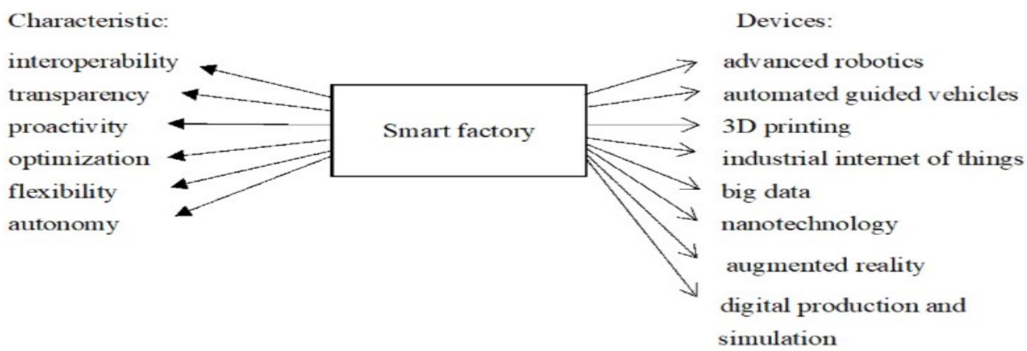

Figure 1. Features of an intelligent factory and its essential devices. Source: elaboration of the author.

- ➢ Interoperability, i.e., integration of machines, sensors, and people understood in terms of their ability to communicate via the Internet of Things and to continually download data indispensable for real-time decision making;
- ➢ Transparency regarding data downloaded from different sources (providing better visibility of the whole production process) and monitoring its course, which will allow machines and people to make better decisions;
- ➢ Proactivity, i.e., the system's ability to take action before the safety and continuity of production is compromised due to, e.g., machine malfunctions or supply shortages, based on historical and current data analysis;
- ➢ Optimization resulting from minimized use of materials, energy, and workforce; shortened duration of operations and outages; increased precision and higher quality; as well as full or almost full recycling, meaning increased work efficiency and significantly lower production costs;
- ➢ Flexibility that will allow the production system to adjust to the changes in the schedule and the type of goods manufactured quickly and with minimal external interference, because smart devices will be able to configure machinery and procure materials needed to realize, implement, and control a particular project by themselves;
- ➢ Autonomy, i.e., the ability to make decisions regarding the course of the production process, monitoring its harmoniousness, elimination of anomalies, and quality control without or with minimal participation of people.

4.2. Smart Production Technologies and Their Advantages

Already today, to different extents depending on the company, the branch of the industry, and the country, industrial production makes use of modern technologies, such as automatization, robotics, or digitalization. However, the technologies are only being implemented partially, in specific areas of activity in factories, and do not encompass every task related to manufacturing. A number of technologies that will soon be commonplace are, as of now, rarely implemented and are really at an advanced experiment stage. Industry 4.0 devices are used to the highest extent in German enterprises. The phrase "Industry 4.0" (German *Industrie* 4.0) was first used at a fair in Hanover in 2011. In the following years, a work group from the Robert Bosh GmbH company prepared a report about this subject and handed it to the federal government of Germany. The issues of Industry 4.0 were also the subject of the proceedings of the World Economic Forum in Davos in 2016, whose chairman, Klaus Schwab, published a pioneering book on the subject, entitled *The Fourth Industrial Revolution* (2016) [11].

The basic technologies used in the factory of the future will include [23–26]:

➢ Advanced robotics—devices able to function autonomously and to communicate among themselves and with people, equipped with artificial intelligence that allows them to learn from experience, i.e., to carry out recurrent production processes. They can be easily reconfigured, which enables flexible and quick reaction to changes in projects. Their use increases safety in the workplace. The physical interaction of employees with co-robots is possible without protective devices, which makes work easier and increases satisfaction. Robots and automatization shorten the production cycle, increase productivity and precision, and enable better use of the production area.

➢ Automated guided vehicles—vehicles that do not require a driver, already being used to transport materials and raw materials from warehouses to the place of production, to ensure the repeatable movement of the materials in the production process, and to deliver the products to the warehouse. Their movements are precise: they slow down or speed up depending on the circumstances. Their use increases safety and eliminates the risk of damaging the product in transport, which is why they are particularly well suited to transport delicate products. Thanks to them, transport costs are lower and the flow of raw materials, other materials, and products smoother, on time, and failure free.

➢ 3D printing, also called additive manufacturing or distributed manufacturing—automated production of three-dimensional objects based on a digital design or model. Controlled by the computer, the printer layer after layer adds the required material—metal powder, polymer, plastic, ceramic, glass, or an edible material (e.g., chocolate)—and a binding material. This technology enables the creation of products of complicated shapes in one go, which would not be possible using traditional methods. The products are more durable and resistant and precisely match the models. 3D printing is changing the paradigm of production by decentralizing it, i.e., moving the production process closer to the client. Products can be cheaply manufactured in mall series or even individually, which allows for mass customization and personalization. They can be created based on peer-to-peer communication between the manufacturer and the client, where the manufacturer directly delivers to them a model or a description of the desired product. The wide-spread use of this technology will result in an unprecedented diversification of products; development of innovativeness; more effective use of resources; shortening of the time needed to manufacture the final product based on the design delivered; as well as lowering of the cost of design, manufacture, distribution, and transport. The needs of the consumers will be better fulfilled, which will increase the sales and the income of the manufacturer.

➢ Industrial Internet of Things—a virtual global network of unambiguously identified things and devices that can indirectly or directly gather, process, and exchange information using computer networks. This information, provided to them continuously and in real time, is used to increase the effectiveness of operations, helping to effectively manage and monitor the flow of raw materials, other materials, and products, as well as to remain informed about their status: dimensions, quality, expiry date, usage conditions, or location in the warehouse.

➢ Big data analysis—gathering and processing large quantities of data and cloud-computing them in order to carry out smart production and manage supply chains. It allows not only autonomous forwarding of information about threats but also foreseeing and preventing them. The ecosystem of data is characterized by [27]:
  - Volume—amount of generated and forwarded data;
  - Diversity of form—text, image, video, and sound or their synthesis;
  - Speed—the speed of generating and processing data;
  - Authenticity of data quality and value—efficient management of a factory requires analyzing both visible and invisible data, such as the degree of wear of machines and devices.

Big data architecture encompasses the following elements:

- Connection (sensor and networks) refers to devices related to the processing of the data provided by an external service provider;
- Cloud (data and calculations) is a data-processing model provided by an external service provider;
- Cyber (model and memory) is a solution for data protection in mass storage and ensuring their cyber resistance;
- Content and context refer to facts, trends, and statistics and the relationship between them;
- Community (sharing and cooperating) means the data are generated from social media and made available by online platforms to authorized users;
- Personalization and value means the type of data is adjusted to diverse clients.

The extraordinarily large amount, high diversity, and speed of the data requires the use of a specific technology and complex methods of analysis, such as A/B testing, machine learning, and processing of a natural language. Big data and the Internet of Things act together, downloading data from the cloud using Internet devices.

➢ Nanotechnology—the manipulation of atoms and extremely small compounds (a nanometer is one-billionth of a meter) in order to create materials characterized by high effectiveness, lightness, extreme durability, adaptability, and recyclability. One example of such a material is graphene, 200 times harder than steel, stronger than diamond, and a million times thinner than a human hair [11]. Such materials can be used to make smart products, for instance, ones that remember their original shape or that react to the changes in external conditions, such as temperature, atmospheric pressure, humidity, light, magnetic field, voltage, or chemical compounds (dirt-resistant fabrics). Changes in products with nanoparticles can be repeatedly reversed and externally controlled, thanks to artificial intelligence devices installed in objects with nanomaterials. Nanomaterials will be useful in medicine, pharmacology, production of sensors, microprocessors, solar cells, nanotubes, nanowires, and cars that use less fuel and have cleaner exhaust emissions. In the future, the manufacturing of nanomaterials could be based on the principles of mechanic engineering combined with atomic specificity, that is, on non-biological molecular machines. Such production and its results will be completely different from traditional ones and will constitute an evolutionary variant of a smart factory.

➢ Augmented reality, also called mixed reality—the multimedia generation of a virtual image of objects, spaces, and events, including elements of the real world and the fictional world. The images can be observed on computer screens that can be mini-sized and have a 3D format. This technology can be used, e.g., in the entertainment industry (computer games), medicine, marketing, training, weather forecasting, military and civilian aviation, astronautics, industrial production, and construction. Augmented reality is also called digital prototyping because it is extremely useful in designing machines, devices, cars, and various appliances as it makes it easier for engineers to design and configure complex products and verify the designs, eliminating the need to create physical models. The virtual augmented reality scenarios also serve to test new machines and devices as well as the production processes, not only in normal, but also in extreme and unusual conditions, and to reveal and gather hidden knowledge and locations of items in the warehouse and the factory. The whole life cycle of the product, from design to implementation to production, service, maintenance, distribution, and repairs in the client's home, can be better monitored and rationalized using augmented reality, which as a consequence increases the value for the producer and the client.

➢ Digital simulation of production—using special computer programs in the early stages of the production cycle in order to plan, implement, and test the production process [28], as well as to evaluate the process, the improvements and changes introduced, and the impact of the planned investments during the process. A digital simulation of production provides information that serves to optimize the production process and create its new model, for instance, by configuring new production lines or changing the existing ones, eliminating bottlenecks, shortening the time required to deliver materials and perform certain operations, and improving their synchronization. It is also the basis for implementing such production organizing techniques as Just-in-Time, Kanban, Lean Management, Total Quality Management, Six Sigma, and Demand-Guided Production. Smart simulation is based on integrating its different techniques with artificial intelligence, augmented reality, and 3D printing. It enables experimenting, comparing alternative solutions, validating them, and choosing the optimal variant. In comparison to traditional methods (calculation sheets, modeling, etc.), digital simulation using the aforementioned Industry 4.0 devices constitutes enormous progress because of time saving; precision; flexibility; low costs; and the ability to foresee disturbances in, outages of, and disruptions in the production cycle due to internal and external occurrences, as well as their elimination or limitation of their negative impact. This is a modern, holistic approach to the programing of the production process.

4.3. Factors Stimulating the Implementation of Intelligent Production

Industry 4.0, as mentioned before, is a revolutionary change in the functioning of supply chains, value chains, and, first and foremost, production. Its full digitalization and the use of automated and autonomous devices communicating with themselves and with people, able to download and process data from a global environment, program their activity, foresee its results, and, as a consequence, optimize the process of production is a milestone in the development of the culture of manufacturing goods that fulfils the needs of the customers to a much higher degree than before due to the goods' quality, cost, and adaptation to their personal tastes.

The application of individual devices of Industrial Revolution 4.0 in industrial production takes place gradually however and is determined by a complex of factors related to the progress in research and development; economic, natural, political, and social reasons; and competition.

The higher the level of development of a given country, the greater the involvement in R&D and the higher the expenditure on these goals and investments in their implementation. Large financial resources and research laboratories equipped with the most modern devices attract talented staff also from abroad. The greatest research and investment activity in this sphere is shown in the United States and China [29–31]. Germany, Japan, Canada, and the United Kingdom are in the second place, achieving significant successes in the commercialization of Industry 4.0 inventions from the above-mentioned economies of scale and networking associated with their large market potentials. A high level of research and implementation takes place in several relatively small countries belonging to the most developed in the world, i.e., Belgium, the Netherlands, South Korea, Singapore, Taiwan, and Sweden. The third group is, among others, Italy, Brazil, India, and Malaysia, whose position is significantly weaker compared to the previously mentioned countries. The remaining largest group includes emerging and developing countries, including Poland, which according to research conducted in 23 countries around the world on the degree of readiness to introduce artificial intelligence in the industry, was ranked 18th [32].

The leaders of Industrial Revolution 4.0 are large digital platforms, such as Amazon, Facebook, Yahoo, Apple, Baidu, Google, Netflix, Twitter, LinkedIn, Instagram, and Pinterest.

The second group consists of transnational industrial corporations, including Toyota, BMW, ABB, Tesla, Bosch, General Electric, Siemens, Volkswagen, Microsoft, Toshiba, IBM, Panasonic, Lenovo, Huawei, Oracle, Sony, Hitachi, Samsung, Electronics, Software AG, and Mitsubishi.

To increase efficiency and shorten R&D implementation time, large corporations enter into hundreds of strategic alliances, carry out mergers and acquisitions, buy high-tech start-ups, and create innovative ecosystems on Internet platforms in order to solve complex technical and technological problems in a team. They are ready to pay from 5 to 10 million USD for the acquisition of a high-class specialist [32,33].

The main factor persuading companies to innovate the transformation of production processes is the expected economic benefits, the achievement of which gives them a competitive advantage over their rivals.

The benefits of using new technologies are of significance for the operational, material, and business aspects of production and are included in Table 1 [12,13,25,34–36]:

Table 1. Benefits of and barriers to the implementation of Industry 4.0.

Type	Benefits	Barriers
Economic	- Increase in efficiency - Lower costs - Higher quality - Product customization - Shorter production cycle - Reduction in the product life cycle - Inventory reduction	- High cost of smart devices - Lack of highly qualitied employees - Complexity of the new production model - Lack of strategic orientation of management
Social	- Increase in wages and profits - Increase in professional qualifications - Reduction in the physical effort of employees - Shorter working time and remote work - Ergonomic and safe operation of devices - Increase in work comfort and reduction in monotony	- Increase in unemployment - Employment polarization - Widening of the gap between wages and salaries - Deepening of the differences between income from work and capital - Increase in social conflicts and immigration - Protest by workers and trade unions
Ecological	- Reduction in the consumption of material factors of production - Employment reduction - Waste reduction - Closed cycle production - Shorter global supply chain - Use of environment-friendly sources of energy and innovative materials - Reduction in green-house-gas emissions	- Technical and technological complexity of devices producing clean energy - Costs associated with the transition from traditional to ecological energy sources - Resistance of workers and trade unions in plants producing "dirty energy" - Lack of adequate support from governments - Lack of relevant legislation

Source: elaboration of the author based on the literature [13,17,34,36].

Here are some potential positive consequences of implementing Industry 4.0:

- ➢ The conditions for designing and planning production processes are improved and the time shortened.
- ➢ 3D printing eliminates the need to make prototypes.
- ➢ Ergonomic machines facilitate cooperation with people and guarantee their safety.
- ➢ Automation minimizes the physical effort and range of operations performed by people, thus limiting their required work input.
- ➢ There is better use of space in production halls.
- ➢ Just-in-time deliveries, rationalization of intra-factory transport routes, and autonomous retrieval of the product from the warehouse and its transport to its destination save time and ensure reliability and punctuality.
- ➢ Transparency of the production cycle allows one to monitor and control it, to make the right decisions in real time, and to quickly react to unforeseen events.
- ➢ There is better use of machines' work time.
- ➢ Bottlenecks and outages in production are eliminated.
- ➢ Automation enables autonomous prediction of malfunctions, pre-emptive conservation, and exchange of parts.
- ➢ Automation enables flexible adjustment to changes in the scale, scope, and type of production and problem-free automated reprograming of machines and devices.
- ➢ Products are personalized and customized.
- ➢ Production occurs close to the customers, and their participation in designing the products eliminates the risk of unsatisfactory production and lowers transport costs.
- ➢ There is a decreased need for outsourcing and offshoring due to the cost of the workforce.
- ➢ R&D development enables faster rotation and shorter lifespan of products; smart products can change their features according to external conditions.
- ➢ It is possible to monitor the whole life cycle of products, from production to recycling.
- ➢ It is possible to combine production and high-value services (hybrid products).
- ➢ Materials, raw materials, and energy are used more economically; there is less waste; full recycling, and thus closed-cycle production, is possible, as is more eco-friendly production.
- ➢ Optimization of production processes and use of modern materials enable higher quality of products.
- ➢ Smaller, lighter, and more durable products (nanomaterials) are created.
- ➢ The production cycle is shorter, and the products are delivered faster to the market.
- ➢ There is better vertical and horizontal coordination of supply chains and value chains and full integration of internal operations and connections with partners.
- ➢ There is more effective machine and device control by decentralized intelligence, with minimal participation of people.
- ➢ The technological gap between competitors is eliminated.
- ➢ Production costs are lower—it is estimated that design costs could be lowered by 25%, related to a reduction in the number/amount of company assets by 10%, better use of resources by 30%, optimization of material flow by 35%, a decreased number of machines and devices at workplaces by 40%, and a shorter production cycle by 30% [37].
- ➢ Work efficiency is increased.
- ➢ The return on investments is faster and higher.
- ➢ Wages and profits are increased.
- ➢ There is increased value for the client.
- ➢ There is stimulation of research and development.
- ➢ New ground-breaking digital models of production are created.
- ➢ There is increased competitiveness among companies.

In line with the traditional approach to competition, represented by Porter, a classic of company management strategies, the company can in principle, at a given time, effectively use only one of the three basic strategies of competition, i.e., low cost, high quality, and niche market [38]. Achieving the above-mentioned effects of Industry 4.0 by company means the emergence of the possibility of simultaneous implementation of these strategy, i.e., a new paradigm of competition that determines its advantage over its rivals.

Another factor stimulating breakthrough changes in production is the political, social, and economic risk in countries where individual links on the supply chains are located. Because the risk of their interruption increases, it may induce insourcing companies, i.e., relocating production from foreign, remote locations to their countries of origin or neighboring ones. Backshoring or nearshoring of production enables the use of breakthrough innovations of Industrial Revolution 4.0, such as automation, cyber–physical devices, and 3D printing. They reduce the comparative benefits of employing cheap labor, significantly reducing its share in the production of products and services, and thus create the impetus for an intelligent transformation of production. The above-mentioned risks are the most pronounced in a number of countries in the Middle East, Africa, and Central and South America. They are mainly related to the activities of terrorist groups and piracy in the Gulf of Aden (Figure 2).

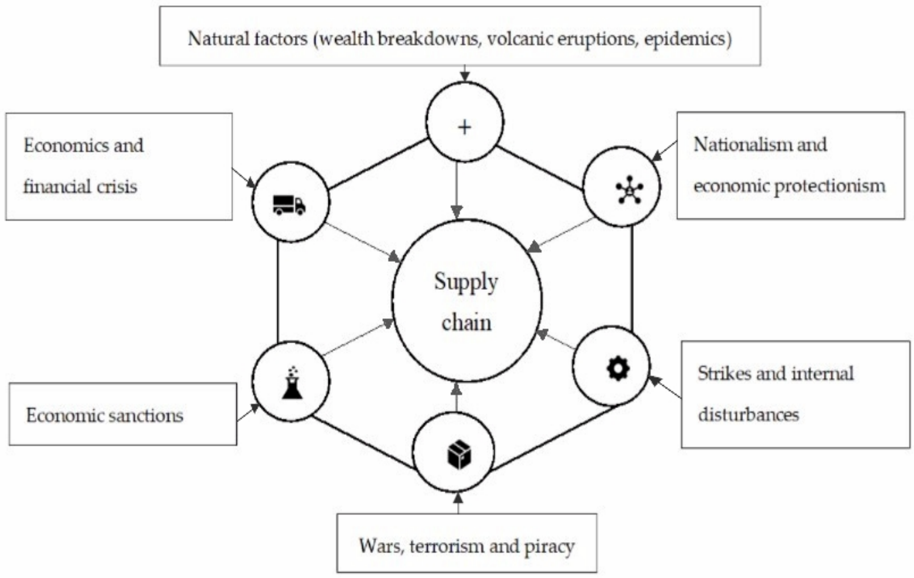

Figure 2. Factors influencing the breakdown of a supply chain. Source: elaboration of the author.

Supply chains are also interrupted or weakened as a result of international political and trade conflicts, such as the sanctions imposed by the US on companies trading with Cuba, Iran, Iraq, Venezuela, Nicaragua, Russia, and Belarus and companies constructing Nord Stream Z; trade conflicts between the US, China, and the European Union; and the emergence of Great Britain from the EU.

International supply chains are adversely affected by crises in the world economy and the related protectionist tendencies in the trade policy of the countries concerned. An example is the global financial crisis of 2007–2009, which caused a permanent weakening of trade and foreign investments and the transition from hyper-globalization to slow globalization.

Offshoring carried out on a large scale by transnational corporations also encounters protests from employees and their trade unions. Under their influence, the governments of highly developed countries put pressure on companies to give up relocating production abroad.

Paradoxically, intelligent production can be stimulated by such unfavorable events as natural disasters and epidemics. They cause the disruption of supply chains, which prompts companies to insource. Such natural disasters as Hurricane Katrina, in 2005; the volcanic eruption in Iceland in 2010; the earthquake and tsunami in Japan in 2011; and the damage to the nuclear reactor in Fukushima, have temporarily disrupted global value chains, as have outbreaks such as SARS, MERS, and particularly the COVID-19 pandemic, which erupted toward the end of 2019 in the city of Wuhan in Central China.

- Many factories in various countries have closed or reduced their production, which has resulted in the disruption of supply chains or a drastic decrease in the size of their supply of materials and semi-finished products. According to the estimates of international organizations, such as the WTO and the UNCTAD, in 2020, world trade fell by a third and foreign direct investment by around 30–40% [39].
- However, it should not be expected that there will be a radical reduction in the factors that increase the risk of global supply chains presented here [40–42], as this would cause, at this stage of implementing the invention of Industry 4.0, a significant increase in costs and, moreover, due to the lack of appropriate raw materials in highly developed countries, finished products will not be possible.
- In the short term, companies will rather diversify their sources of supply, duplicate suppliers, and limit just-in-time deliveries, increasing their warehousing capacity. In the long run, technological progress and a decrease in the costs of related equipment allow forecasting a significant increase in insourcing.

4.4. Barriers and Threats Related to the New Production Paradigm

Apart from the already mentioned possible positive consequences of smart production, its negative effects can also be indicated. However, the former undoubtedly outweigh the latter, which confirms the thesis that—in line with the logic of industrial civilization development—there is no stopping Industry 4.0.

Difficulties in implementing and potential negative consequences of Industry 4.0 are related to issues such as those mentioned Table 1 [14–17,43–45]:

- Technical and technological difficulties;
- High capital expenditures;
- Limited market availability of smart machines and devices, software, modern materials, and suitable technologies;
- Lack of required skills and commitment on the part of management;
- Traditionalism; unwillingness to make changes on the part of employees and unions;
- Difficulties in finding appropriately highly qualified workers;
- High costs of employee training;
- Government regulations;
- Segmentation of the labor market and deepening of social inequalities;
- Layoffs and increased unemployment among poorly and averagely qualified employees;
- Violation of consumer privacy due to acquiring information in order to customize products;
- Security threat to the smart factory due to cyberattacks and data leaks;
- Organizational barriers;
- Lack of international norms and standards facilitating international integration of smart factories and value chains;
- Problems with international protection of intellectual property;
- Risk of unforeseen malfunctions of complicated cyber–physical systems.

The above lists of potential benefits and threats are by no means complete, and their identification has a largely futurological character. Implementing smart production still remains fragmentary—as yet, there are no fully smart factories and the software and equipment needed are still experimental. Only thought-through implementation of revolutionary technologies on a larger scale will reveal their pros and cons, both economic and social.

5. Conclusions

The research conducted allowed the acceptance, with high probability, of the thesis that the ongoing Fourth Industrial Revolution will cause a radical change in the paradigm of production. In the near future, traditional methods in more or less automated factories using digital technology to various degrees will be discarded in favor of production in smart factories—fully digitalized, integrated, flexible, and effective. As a consequence of digitalization, automation, and autonomous cyber–physical devices, production will be carried out with minimal participation of people. Quick and trouble-free changing of programs and configuration of machines will be possible in order to diversify the products following the changes in market trends. The system of dispersed production based on 3D and 4D printing will make it possible to manufacture products close to the desired market. Product personification and material savings as well as shortening of the supply chains will contribute to the protection of the natural environment.

The implementation of the new production paradigm means the emergence of a new competition paradigm; it is the possibility of simultaneous implementation of the three basic strategies of competition. This will be decisive for gaining an advantage in the international economic competition between companies and countries.

Still, there are significant barriers to realizing this idea, mainly technological in nature, related to the industry, the integrated implementation of the discussed Industry 4.0 devices, and their costs. Industry 4.0 production is also connected with social threats—an increase in unemployment among poorly and averagely qualified employees and social stratification—and criminal threats in the form of cyberattacks. Deepening of social stratification can also occur between countries, leading to a further increase in tension related to migration.

The ideas of Industry 4.0 are being successfully developed by industrialized countries. Many of the remaining countries hardly perceive the need to make revolutionary changes in industry or do not have sufficient resources and technology at their disposal. One of these countries is Poland, which in terms of broadly understood innovativeness lags behind other European countries. This is why there is an urgent need to popularize these new trends, implement suitable educational and training programs, and encourage governmental and non-governmental organizations to provide support. It seems that for these purposes, we could acquire significant funds from the EU. If we do not take on the challenges of Industry 4.0, we will lose in competition with other countries and find ourselves on the peripheries of industrial civilization.

Recently, in connection with the COVID-19 pandemic, there has been an increase in the interest of many firms in the world in the implementation of Industry 4.0 inventions. This is mainly due to sanitary restrictions on the direct participation of workers in the manufacturing and transport processes. Digitalization, automatization, robotization, 3D printing, and augmented reality devices will drastically reduce the need for multiple categories of employees and enable remote work. Paradoxically, the COVID-19 pandemic can accelerate the pace of shift in the traditional production paradigm.

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