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Transformation of Transnational Corporations' Supply Chains as a Result of the Fourth Industrial Revolution and the COVID-19 Pandemic

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Abstract: The subject of research formulated in the title of the article was selected due to the fundamental importance of global supply chains (GSCs) of Transnational Corporations (TNCs) in the functioning of the world economy. They determine the size, structure and directions of international trade and foreign direct investment. Currently, they are influenced by the innovative inventions of the Industrial Revolution 4.0 (IR 4.0), as well as the COVID-19 pandemic and the resulting experiences. This article is a review of the conceptual and futurological character and was based on the author's literary studies and reflections resulting from his subject knowledge. Research techniques such as description, predictive analysis, synthesis and modeling have been used. The result of the research is the verification of the hypothesis regarding the uncertain potential impact of the Industrial Revolution 4.0 and the catalytic impact of the COVID-19 pandemic on global supply chains. This article should inspire more detailed, empirical research on these important issues.

Keywords: supply chain; the Fourth Industrial Revolution; COVID-19

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1. Introduction

A characteristic feature of the development of civilization is the transition to more and more complex and efficient ways of producing goods and services. The newest stage of technical and technological development, which began in the 2010s, is called the Fourth Industrial Revolution or Industry 4.0 and is a consequence of the processes dating from the second half of the 18th century, referred to as the first, second and third industrial revolutions. It is defined as leading to the disappearance of differences between the physical, digital and biological spheres [1,2]. Its basic inventions include automation, robotization (cyber-physical systems), artificial intelligence (AI), Internet of Things (IoT), autonomous vehicles, 3D printing, augmented reality, cloud computing, big data, nanotechnology and synthetic biology.

The adoption of these inventions results in a transformation of supply chains of not only TNCs, but also enterprises of other categories, especially virtual categories. As a result, the processes of procurement, production, storage, distribution and customer relations are faster, more flexible, oriented towards customer micro-segmentation, more transparent, more efficient, fully integrated, more environmentally friendly and fully or semi-autonomous. However, the impact of these inventions on GSCs is uncertain, for while they contribute to their optimization and intelligent transformation, they also lead to their diminishing importance. Automation, robotization, 3D printing and the IoT in particular will make it more profitable for TNCs to locate all of their production operations in their country than abroad, where wages are lower and environmental protection regulations less stringent. Moreover, by reducing employment to a minimum, they will lower the amount of the most important component of production costs in highly developed countries—human labor. Their use will improve the quality of products and ensure that they are better tailored to the requirements of individual buyers, facilitate communication with customers, cut the consumption of materials and raw materials thanks to higher recycling rates or even closed-loop manufacturing, create country-of-origin effects and, above all, significantly reduce transport and transaction costs. Not without significance are also the political benefits for governments which, under pressure from workers and trade unions, support insourcing or even push TNCs to make investments in the country. Manufacturing on site also eliminates the economic, social, political and natural risks associated with GSCs. The most notable in this context was the outbreak in 2019 of the COVID-19 pandemic, which caused an unprecedented collapse of supply chains, thus becoming a catalyst for their transformation towards optimization, backshoring and nearshoring. The author was persuaded to undertake the research in question by the lack of studies comprehensively examining the relationships between global supply chains, the Industrial Revolution 4.0 and the COVID-19 pandemic.

The purpose of this paper is to identify and assess the impact of the Fourth Industrial Revolution (IR 4.0) and the COVID-19 pandemic on the global supply chains (GSCs) of transnational corporations (TNCs). It identifies the risks associated with the supply of products over long distances and the ways to reduce these risks by adapting IR 4.0 inventions and other methods that introduce changes into the process of supply chain management. The findings and conclusions presented in this paper concern TNCs. This is because, firstly, they are the main actors organizing and managing GSCs—approximately 80% of their trade is made through these channels, and it is estimated that about half of world trade, one third of production and GDP, and one fourth of employment are generated by TNCs [1]. Secondly, they are leaders in research and development and the implementation of IR 4.0 inventions, because competition between TNCs mainly consists of striving to stay ahead of rivals in introducing technical and technological progress and, consequently, in manufacturing products that meet all three of the following criteria: high quality, low cost and adaptability to individual tastes of consumers.

The structure of the article includes an introduction, a literature review, research methodologies, discussions and conclusions. As part of the discussion, the definition of an intelligent supply chain was formulated and its features were presented, and the impact of IR 4.0 on its components, i.e., procurement, production, distribution, and customer relations, was examined. In the final fragments, certain aspects of an intelligent supply chain and the risks that stimulate this process, in particular COVID-19, were analyzed.

2. Literature Review

Since roughly the mid-1990s, economic literature has been taking increasing interest in global supply chains. The coining of this term is attributed to Gereffi [3], who, using the US as an example, described international production as spatially integrated relations between suppliers and recipients located in different countries of the world. The growing importance of foreign direct investment and transnational corporations as main investors was accompanied by the publication of studies on offshoring and problems related to international supply chains in scientific and popular science literature. The interest in this subject intensified in the 2010s due to the progress achieved in research on modern techniques and technologies based on digitization and artificial intelligence and their applications in global value-creation processes. Numerous articles and books have dealt with the impact of these developments on GSCs. Some of these take a comprehensive approach, analyzing and assessing the significance of main IR 4.0 inventions for various GSC links as well as their advantages and disadvantages. These include the following: Rymarczyk [1]; Schwab [2]; Gereffi [3] Alicke, Rachor, Weyfert [4]; Mussoneli, Gish, Lapper [5]; Tiahjono et al. [6]; Impact [7]; Ghadge et al. [8]; Strange, Zucchella [9]; Nowicka, Szymczak [10]; Preindl, Nikolopulos, Litsiou [11]; Raab, Griffen-Cryan [12]; Ghobakhloo [13].

Another group of authors present changes that have occurred in selected GSC links:

- Procurement: Geissbauer, Weissbarth, Wetzstein [14]; Nicoletti [15]; Jahani et al. [16];
- Production: Fatorachian, Kazemi [17]; Hozdic [18]; Burke et al. [19]; Al Mulchim [20];
- Storage: Liu et al. [21]; Yuan [22]; Andiyappillai [23]; Žunič et al. [24]; Logistics [25];

- Distribution: Taliaferro et al. [26]; Christopher [27]; Kersten et al. [28];
- Customer relations: Chen, Popovich [29]; Buttle, Maklan [30]; Gandhi, Magar, Roberts [31].

Publications dealing with the role of particular breakthrough inventions concern the following:

- Artificial intelligence: Toorajipour et al. [32]; Abrardi, Cambini, Rondi [33]; Azizi [34];
- Internet of Things: Ben-Daya, Hassini, Bahroun [35]; Kalsoom et al. [36]; Patel, Doshi [37]; Patel, Patel [38];
- Automation: Winterberg, Lemos [39]; Nof [40]; Manyika et al. [41];
- Robotization: Esterele, Grosu [42]; Roboterverkäufe [43]; Sandhya, Manjith [44]; Szozda [45];
- 3D printing: Kubač, Kodym [46]; Zastrow [47]; Shahrubudin, Chuan, Ramlan [48]; Laplume, Petersen, Pearce [49]; Jiang, Keller, Piller [50];
- Augmented reality: Benassi et al. [51]; Santi et al. [52]; Stobiecki [53];
- Blockchain technology: Ganne [54]; Dash, Gantayat, Das [55]; Dhillon, Metcalf, Hooper [56];
- Cloud computing: Helo, Shamsuzzoha, Sandhau [57]; Varghese, Buyya [58]; Ava et al. [59];
- Big data: Vanani, Majidian [60]; Gravili et al. [61];
- Nanotechnology: Pitkethly [62]; Nouailhat [63]; Rai, Rai [64].

Shortly after the outbreak of the COVID-19 pandemic, publications on this subject started appearing in various fields, the number of which was steadily growing. Some of them concerned its impact on GSCs in the context of IR 4.0. These include: Van Zijverden, Kluge, Jovanovic [65]; Magablech [66]; Javorcik [67]; Görg, Mösle [68]; Kilic, Marin [69]; Abel-Koch, Ullrich [70]; Bunde [71]; Schnelle, Schöpper, Kersten [72]; Elia et al. [73]; Fu [74]; Antras [75].

The economic literature will likely continue to discuss and attach much importance to the impact of IR 4.0. The dynamics, turbulence and uncertainty of changes require continued research into the possibilities of reducing their negative effects. IR 4.0 inventions, while creating new threats, appear to be a measure that could, in the long term, mitigate the risks to global value-creation processes. This includes risks associated with COVID-19 and other pandemics, which provide a strong motivation for economic entities to seek the transformation of their model of network connections.

3. Materials and Methods

The present research was undertaken in response to the lack of systematic and comprehensive studies on the impact of Industry 4.0 on GSCs in the context of the COVID-19 pandemic. A critical analysis and synthesis of previous findings presented in various studies (monographs, periodicals, online sources) allowed for the formulation of a hypothesis regarding the uncertain effect of IR 4.0 on GSCs and the catalytic role the COVID-19 pandemic will play in their bipolar transformation—the breakthrough IR 4.0 inventions will bring about a paradigm change, leading to the emergence of intelligent GSCs. An intelligent supply chain is defined as a holistic cyber-physical value-creation system, in which the use of IR 4.0 inventions makes the processes of procurement, storage, production, distribution and customer relations faster, more flexible, oriented towards customer micro-segmentation, more transparent, more efficient, fully integrated, more environmentally friendly and fully or semi-autonomous, all of which ensure greater optimization and risk resilience; in other words, the use of IR 4.0 inventions leads to development in GSCs. Paradoxically, however, IR 4.0 inventions, as already mentioned, will stimulate the transfer of domestic production back from abroad, thus weakening the role of GSCs. The factor that may considerably accelerate this bipolar transformation is the COVID-19 pandemic and the threat of subsequent pandemics with the potential to cause supply-chain collapse.

The presented hypothesis is verified based on an analysis of the characteristics of an intelligent supply chain, the transformation process of its particular links and the significance of specific IR 4.0 inventions. An important part of the research process is the assessment of COVID-19 impact on GSCs. Moreover, paths of their transformation alternative to digitization are indicated, leading to the conclusion that in each case, the choice will depend on an individual enterprise's understanding of the relationship between efficiency and risk. In the short and medium term, however, it is unlikely that we should witness any dramatic changes in the global value-creation paradigm, based on the fragmentation of supply chains, arbitrage and the use of comparative benefits of direct investment in low-wage countries. Rather, the fundamental transformation of GSCs will take place over a long period of time and most likely lead to the emergence of intelligent or *quasi*-intelligent supply chains on the one hand and to their diminishing importance due to insourcing on the other. It is as yet impossible to predict which one of these trends will prevail. The limitations of the conducted research are related to the applied desk research method and its tools. Undoubtedly, the verification of the adopted hypothesis would be more convincing if it were supported by empirical research, which the author intends to implement in the future.

The author's considerations and conclusions were based on extensive literature studies, from which 87 items selected from various databases were included in the article (Google Scholar, Web of Science, Scopus). The selection criterion was their representativeness for the characteristics of the studied phenomena. As part of the general desk research method, the author used tools such as various types of analysis (comparative, complex, predictive) synthesis, classification, modeling, logical reasoning and critical validation.

4. Results

The result of the conducted research is the characteristics of changes taking place in global supply chains under the influence of the Industrial Revolution 4.0 and the COVID-19 pandemic. The impact of modern, breakthrough inventions on individual GSCs phases, i.e., procurement, storage, production, distribution and customer relations processes, has been studied in detail. It has been found that the implementation of these inventions causes the GSCs to become more and more digitized and intelligent, but at the same time they cause replacing human labor with cyber-physical devices. This creates a tendency towards reshoring and reducing the importance of GSCs. Paradoxically, these trends were reinforced by the COVID-19 pandemic the temporarily interrupted the GSCs. If technical and technological changes can be considered systematic, the COVID-19 pandemic is a so-called black swan.

The theoretical considerations carried out at the beginning of the article, regarding the uncertain influence of IR 4.0 on GSCs and the catalytic influence of the COVID-19 pandemic on them, are accurate.

5. Discussion

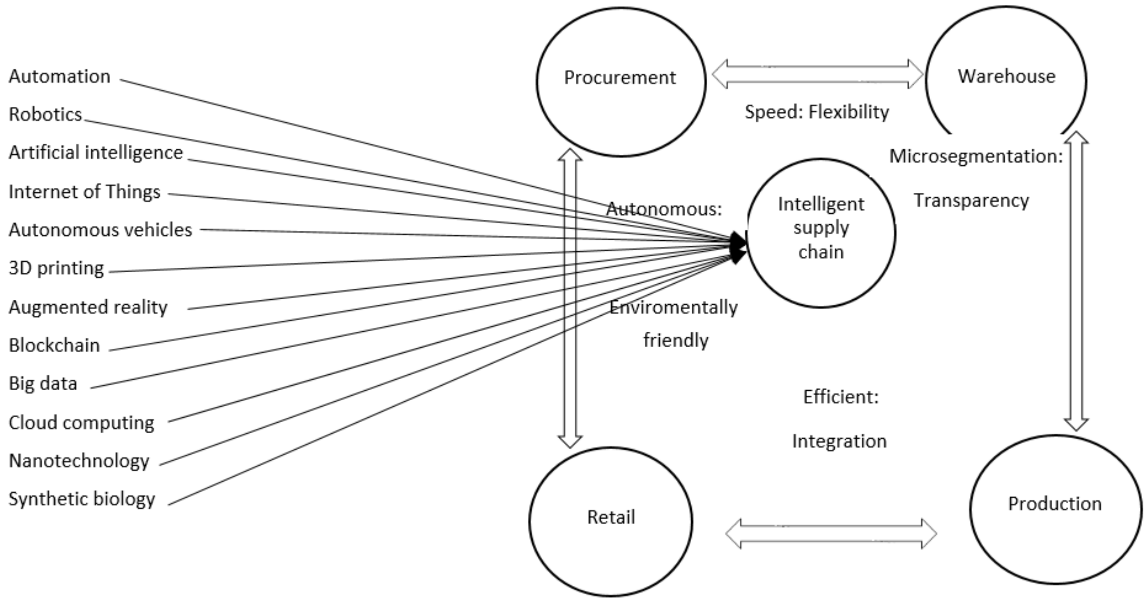
5.1. Characteristics of an Intelligent Supply Chain

A supply chain is a virtual network of independent or quasi-independent entities realizing tasks related to the procurement, production, storage and distribution of products. It includes suppliers, producers, wholesalers, retailers and customers, and its aim is the efficient management of the flow of raw materials, materials, products, services, payments and information between producers or proprietors and end-users, i.e., customers [76,77]. Transnational corporations operate based on supply chains that spread across different countries, which significantly affects their complexity, design and functioning.

The most important factor which is already contributing to the changes in the supply chain model, and within the next decade or so will lead to its complete transformation, is Industry 4.0. This term describes the revolutionary technological changes resulting in the creation of cyber-physical systems, which in turn will bring about a total transformation of production processes. This will lead to the creation of a "digital twin", i.e., a virtual model replicating in real time the processes occurring in a physical supply chain. Integrating AI, IoT, autonomous learning and software analysis will enable the monitoring, diagnostics, programming and autonomous reprogramming of processes with the aim of optimizing them and removing threats to their harmonious progression. The implementation of a "digital twin" in supply chain management, which will thus become an intelligent supply chain management (Scheme 1), will have the following effects on the processes of procurement, storage, production and distribution [2,4,5,28,29,78–80]:

- Faster. New approach to product flow will shorten procurement time even by a few hours. Advanced forecasting methods such as predictive analysis of internal and external information will allow for much more accurate prediction of consumer demand. Forecasts will be made on a daily basis and products delivered even before the order is actually placed by the customer. The order will be later attached to a delivery note already registered in the logistics network;
- More flexible. Planning will be taking place continuously in real time, which will significantly shorten its cycle and facilitate dynamic reactions to changes in demand and supply. Increased flexibility of the delivery process will allow customers to change delivery destinations. Organizational flexibility will increase the possibility of using external services instead of creating proper supply-chain structures within companies (as exemplified by the "uberization" of transport, which greatly increased the efficiency and flexibility of the distribution network);
- Oriented towards the micro-segmentation of customers. In response to the growing individualization of consumer tastes, companies will implement mass customization, i.e., mass production of personalized products and services based on modularity and programs allowing for the addition or removal of functions. Customers will be offered a wide range of products, diversified in certain aspects, from which they will be able to choose those best tailored to their preferences. Predictive analysis will make it possible to anticipate demand and customer needs even before desire to purchase is expressed. Individual and high-value products will be delivered efficiently and very quickly (same-day delivery) thanks to modern means of transport such as drones;
- More transparent. Increased transparency, particularly important for highly complex GSCs, will be founded on efficient information exchange and commitment to increasingly rational decisions. Cloud platforms will allow all participants to use a shared data base. Real-time integration and availability of data for the whole supply chain will improve its efficiency. It will be possible to check product status at any moment of its movement regardless of the means of transport, and to monitor its conditions (temperature, air humidity, etc.) with the use of GPS technology and ground sensors. Business-to-business and business-to-customer relations will become closer, easier and more efficient. Advanced digital automated efficiency management systems and cost optimization models will autonomously set desired delivery, storage, transport, production and distribution targets. They will also be able to recognize risks and uncertainty resulting from, e.g., natural disasters and social unrest, and autonomously change supply chain parameters in order to mitigate their impact, set realistic targets and ensure their attainment;
- More efficient. Increased efficiency will result from automation of processes both at the stage of planning and performance. Robots will automatically receive materials, load and unload vehicles, drop off consignments in the warehouse, as well as assemble, package and prepare items for dispatch, after which autonomous vehicles will take them to their destinations along the supply chain. These devices will greatly improve efficiency, and elimination of human labor will significantly lower production costs;
- Fully integrated. All supply chain participants will be in constant communication with each other and the control center operating in the cloud and will have access to full information about stock levels, demand, production and logistics capacities, etc. They will receive signals in real time about bottlenecks resulting from material shortages or transport problems, which will be dealt with autonomously without the need for human intervention. Removal of barriers to information flow and strict cooperation, both vertical and horizontal, will increase efficiency as well as allow for

better evaluation of a company's potential and choose the way to meet its targets that best serves its own interests and those of its customers;
- Autonomous or semi-autonomous. Intelligent devices will independently make and execute all or selected decisions based on processed data they will be collecting from the environment so as to best realize their programmed goals;
- Environmentally friendly. Manufacturing will use materials and raw materials causing the least pollution, in addition to using recycling technologies, renewable energy sources, and intelligent logistics and vehicles.



Scheme 1. Intelligent supply chain.

5.2. Transformation of the Procurement Process

The ffective integration of individual order placements with other supply chain links is critical for its efficient functioning [14–16]. Digitalization and big data cause the blurring of boundaries between individual supply chain links and thus to the creation of a new added value. As a result, purchasing departments are able to adopt a new business model, transforming from cost centers into profit centers. Having strategic knowledge regarding the suppliers, their markets, the products and services they offer, delivery methods and innovations in the relevant area, they can combine it with customer data to improve the management of goods flow, reserves, storage, control and other operations of the supply chain, and even sell it to external partners.

Digitalization will encompass tasks such as planning purchases, making trade enquiries, conducting financial analyses of suppliers and supply risk assessments, signing contracts and making payments—processes which will be realized autonomously using blockchain technology. Intelligent technologies and algorithms will enable the gathering, sorting and predictive analysis of very large amounts of data originating from various sources. Key data will be registered by sensors, collected, analyzed in real time, shared with supply chain partners and translated into actions performed by various cyber-physical devices. They will facilitate a better understanding of suppliers, markets and customers, predict market trends and identify possible threats to the procurement process, whose duration and costs will consequently be reduced. Excellent communication between people, objects and systems will enable the transformation of supply chains into cyber-physical systems of supply. A new category of digital interaction will be created, increasing efficiency and giving advantage to all supply chain participants.

This will also result in an increased demand for intelligent products, i.e., those that are a combination of a physical object and a service, such as intelligent sensors activating communication, drivers and software. The aim of procurement will be not the purchase of items, but rather the paid-for use of services. Digitalization will necessitate the development of a new way of organizing purchasing departments, the creation of new jobs, and the elimination of jobs now made obsolete. The key to success will be to create a new structure, fill it with digital content and employ highly qualified specialists in the field of economics and IT. Mass customization will put pressure on companies to decentralize their procurement operations and carry them out in individual markets.

5.3. Transformation of the Storage Process

Just like procurement, storage is increasingly treated not as a cost center but as a strategic link of the supply chain that contributes to a company's competitive advantage. The traditional warehouse will be transformed into an intelligent distribution center operating based on an IT management system—a digital program for managing the movement of products in warehouses. It will enable real-time communication with delivery vehicles, establish their location and time of arrival, as well as prepare the unloading area, optimize delivery time and adapt it to the operations performed on the assembly line in terms of their sequence. Radio-frequency identification scanners will identify delivered products by scanning their labels and forward the information along the entire supply chain. On receiving the information, the system will automatically allocate products to locations in the warehouse and assign autonomous devices best suited to place them there. Their state will be continuously monitored using sensors located both in products themselves and in the warehouse. Conditions inside the warehouse, such as light, temperature and humidity, will be automatically controlled and regulated. In accordance with the established timetable, products will be automatically selected, packed, loaded onto autonomous vehicles and delivered to production lines or, in the case of ready-made products, to customers. The following ground-breaking Industry 4.0 technologies will be used to achieve partial or full storage automation [21–23,81]:

- Vocal selection. Based on voice recognition, special devices will direct warehouse staff to the manufactured goods;
- Visual selection. Augmented reality technology will be particularly useful in locating individual non-standard products by displaying a graphic image in the field of vision of a warehouse worker wearing special glasses. This will not only enable products to be found faster and more easily, but will also limit the need for their segregation and aid in optimizing transport;
- Autonomous vehicles with robots that adapt to the surrounding conditions. Using infra-red technology to detect obstacles and cameras in the floor to read modular codes, driverless vehicles will carry out all transport operations inside the warehouse without any collisions. This will help robots to adapt their movements to the changes in their environment and even correct their mistakes. Built-in sensors will automatically detect a human approaching their area of operation and make them adjust their movements to ensure safety;
- Semi-autonomous machinery. In order to perform a variety of warehouse services (value-added services) such as assembling, packing and sending, the built-in sensors of these machines will be able to detect changes in product specifications such as weight and size, and will automatically inform the control system in order to reset the configuration and check whether the right products were selected;
- Fully automated storage, retrieval and quality control systems. They will be particularly useful in warehouses with a fast turnover of goods resulting from demand fluctuations, ensuring optimum use of warehouse capacity, minimization of reserves and flexible adaptation to changes in production volume;
- Next-generation distribution management systems. Based on modular technologies that combine in real-time automated product transportation systems with complex transactional systems for managing resources, orders and customers, they will au-

tomatically monitor resource levels taking into account amounts required for the fulfilment of orders, optimizing efficiency and ensuring high warehouse capacity;
- Intelligent warehouse management. Remote-controlled intelligent warehouse management systems will be able to closely monitor and regulate conditions such as humidity, light and temperature, as well as collect data on working conditions to analyze co-dependencies between systems, services and operations within a warehouse in order to increase the efficiency of its functioning;
- Modularity. It will make it possible for robots to autonomously reconfigure their functions, allowing them, without the need for reprogramming, to switch dynamically between different tasks. They will be able to automatically adapt to a dangerous environment and handle objects of various sizes and shapes.

5.4. Transformation of the Production Process

Intelligent production is based primarily on automation and application of cyber-physical systems—automatic machine mechanisms endowed with AI, i.e., devices that operate partially or fully autonomously and interactively communicate with people [7,8,16,18,19,42,59,64,82]. They are able to modify their actions based on information obtained through sensors. Combining those pieces of information with big data sets, cloud technology and the IoT enables optimal design, planning, implementation, monitoring, control and reprogramming of production processes. They can perform their own maintenance and remove or even predict failures. They are at the heart of the "smart factory"—autonomous implementation of production processes with little participation of people and technical, quality and economic effects that are impossible to achieve in traditional production. Smart factories will be characterized by a shorter production cycle, excellent product quality, a reduction in material and raw material consumption, and a reduction in production costs and mass customization. Human labor inputs will be minimized because machines will replace people in the performance of not only physical but also mental work.

The last extremely important effect can be achieved through the use 3D-printing technology, also referred to as additive manufacturing [47–49,49,50], which generates three-dimensional products based on models usually created with computer-aided design software. A 3D printer applies a series of layers of a basic material such as metal dust, plastic, polymers, ceramic, glass or even food products mixed with a binding substance to obtain the designed object. This technology enables designing and creating products of complexity impossible to achieve with the use of other methods. Moreover, where traditional technologies can only provide an object made up of several separate elements put together, 3D printing can create it in one piece, thus increasing its resilience and durability. It is widely used in the production of car and plane parts, medical implants, clothes and shoes, decorative articles and weapons, in the food industry, to reproduce antique works of art, etc. It accelerates the production of prototypes and provides greater freedom of design. The addition of organic matter can reduce the weight of products without affecting their resilience and consistency. The main advantages of 3D technology include greater ease of manufacturing complex and highly personalized objects; the possibility of modification during production; greater speed, precision and quality; and much lower costs than in traditional manufacturing methods. Additionally, 3D printing allows to decentralize production, locate it closer to customers and better adjust it to their needs and tastes. Manufacturing small series or individual pieces would not be feasible with the use of other technologies. Three-dimensional printing may deeply affect the supply chain model by largely eliminating outsourcing and offshoring—"chasing" after low-cost localizations, above all due to low labor costs—in favor of insourcing; which, to a degree, is already happening. This will also have a significant impact on the processes of procurement—by replacing it, to a great extent, with in-house production; storage—by considerably reducing the quantities of stored parts; transport—by shortening routes; and sales—by reducing delivery times and, possibly, product prices. It will also ensure savings on raw materials and other components used in production by reducing or eliminating waste, thus also benefiting the natural environment.

5.5. Transformation of the Distribution Process

Distribution refers to operations whose final aim is to deliver correct products or services at the right time and at an acceptable price to the appropriate customer. They can be delivered directly or through intermediaries such as wholesalers, commercial agents, retailers, etc. The distribution process consists of such steps as ordering; packing; labelling; preparing documents; answering customer enquiries; arranging deliveries and returns; storage; reloading products; acquiring parts, servicing and maintenance; planning and organizing transport services.

As a result of Industry 4.0, all of these processes will become digital and automated; which, to a degree, is already happening [21–24,26]. Big data, cloud computing, IoT and advanced methods of analysis will enable the continuous gathering and processing of large amounts of relevant information, which will serve as the basis for the decision-making processes of autonomous robots equipped with AI. Their decisions will not only apply to ongoing matters, but will also be predictive (e.g., foreseeing possible turbulence) as well as prescriptive (e.g., suggesting preventive measures).

External transportation will be carried out without human participation by drones and autonomous vehicles. Along with so-called distributed manufacturing (localized near customers), this will significantly speed up deliveries. Traffic flow and road safety will improve and fewer accidents will translate into reduced human resource losses and equipment losses as well as lower insurance costs. Transport costs can be expected to fall significantly, largely due to the elimination of the need to employ drivers and the reduction in fuel consumption. Precise, safe and punctual product deliveries will become the overriding rule.

5.6. Transformation of Customer Relations

Mass customization will necessitate interaction between manufacturers (intermediaries) and customers. The latter will actively participate in product design, presenting their own opinions and proposals. The former, in turn, before commencing the manufacturing process, will be required to conduct a detailed analysis of consumer tastes in various market segments, anticipating and even suggesting future trends. Digitalization of business-to-consumer and business-to-business-to-consumer relations, together with the use of cloud computing, AI, big data, augmented reality and autonomous transport, will ensure high quality and efficiency of those relations. Interactions will take place in real time through mutually integrated communication channels for transmitting information (omnichannels) [29–31]. Customer satisfaction will eventually translate into increased sales volumes and growing profits. Many companies are already implementing computerized customer relationship management systems which provide support at all stages of customers relations, from identifying their needs and preferences, to finalizing transactions, to after-sales service. This involves three highly automated and, in the future, fully automated sub-systems:

- Analytical. Responsible for gathering and comprehensively analyzing customer data, as well as supplying product information;
- Interactive (communicative). Responsible for contacts with customers using all the possible channels of communication;
- Operational. Responsible for digitally registering orders, invoicing, running a customer data base, configuring the product range, managing sales and product returns, and an after-sales service.

The customer relationship management system is part of a company's entire IT system and ensures transparency of the flow of digital information from the final link of the supply chain back to its preceding links, thus having a crucial influence on logistics in all its aspects.

5.7. Implementation Process of Intelligent Supply Chains and Risks That Stimulate It

As research progresses and relevant technical, economic, social and political barriers are overcome, breakthrough inventions are, gradually and with varied intensity, being implemented in value chain links in different regions of the world, countries and companies. The leading regions are North America, East Asia and Western Europe, with the greatest growth recorded in the United States, China, Germany, Japan, South Korea and the United Kingdom. In terms of the number of robots and cobots installed, the first place belongs to China (as many as 1 million robots and cobots out of 3 million operating worldwide worked in this country in 2020) [43]. The leaders in the implementation of IR 4.0 technologies are transnational corporations—large digital platforms such as Facebook, Amazon, Apple, Google, Baida, Netflix, LinkedIn, Instagram, Yahoo and Alibaba, and industrial companies including General Electric, Microsoft, Toyota, IBM, Panasonic, Lenovo, Siemens, Volkswagen, Toshiba, Huawei, Oracle, Sony, Samsung, Mitsubishi, ABB, BMW, Tesla, Bosh and many others.

Recently, a slowdown in the implementation of new technologies has been generally noted, with nearly 70% of companies across the world stuck in the pilot phases. Therefore, in order to promote and develop smart value chains, in 2018, the World Economic Forum in cooperation with McKinsey & Company created the Global Lighthouse Network, which brings together leaders in the implementation of smart value chains. At the end of 2021, 90 companies representing different countries and industries were members of the network [83], including the following:

- In Europe: Novo Nordis, Groupe Renault, Jansen Large Molecule, De'Longhi Group, Johnson & Johnson, Vision Care, Procter & Gamble, Simens, Flex, Henkel;
- In America: Vision Care, DCP Midstream, Schneider Electric, De Poy Sunthes, Henkel, Protolabs, Ericson, Procter & Gamble, Johnson & Johnson, Schneider Electric, Alibaba;
- In Asia: Unilever, Western Digital, Foxcom, Hitachi, Saudi Aramco, Bosh, Midea, Tata Steel, Alibaba.

The list is constantly growing, although recently the initiative, as well as globalization in general, has experienced a temporary slowdown. However, an acceleration can be expected in the implementation of changes stimulated by risks associated with long-distance deliveries. These include economic and financial crises, economic sanctions, nationalism and trade protectionism, local wars, terrorism and piracy, domestic strikes and disturbances, and natural factors such as extreme weather conditions, volcanic eruptions, earthquakes, tsunamis and epidemics.

The COVID-19 pandemic is by far the most significant of these risks, negatively affecting the overall management processes and the functioning of GSCs. Due to the numerous restrictions on gatherings, social distancing, internal and cross-border movement, up to lockdowns, as well as infections and deaths of employees, quarantines and compulsory remote work, the production of intermediate goods was shut down or reduced. This resulted in delay, uncertainty, volatility and collapse of their supply. Disruptions in one link of the supply chain affected the entire value-creation system. Factories manufacturing final products, due to the above-mentioned circumstances and the lack of raw materials and materials, also temporarily suspended or reduced production. In a number of factories, production lines had to be stopped several times for several days or even longer. This mainly concerned the electronics, electrical, chemical, automotive, mechanical, textile and clothing industries, as well as the manufacturing of medical equipment and supplies (respirators, masks, hygiene products, protective clothing, etc.). This was accompanied by rising prices of products, insurance, shipping containers and freightage, which in Asian markets increased up to 10 times [84]. The generally high and sustained level of inflation is also related to the practice of governments to compensate for losses and stimulate production by increasing budget deficits and printing money, and to political conflicts affecting energy prices.

It is estimated that in 2020, the contraction of GSCs due to COVID-19 by 35% resulted in a decline in world trade by 30% and in foreign direct investment by 30–40% [61,69].

Research conducted by Deutsche Industrie und Handelskammertag at the beginning of 2021 among German companies showed that 40% of them had problems with their supply chains [59]. In turn, according to the British Institute of Supply Management, in 2020 75% of the surveyed companies reported disruptions in the volume of supplies from China and 62% reported delays [66]. For example, at the beginning of 2020, this caused a decrease in the supply of new cars in the UK by 99% and in Germany by 97% [71].

The stronger the companies' integration into the GSCs in a given industry, the more they felt the effects of their collapse. This turned out to be particularly risky for final product manufacturers in Europe, North America and Asia, whose imports of intermediate goods depended on a single supplier, i.e., China—home to approximately a quarter of high-tech industry suppliers (chemicals, machinery, means of transport) to the US, Mexico, Japan and South Korea. China also accounted for a significant share of imported components for the production of antibiotics in countries such as Japan (60%) as well as Germany, France and Italy (40%) [67]. Companies around the world are very dependent on the supply of advanced semiconductors from Taiwan, which is responsible for 92% of their global production [85].

The dire effects of COVID-19 sparked a lively discussion in scientific and economic circles about the need to change the current production paradigm based on the fragmentation of GSCs and the tendency in many companies to make appropriate changes with a view to reducing the risks it poses. A number of options are being considered, of which the following will undoubtedly have the greatest impact on the transformation of GSCs [68–75,86–88]

- Digital transformation of GSCs through the use of IR 4.0 inventions. This path, setting the primary direction of change, has already been followed by international companies for a number of years. The COVID-19 pandemic will undoubtedly serve as a catalyst in this regard, considering that smart supply chains will minimalize the need for human labor and direct human contact, and thus reduce the risk of spreading the pandemic;
- Resignation from single sourcing and diversification in terms of type and localization of suppliers;
- Replication (geo-redundancy) of sources of supply;
- Changing the inventory management strategy from just-in-time to just-in-case, i.e., adjusting the amount of stock to expected demand levels, thus allowing cheaper rail or sea transport to replace air transport;
- Selection of suppliers for their reliability, quality of deliveries, timeliness, flexibility, eco-friendliness, price levels and price stability, as well as compatibility of goals and strategies;
- Cooperation with other supply chain participants through strategic alliances, joint ventures, mergers and acquisitions;
- Holistic approach to supply chains (end-to-end) and, if participating in more than one, building an optimal portfolio;
- Reduction in irreversible foreign direct investment flows;
- Entering into relational (more flexible) contracts rather than formal ones.

The above notwithstanding, no radical changes in GSCs should be expected in the short and medium term. They are an important pillar supporting the world economy, generating approximately 12% of the world production and, in the case of Germany, as much as 17% [86]. Due to the efficiency of and pressure from the competition, TNCs will now most likely opt for the higher-risk use of arbitrage and comparative benefits of production in low-wage countries.

6. Conclusions

TNCs have extremely complex supply chains. Up until now, their functioning has been marked by an insufficient integration of individual links, which represent separate "silos". In particular, their weakness is connected with the lack of sufficient and efficient horizontal integration, i.e., cooperation with other independent partners at subsequent production stages. Adapting IR 4.0 instruments should remove these shortcomings, above all through digitalization, which will make supply chains more transparent, flexible, fully integrated, environmentally friendly, efficient, faster, oriented towards customer micro-segmentation, as well as more rational and autonomous owing to the use of AI.

On the other hand, as mentioned above, those breakthrough inventions may reverse the trend towards international fragmentation of manufacturing processes, creating pressure to centralize the whole value-creation process in the proximity of the markets, mainly in highly developed countries, in order to reduce the costs of transport, logistics, storage, etc. There is a need to monitor and control product flows and damage risks and thus eliminate possible delays in deliveries. Country-of-origin effects, created by consumer preferences regarding the purchasing of goods manufactured in particular countries, may also prove to be not without significance. It seems likely that, paradoxically, two opposite trends will occur simultaneously, one leading to the development of GSCs and the other to their liquidation. At this stage, it is impossible to predict which one will prevail.

COVID-19 will undoubtedly accelerate the digital transformation of GSCs. It has faced them with threats significantly greater than all others, and made backshoring and nearshoring seem like more efficient options. However, this "slowbalization" is generally considered to be a temporary phenomenon. Within the next two decades or so, the forecasted changes in supply chains will probably take place in a predominant majority of TNCs. Those which, for whatever reasons, will not be able to implement them, will lose out in the global competition and, consequently, disappear from the market. A change in the supply chain model, and the business model in general, is unavoidable. The cognitive and practical relevance of the issues discussed in this paper requires their constant observation and analysis aimed at revealing threats and formulating recommendations that would facilitate the optimization of company operations through a revolutionary transformation of their value chains. This is particularly important for Polish companies whose level of innovativeness still places them far behind the global market leaders. In particular, empirical research will be needed to provide answers to the following questions:

- Are TNCs planning or undertaking further digitazition of GSCs and with what tools?
- Are TNCs planning or undertaking backshoring/nearshoring?
- If so, what are the motives of such actions/economic, natural, political and other risks?

The theoretical significance of the research conducted is to explain the essence of the relationship between such economic components as GSCs and IR 4.0 and natural components, including in particular COVID-19. The practical aspect of the research is related to the dissemination of the awareness of the links in question through the publication, which should encourage entrepreneurs to take steps to adapt their supply chains to the changing reality.

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