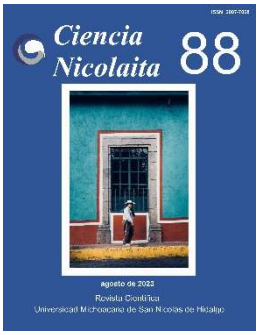

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Global value chains in the industry 4.0 ecosystem: Literature review

Cadenas globales de valor en el ecosistema de la industria 4.0: Revisión de literatura

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Abstract

Global value chains (GVCs) are undergoing a revolution in the industry 4.0 (I4.0) environment, which is driving changes in organizations as well as in business models and have also experienced pressure from the COVID-19 pandemic. However, in this context, further digitization has been triggered and should generate value. The aim of the present article has been to analyze the main scientific contributions applying a regional segmentation related to GVCs in the field of I4.0. In this sense, the study included a systematic review of contributions from the academic, scientific and business fields from a collection of 50 articles, 25 complied a period between 2016 to 2022, allowing to identify factors and variables that influence digital transformation. The results indicate the need to promote models, frameworks, or action plans by governments, as well as organizations, seeking to embrace I4.0, in which the cornerstone is the human factor. It is necessary to understand the challenges in the coming years, seeking strategies through the application of models on technology adoption to facilitate digital transformation, strengthening global chains with greater value for related parties.

Keywords: industry 4.0; global value chain; digital transformation; technology adoption, ecosystems, innovation.

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Introduction

This article provides a literature review focusing on understanding how global value chains (GVCs) are evolving, which have recently been in turmoil because of the COVID-19 pandemic, factors such as the trade war between the United States and China, as well as a technological revolution driven by technologies that make up industry 4.0. The goal of achieving automation and digitization requires key elements that facilitate their adoption, to raise productivity, increase efficiency and improve the management of resources that could create greater value.

GVCs are considered the backbone of modern trade, contributing for emerging economies to not only depend on exports of raw commodities, but to become exporters of products and services, where small and medium-sized enterprises (SMEs) have started to play a relevant role in the global economy. The changes driven by technology and internet, generated opportunities to participate in global trade through the digital economy, allowing the integration of foreign customers or suppliers, through digital platforms that drive e-commerce, financial operations, obtaining information for market analysis, promotion and marketing, regulatory knowledge of the target market decreasing costs as well as facilitating access to information (World Trade Organization, 2019).

This article is structured as follows: the introduction presents a brief context of the topic, the second part shows the methodology while the third part discusses in depth the topic of GVCs and I4.0 and presents the topic of ecosystems, their influence on GVCs and digitization. Finally, the last section presents recommendations for future research.

Materials and Methods

The information was collected using databases such as Ebsco, Scopus and ResearchGate. The analysis was directly related to the GVC and I4.0 study. The relevant information was filtered and different Boolean combinations were applied to help gather specific information. The search was conducted from articles published within the period 2016 to 2022, with the following combinations of keywords in English: industry 4.0, global value chain, ecosystems, innovation, digital transformation and technology adoption.

Global Value Chains

Globalization increased vertical specialization in GVCs, so that countries have been specializing in some stage of the production process (Sposi *et al*., 2021). A multi-stage sequential model was presented regarding production and capital accumulation, based on both micro and macro Heckscher-Ohlin and Ricardian models, to analyze the link between investment, growth and trade. Both finished and unfinished goods are subject to iceberg costs, thus the authors compared trade flows using the spider model and the snake model, the latter being the one that generates higher flows. Specialization and segmentation reduce barriers to trade, allowing to increase GVCs, either by comparative advantage or by capital accumulation, which results in a good decision to boost the economy.

Reddy *et al*. (2021) indicated that international trade and innovation are forces that drive the global economy, giving way to technological spillovers, as well as differentiation, so developing countries can participate in GVCs, allowing their companies to acquire technology, knowledge and networks to achieve economic growth, boosting quality, efficiency levels, and competitiveness. Information from the World Bank (WB) shows that companies use radical or incremental innovation to enter new markets, from 90 countries in the period from 2006-2017 that included 22, 680 companies, promotion of organizational capacity and innovation arise as major factors, since innovative capabilities will change behavior in international markets.

Pattnayak and Chadha (2019) discuss the case of GVCs in the information technology and business process management (IT-BPM) sector in India. GVCs offer opportunities for developing countries to increase their participation in the global economy, with specialization being a requirement to improve the value chain, reduce costs or increase efficiency. India is the largest destination for IT investments, with a market value of $124-130 billion, employing more than 10 million people, 3, 100 technology start-ups, exports of $88 billion in IT services and positive effects on the

education sector, which demands engineering and computer science disciplines. From 1990 to the present, the technology industry has improved significantly along the value chain (VC), first offering low-skilled services, now more complex and high-skilled Research and Development (R&D), triggering intellectual property (IP) and technology transfer. As a result, innovative firms earn higher profits in GVCs from patenting and licensing. Among GVCs with transformed trade in services, the higher the investment in soft assets (human resources), the higher the returns of technology firms.

Miroudot (2020) assessed GVCs in the East Asian region, which have played an important role in the export leadership strategy by achieving the term Factory Asia, thanks to information technologies as well as China's entry into the WTO in 2001. However, the global economic crises, in addition to the COVID-19 pandemic, triggered a debate on the future of GVCs due to the vulnerability of supply chains (SCs). He conducted a quantitative analysis on the evolution of trade costs along the VCs by looking at the intensity of global imports, and found that in this region imports have fallen, increasing the value of regional content to their products, so the pandemic caused companies to reconsider complex GVCs and rethink strategies.

Because of Covid-19, Phillips *et al*. (2022) conducted a study to find out whether GVCs through manufacturing redeployment (MR) could be more flexible in the face of unexpected events, which were affected in the supply flow, causing shortages and production line stoppages. It was unable to meet demand, showing vulnerability and lack of coordination. Therefore, multiple supply strategies must be devised to configure GVCs and decentralize SC without geographical restrictions, in this sense RM could be the answer through the convergence of technologies brought by I4.0 such as additive manufacturing. The disruptive potential to change the current high volume and low cost of GVC, small scale but immediately responsive and autonomous manufacturing came through an analysis of the healthcare sector in the UK by mapping GVC, finding that structural barriers such as production barriers could slow down the implementation of RM, so the authors concluded that collaboration opportunities should be sought with early adopters, innovative companies or universities.

Park and Kim (2019) conducted a study on how preferential trade agreements (PTAs) affect the growth of the countries that adopt them, as well as their network of trading partners, influencing GVCs, choosing them as part of their economic growth strategies, in addition to providing credibility in the international environment, influencing investment decisions, since they have come to play an important protective role. An analysis of the relationship of actors in the networks of an agreement, identifying local partners, groups and global actors, from different sectors, such as primary, manufacturing and services, help to understand their contribution in GVCs. Using the World Input-Output Database (WIOD) and Koopman, Wang and Wei's GVC decomposition method, they evaluated the regional context of exports; this exercise makes it possible to identify domestic value added, returned domestic value added and foreign value added. They concluded that PTAs contribute to the creation of scenarios that can trigger the expansion of an industry, where the greater the contribution of value added in exports, the greater the economic growth, linked directly to innovation and investment.

Rigo (2021) pointed out that in the 20th century production and trade relied on GVCs spreading production stages or processes internationally, taking a new path of industrial development, where companies in developed countries combined their activities to pay low wages in emerging economies. However, international trade has allowed the transfer of technology, intellectual property, and know-how to their suppliers in developing countries along with the receipt of foreign direct investment (FDI). A study was conducted from 2006 to 2016 with information from the WB, indicating that cross-border trade can bring advantages for companies in developing countries, mainly for those exporting to advanced economies, therefore many countries seek to participate in GVCs to stimulate the growth of their economy and obtain transfer of knowledge.

Yang *et al*. (2020) presented an article on intellectual property in GVCs, in which developing countries obtain intra-industrial specialization, which brings benefits such as knowledge, technology and innovation, making use of the North-South model, developed economies transfer assets to emerging economies, and raise the importance of IP, in which the need to

strengthen IP protection has been observed. Otherwise there is a risk of slowing down innovation, which will improve the position in the GVCs, hence the importance of knowing the origin of inputs to know the level of participation, they analyzed the nominal IP protection using the Ginarte and Park index that measures the legislative level, but does not follow the application of the law. A comparison from 2005 to 2015 between Japan and the United States, shows that both maintain high levels of protection, regarding Mexico and China, the latter increased its position in the GVCs as well as its level of protection, contrary to Mexico. They concluded that a system of IP protection compatible with the economic phase and technological development is key to improve the position in the GVCs.

Konishi (2019) commented on Japan's economic slowdown finding that one of the reasons is the low productivity in the services sector, since 2005 the Organization for Economic Cooperation and Development (OECD) had ranked Japan in 20th place in the services sector, as well as in 6th place in manufacturing, whereas in 2014 it ranked it in 19th and 11th place, respectively. However, 75% of Gross Domestic Product (GDP) is accounted for by non-manufacturing industries, an increase in both contribution to GDP and employment generation is observed in the services sector (education, finance, insurance, transportation, logistics, food) in the period from the years 1994 to 2014, contrary to the manufacturing sector, which has been slowing down. Each country integrates its GVC with a different scope to measure the degree of integration, the OECD created a forward or backward participation index, recording that from 1995 to 2009 all developed countries increased their GVC integration with the Asian region.

GVCs are important sources of investment and resources for supplying technology, knowledge, and expertise to emerging economies, which in most cases rely on developing countries through multinational companies. However, in the aftermath of the pandemic, the world is rethinking future strategies, not only to relocate sources of supply but also trusted partners.

Industry 4.0

The concept of I4.0 was coined in Germany (Patil, 2021). It involves the change from traditional manufacturing processes towards integrated processes supported by internet-based technology, facilitating remote interaction and impacting SC. Implied benefits such as transparency or precision decision making, gave rise to concepts such as Automotive 4.0, Logistics 4.0, or Education 4.0, referring to the collection as well as the analysis of information in real time. The main components of I4.0, such as the Internet of Things (IoT) with its architecture, Big Data applied, as well as Cyber Physical Systems (CPS), influence SC management from procurement, manufacturing, warehousing, logistics to the fulfillment of customer orders. Thus, I4.0 generates collaborative and predictive benefits by improving the business-to-business value chain.

Lavalle *et al*. (2017) mentioned that before considering the technological revolution driven by I4.0, there is a cultural revolution, because it influences the way we think about industrial goods, work systems or the modalities in how factories operate in terms of the way people interact with machines and the relationship between companies. The European Union has initiatives to support technological innovation and develop a digital skills agenda, such as the *Plattform Industrie 4.0* driven by the German government, the *Produktion der Zukunft* initiative of the Austrian government, and the *Piano Nationale Industria 4.0* driven by the Italian government, due to the importance of jobs in this environment, universities play a crucial role and new skills will be required to perform their activities.

Basl and Doucek (2019) mentioned that the word revolution is completely justified, since I4.0 is changing most areas of society, from agriculture, health, education, and government, so the authors support the definition of *Information Society*. They conducted a study on maturity models, the most recognized of German origin, which are applied to specific entities, such as the Reference Architectural Model Industry 4.0 (RAMI 4.0), IMPULS of the VDMA Engineers Association, SIMMI 4.0 of the Dresden and Heilbronn University of Technology and several more, currently there are more than 20 models. There are also readiness indexes, such as the Networked Readiness Index (NRI), the Global Innovation Index (GII), the Global Competitiveness Index (GCI), the OECD Scoreboard,

the Readiness Index of the consulting firm Roland Berger, all of them through indicators help at determining the levels of digitization and innovation. No model has been developed for a specific industry or sector, focusing on organizational management issues, their conception of technology is different without mentioning attributes. They do not consider SMEs or security risks, for that reason, the authors proposed a 7-level model that should consider the social context, the specific area, as well as the specific activities.

Ravina-Ripoll *et al*. (2019) commented that I4. 0 is characterized by the erosion of the welfare state. They reviewed *Happiness Management* as an effective instrument in the innovative design of organizational strategies in the digital society environment, finding that organizational happiness should be understood as the commitment by management levels to generate an open work environment to encourage technological innovation and achieve the promotion of the culture of innovation. It is based on the construction of virtuous circles of corporate happiness, encouraging internal customers in innovation, creativity, as well as teamwork by applying models with an entrepreneurial approach, oriented more to the happiness of human capital than to the maximization of profit, promoting collective happiness.

According to Hahn (2020) the I4. 0 embodies a vision of assets, products as well as intelligent machines. It is distinguished by activating innovations in the supply chain, which are manifested in three dimensions; business processes that include orchestrated, operational and support activities; digital technology divided into core technology (people, technical systems, intelligent entity) and complementary technology (driven by hardware and software); finally, enterprise architecture focused on product, service, and/or platform. The digitization of the industrial sector requires changing the value proposition in business models, the first initiative with government funding originated in the region of Baten-Württemberg, Germany, with the *Allianz Industrie 4.0* initiative, concluding that digitization in supply chains is being driven by entrepreneurship, where there is still an opportunity for comprehensive action.

Jian et al. (2020) mentioned that the I4.0 points towards a high degree of automation as well as the digitization of processes, which requires the combination of new emerging technologies, allowing companies to connect horizontally and vertically. However, strategic decision making in the technological field to obtain competitive advantages are complex, and must be guided in their development by technological standardization that includes robustness and reliability.

Global value chains in the Industry 4.0 ecosystem

Digital transformation requires digital strategies, which should not be treated in isolation as a separate component of the business operation. Digital transformation requires a profound transformation in business, as well as organizational activities, processes, capabilities and skills, to take advantage of the changes and opportunities of the digital technology mix to accelerate its impact on society, and respond quickly to the market (**Fig. 1**; Gobble, 2018).

Digital transformation is made up of five key stages according to Tierky (2017): first, customer expectation continues to rise, with customers expecting consistent

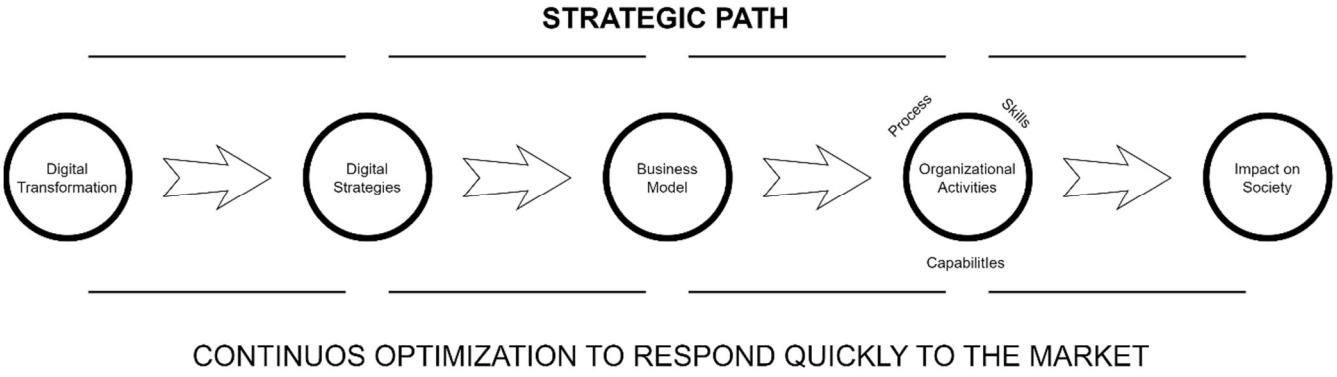

Figure 1. The path to optimization, its impact on the market and society. Gobble, 2018.

personalized experiences through the power of technology; second, adapting is more important than ever, companies must stop thinking linearly because by the time they want to respond to an opportunity or threat, the world would have changed, the challenge for many companies is to move fast towards the digital disruptions that already exist; third, responsiveness to customers is essential, being able to respond quickly to the needs of each segment; fourth, artificial intelligence (AI) is front and center, where there are signs that AI strategies are required that have components such as sensitivity (input), insight (idea), analysis (review), guidance (confirmation), as well as action (response); finally digital transformation means business model transformation, which requires both scalability and reach, primarily to know how the organization delivers value, generates revenue and drives innovation (**Fig. 2**).

In this sense, the digital transformation can be supported by business ecosystems, which are formed by a network of entities with different interests, but linked each other, through communities, organizations, processes as well as technology. An industry is based on the creation of a new collaborative strategy that improves competitiveness and innovation seeking to create value, changing the scheme from economies of scale to economies of networks. A study in the Korean pop industry, which involves artists, entertainment companies, media, and platforms, which generates 40 billion dollars and has 30 billion fans in the world, found that it is important to consider the barriers or boundaries of objects (infrastructure) and information to achieve transition with value delivery in the network, rather than linear or chain (Tan *et al*., 2020).

Ecosystem fosters cooperation and increases efficiency, improving business performance, leading to a value proposition through new stages that can emerge scientifically and practically for new products or services. There are two key factors to achieve transition to digitization, first, the knowledge of the organizational structure, second, the technological enablers, also digital services are constantly growing because of the network effect. The performance of the value proposition requires the union between the production and consumption ecosystems through the digital business that will allow better integration of VCs (López *et al*., 2021).

Attour and Lazaric (2018) conducted a study on the relationship between knowledge and business ecosystems, in the Sophia Antipolis technology park in Nice. In this scenario, knowledge plays a fundamental role in the filtering of useful information for business development, based on spatial concentration for the formation of clusters, as is the case of universities or research centers that provide knowledge for innovation. They analyzed four projects on proximity communication involving different actors from universities, students, restaurants, banks and companies from different sectors, and found that technology platforms play a fundamental role, as well as the anchor host, and concluded that the joint participation of public and private entities facilitates the creation of ecosystems.

Zhang *et al*. (2021) mentions that business innovation ecosystems are complex networks made up of companies, universities, governmental and financial institutions that are integrated with human talent, technology, capital, and information to achieve a convergence of innovation that results in the creation of value, being dynamic and collaborative spaces. Studies show a positive correlation in dynamic technological innovation systems, when there is cooperation in research and development, standardization, knowledge transfer and high technology, in addition to

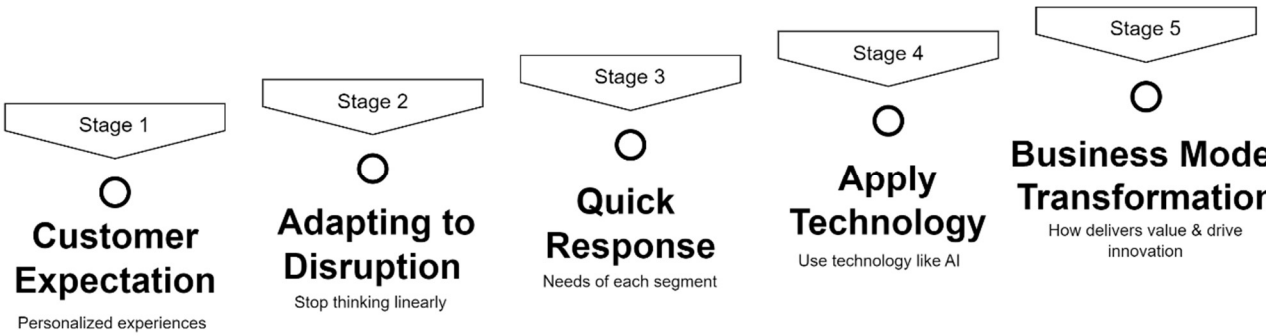

Figure 2. Key elements of digital transformation (Tierky, 2017).

knowledge acquired outside or generated within the company, such as patents. The study, conducted in China, indicated that one way to achieve technological transformation into economic benefits is to extend innovations throughout the SC, being important to receive or create technological innovations in organizations and assimilate them to achieve value generation.

Katimertzopoulos and Vlados (2019) described policies capable of driving regional innovation systems, where there are divided opinions on whether it is the regional concentrations that drive innovation or the companies, considering that there are external (infrastructure, legislation, education) and internal (knowledge, motivation, organizational rigidity, hierarchy) barriers to trigger innovation. In this sense, the Triple Helix theory helps to create functional hybrid organizations for lagging regions. Based on the *Strategic Technology Management* model to consolidate the innovative potential of an organization, they proposed a combined model to create innovation and development institutes in Greece, providing conditions that foster innovation and enhance dynamic capabilities.

Lee *et al*. (2017) conducted a study on the business ecosystems for the life cycle of high-tech startups in China, Korea, and Japan, from which they offer new perspectives, the idea is to transform the strategies that drive innovation, where the relationship between stakeholders is reciprocal as well as with the business environment. In contrast, startups must face two scenarios, the *Valley of Death* (generating revenue) as well as the *Darwinian Sea* (competition). China is the largest generator of patents but with low per capita rate with a market focus, Korea is a smaller generator, but higher rate focused on supply, finally Japan has decreased registrations, but it is the only one that receives payments for high technology licenses.

The concept of business models brought a change in the thinking of strategic management, which already explained the generation or capture of value as well as the environment. This concept has renewed the meaning of value and strategic innovation towards a business ecosystem, which is distinguished because a specific vision of the environment, instead of focusing on an organization. An example is the digital platform connected with multiple actors, where each participant collaborates in certain actions with its own logic and particular interests, establishing collective relationships to create value for customers and capture value for the organization (Demil *et al*., 2018).

Companies should constitute collaborative spaces such as innovation ecosystems, however there are risks related to these initiatives, such as interdependence and integration. Jian *et al.* (2020) presented a study using the Lotka-Volterra model applied to business to analyze the behavior of an innovation ecosystem and found that a technology standardization strategy is required to achieve a competitive advantage.

Conclusion

GVCs have evolved towards a more direct relationship with suppliers and customers, reducing response times, optimizing activities, improving service, obtaining real-time information for decision-making, facilitating the creation of communities, enabling the creation of new market segments, and serving a greater number of people (**Fig. 3**).

Readiness models for the implementation of I4.0 must be applied to have a wider scope to achieve a better understanding of the key factors, helping the strategic planning and reduce some impacts generated by its implementation. Organizations must analyze their business models to be able to face the challenges, taking advantage of it, without thinking that it only represents a threat to the current model, on the contrary, companies must try to discover the opportunities that will arise, such models must consider the digital environment and partnership schemes such as innovation ecosystems. Benefits of automation and digitization driven by I4.0 on GVCS include better efficiency and control, enhance legal and regulatory compliance, improve supply chain management, and increase productivity.

By reviewing literature from 2016 to 2022, it is concluded that change should be embraced as soon as possible, considering existing innovations, analyzing how to implement them aligned to the organizational culture through new business models, which should be linked to technological change, since competition will come from other industries, strategies should be devised that allow to be at the forefront to be able to compete directly or indirectly against rivals and newcomers.

Figure 3. GVCs on I4.0 ecosystem.

Efforts should be focused on promoting plans and policies that facilitate the implementation of technology along GVC, as has been done by leading countries in the field of I4.0, following up on long-term projects, working together with companies, government, and society in order to create ecosystem that powered the technological development, competitiveness and innovation. It is recommended that future research focuses on the impact that smart or automated GVCs will have on issues related to regulations, restrictions or standards that could affect certain sectors or operations, as well as the labor impact on GVC resulting from digital transformation.

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