



Industry 4.0 and circular economy in an era of global value chains: What have we learned and what is still to be explored?

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ABSTRACT

This article reviews the industry 4.0 (I4.0) and circular economy (CE) literature from a global value chain (GVC) perspective. More specifically, it (1) summarizes the empirical findings on the applications of I4.0 and CE practices; (2) explores the previous literature and identifies several future research directions to advance the existing literature. In this respect, the interface between I4.0 and CE research is a relatively young field of inquiry that has been little concerned with developments in GVCs. We systematically review 112 peer-reviewed papers in the field of I4.0 and CE to distill key future research opportunities and trends in the GVC field. We develop three specific conclusions from our literature review. First, GVCs can vary widely within the various forms of I4.0 technologies with the various CE practices. Second, GVC research is underdeveloped with regard to I4.0 and CE. Third, our findings are congruent with previously published studies, which recognize the importance of GVC research that has generated a rich body of knowledge, mainly from a governance perspective in operations management, supply chain management, and international business. Likewise, our study offers promising avenues for future research studies at the intersection of I4.0, CE, and GVCs. Our systematic literature review suggests that there are many opportunities to advance the I4.0 and CE debates in the burgeoning field of GVC.

1. Introduction

Industry 4.0 (I4.0) - a fourth industrial revolution that is mainly represented by state-of-the-art digital automation technologies, such as cyber-physical systems, the internet of things (IoT), and cloud computing (Xu et al., 2018), represents a fundamental transformation in how products and services are produced. Likewise, the circular economy (CE) - a closed-loop production system concerned with reducing the consumption of materials, reusing the products and services, and recycling the waste products (Goyal et al., 2018) - is widely recognized as a pivotal phenomenon for contemporary economic production among scholars. I4.0 encompass various digital technologies, procedures, and systems to make the production process more customized and autonomous and achieve improved operational performance (Dachs et al., 2019). I4.0 plays a major role in global value chains (GVCs) and in transforming production processes embedded in GVCs. Scholars have recently recognized the increasingly visible transformation of CE within

GVCs through I4.0 (Dachs et al., 2019; Laplume et al., 2016; Strange and Zucchella, 2017). As GVCs are concerned with product flows and governance (Gereffi and Korzeniewicz, 1994), I4.0 permits production firms to move “production back to increase flexibility and reduce lead time” (Dachs et al., 2019). Similarly, as GVCs are becoming increasingly concerned with environmental sustainability issues (e.g., Gölgeci et al., 2021), it can enhance and promote a sustainability agenda within GVCs.

Although GVCs have recently drawn the academic community's attention, the literature reviews provide mixed conclusions about how I4.0 technologies influence the CE (Rosa et al., 2020). Despite the significance of GVCs, Zavadská and Zavadský (2020) suggested that evidence of a link between the implementation of I4.0 and enabling value co-creation is fragmented. Scholars have become increasingly interested in how different dimensions of I4.0 support GVCs (Chen, 2019). Existing GVC research has largely focused on governance structures and upgrading issues (Gereffi et al., 2005; Kano et al., 2020). However, recent advancements in new technology and growing pressure on firms

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to improve their environmental performance are opening new avenues for the GVC research community. This provides a strong linkage point between I4.0 and CE literature with GVC research, particularly in better understanding of whether digital platforms change GVC governance or how CE business strategies can lead to a more sustainable natural resource use in GVCs. Indeed, some studies already emphasize the potential of I4.0 for enhancing competition and corporate strategies (Chen, 2019; Strange and Zucchella, 2017). Others focus on its performance effect on GVCs (Chen, 2019) or as a set of technological tools for improving the effectiveness of organizational control. Mixed findings on I4.0 and CE literature lead to various challenges for decision-makers on how these two streams of literature support GVCs. Linkages between the I4.0 and CE literature streams and GVC research remain underdeveloped.

The GVC paradigm has found a sweet spot of academic acceptance and policy significance amid the chaotic debates over developing and establishing a complete value chain in production networks in both the private and public sectors (Gereffi, 2019). However, the extent to which I4.0 can be applied to support GVC practices is unclear. The literature on firms' value chain streams has emphasized the importance of institutional power framework, inter-firm networks, competitive dynamics, and technological innovation (Kano et al., 2020). There are inconsistencies and fragmentation in research exploring the interface between I4.0 and CE for GVCs. Accordingly, the divide between relevant research streams has prompted the need to integrate how organizations optimize value-added processes, capture value using I4.0, and follow CE principles in GVCs.

In this study, attention is devoted to firm involvement in I4.0 and CE and their effect on GVCs (Strange and Zucchella, 2017). Given this array of perspectives, we believe that a systematic literature review of the I4.0-CE interface in GVCs can help inform ongoing discussion and advance our understanding of how it affects GVC governance. Our literature review seeks to address this literature gap and advance the literature on I4.0 and CE to build a valuable research agenda. The following research questions will be addressed in this study: What is the profile of previous research at the interface of the I4.0 and CE in relation to GVC? (2) What key themes and research topics can guide future studies in this domain?

We have two objectives. First, we identify and analyze the literature on I4.0 and CE in relation to GVCs and examine the contributions of the articles at the interface of I4.0 and CE in GVCs. Second, we develop a comprehensive future research agenda at the interface of I4.0 and CE in GVCs and discuss key research themes from the articles reviewed. Our study adopts a systematic literature review methodology and analyses 112 relevant papers published over the last ten years to pursue this objective.

The current study contributes to the I4.0 and CE research agenda by suggesting future research directions to advance the existing literature. First, previous literature reviews analyze GVC literature by focusing on governance at the micro, meso, and macro-level (Kano et al., 2020; McWilliam et al., 2020; Strange and Humphrey, 2019). However, this literature review has addressed GVCs from the manufacturing perspective by considering links between I4.0 and CE. Studying how these two emerging areas affect the change of GVCs will lead to a deeper understanding of the reformulation of chain or network dynamics. Second, existing literature in I4.0 and CE has focused on applying new technologies to achieve production efficiency and improve the product-service system (Rosa et al., 2020). Our literature review provides the understanding and making use of new digitalization tools (I4.0) to upgrade the product and process and improve the embedded position of GVC from a manufacturer's perspective. Third, this literature review contributes to the continuing debate over linking I4.0 and CE from the theoretical perspective. It reveals that the lack of involvement of recycled material suppliers and upstream customers and institutional arrangements hinder bringing I4.0 and CE to the forefront of GVCs (Chiappetta Jabbour et al., 2020). Extending the literature review on

I4.0 and CE interface might lead to a better understanding of possible future research directions in GVC. We also contribute to the CE business model research by suggesting future research direction at the interface of I4.0 and GVC.

2. Background on the link between industry 4.0 and circular economy in global value chains

GVCs denote the set of inter-organizational linkages between firms and other actors through which the geographical and organizational reconfiguration of economic production occurs (Gibbon et al., 2008). Many firms typically seek to optimize global efficiencies by having different foreign locations specialize in different production activities (Strange and Humphrey, 2019), leading to foreign investment across multiple countries. GVCs are important underpinning forces for international investment and trade for the sustainable development of countries across the world (UNCTAD, 2013).

GVCs are characterized by the tensions of international expansion out of domestic markets and the fragmentation of those same markets by new entrants (Gereffi and Lee, 2012). GVC framework examines the entire structure of an industry or a firm, from the supply of raw materials to the delivery of a specific end-product and the global spatial scale of that process (Gereffi et al., 2005) and provide a fuller picture of technological and paradigmatic challenges embedded in GVCs.

As the pressure to achieve environmental sustainability is unprecedented, adopting practices and production systems beyond the firm boundaries, particularly in emerging market contexts, is becoming increasingly prevalent (Gölgeci et al., 2019). Hence, holistic production systems like CE have witnessed accelerated popularity and adoption (de Sousa Jabbour et al., 2018; Ferasso et al., 2020; Govindan and Hasanagic, 2018). CE is a restorative production system that aims to keep products, components, and materials at their highest utility and value (Govindan and Hasanagic, 2018). At the micro-level of analysis, CE can be considered a business paradigm that guides production and consumption patterns in an industry or region (Awan and Sroufe, 2022). At the micro-level of analysis, it is viewed as a business model that reflects the firm's realized strategy of prioritizing and working toward achieving environmental sustainability in a holistic fashion by means of eliminating waste and adopting circular production flows (Ferasso et al., 2020; Goyal et al., 2018).

I4.0, as a holistic technology-driven transformation of production processes (Xu et al., 2018), has emerged due to the development and adoption of revolutionary production technologies. These technologies include cyber-physical systems, IoT, artificial intelligence, machine-to-machine communication, blockchain, and cloud computing (Xu et al., 2018). Plethora of related products and business technologies has paved the way for I4.0, which completely transformed and revolutionized economic production (Awan and Sroufe, 2022).

Concerning the CE-I4.0 interface, while CE research has begun to focus on I4.0 in the last few years, there is still a lack of research in these domains from a theoretical perspective. It has been recognized that I4.0-associated technologies can design CE business models by developing more efficient technologies (Ingemarsdotter et al., 2020). Accordingly, I4.0 and CE are clearly related. Research on the effects of I4.0 on CE is mainly focused on identifying novel ways in which digitalization changes the nature of the products or facilitates the organizational process (de Sousa Jabbour et al., 2018).

There have been few studies that pointed out that the implementation of CE depends on policy incentives and regulatory decisions, financial gains over the supply chain through reduction of material cost (Field and Sroufe, 2007), and remanufacturing gaining interest among firms (Govindan and Hasanagic, 2018). The topic of I4.0 and CE business model implementation has received growing attention in technology management and operations management (Ingemarsdotter et al., 2020). With the rapid growth of awareness of environmental-related problems, researchers from different industries started taking an interest in

studying what factors compel firms to manage the natural environment through emergent technologies embodied by I4.0 and a novel business model of CE (Ferasso et al., 2020).

The linkage between I4.0 and CE has been increasingly recognized by practitioner (Mckinsey, 2019) and academic research (Rosa et al., 2020)). Research on I4.0 and CE recognizes that modern production systems entail a holistic perspective that accounts for processes, technologies, and resources outside the firm's boundaries. However, it largely fails to integrate and incorporate insights from the GVC perspective to arrive at a fuller understanding of I4.0 and CE in the context of global production systems. Hence, despite the overall surge of research on the linkage between I4.0 and CE, there remains a need to better understand I4.0 and CE within the wider context of GVCs (Strange and Zucchella, 2017).

3. Literature review methodology

To identify the relevant articles in I4.0 and CE, we have followed (Denyer and Tranfield, 2009), systematic literature reviews guidelines. It helped to reconceptualize a specific topic further as it develops (Snyder, 2019). Systematic literature review studies involve a step-by-step methodology. It permits the researcher to determine what article should be included or excluded on the topic under study by screening in different databases, performing a search, and containing previously published studies. This shows that inclusion or exclusion criteria provide strong support for the validity of selected articles. The inclusion or exclusion criteria are based on reason and logic regarding the type of studies having major consequences for the results and conclusions (Snyder, 2019).

The systematic literature review consists of multiple phases to overcome the potential issue of bias using inclusion or exclusion criteria. We also carry out different steps and checks (see Appendix 1 for details). We limit our systematic literature review to the published peer review articles held within the Web of Science and Scopus databases. Appendices 1 and 2 provide an overview of search strings, scope, search date, date range, inclusion, and exclusion criteria. All the retrieved documents were exported to Mendeley, a reference insertion tool for duplication checks and removal of duplicate entries. This check eliminated 520 documents that were duplicates, which led to the sample of 588 documents that were not duplicates, as shown in Fig. 1. Second, the authors went through the initial manual screening of the remaining 588 documents and removed 86 documents that were non-academic books and book chapters, reducing the sample base to 502. Third, 359 documents were eliminated following the iterative further reading of study titles and abstracts and consultation among the co-authors. Fourth, after further reading, 31 modelling-based documents were excluded from the remaining sample of 143, leading to the final sample of 112. Thus, 112 documents were considered relevant and selected as a final set of documents to be analyzed further. Fig. 1 details the selection and filtering phases.

Article was removed from the further analytical process if it was not clearly linked to I4.0, CE, CE business models, and GVCs. Previous research studies, such as Ferasso et al. (2020) and Rosa et al. (2020), followed the categorization of the keywords approach in a similar domain. Appendix 3 details the sub-set of seminal articles included in our review and summarizes the findings on common themes in the I4.0 and CE research fields.

4. Findings

4.1. Industry 4.0 and circular economy in the context of global value chains

The concept of GVC is far from new and dates back to 1994, when it was originally proposed as the Global Commodity Chain approach (Gereffi and Korzeniewicz, 1994). According to Kano et al. (2020), GVCs

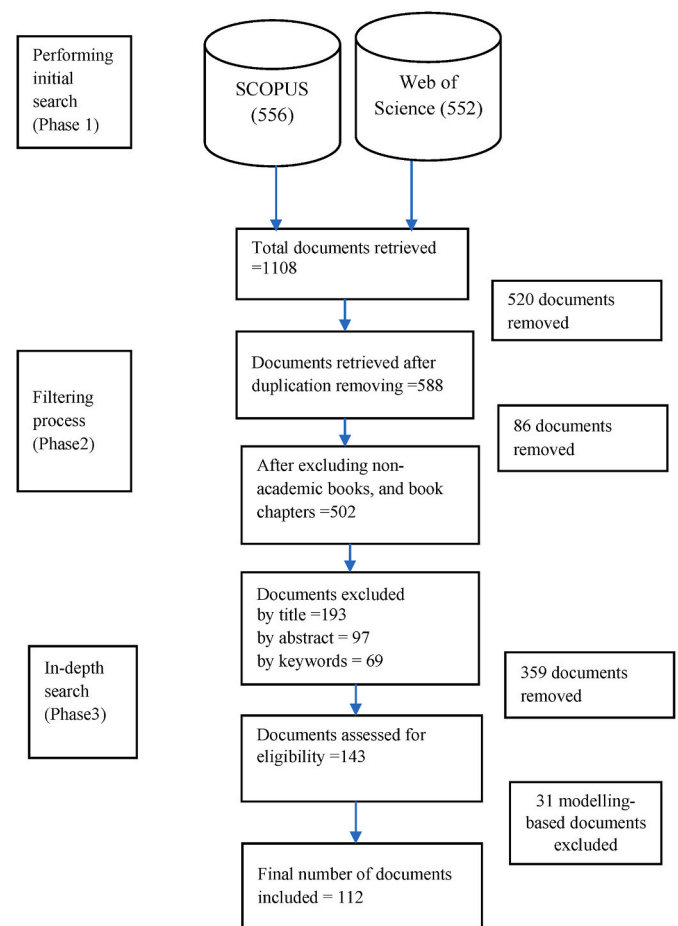


Fig. 1. Detail of literature selection phases.

refer to how “firms work with and integrate their geographically dispersed strategic partners, specialized supplier and customer base into complex structure” (p.578). They provide important development pathways for local firms, particularly from low-income and emerging markets, to enter international markets, develop new capabilities and capture more value through upgrading. Initially used to inform development-oriented research (Gereffi et al., 2005; Gibbon et al., 2008), more recently, the phenomenon of GVC has found acceptance in wider management disciplines and grown to characterize the interconnectedness of global production and how value is generated and distributed among different actors in global trade (De Marchi et al., 2020). Whilst the governance and upgrading have been the dominating themes in GVC research, a handful of studies also speak to the relationship between sustainability and GVCs (Buckley et al., 2019).

Strange and Zucchella (2017) reviewed how I4.0, with existing technologies, can reconfigure relationships with customers and suppliers and capture value in GVCs. I4.0 represents one of the most important and urgent themes in GVCs to anticipate and respond to customer demands about where products are made and bring about the efficient distribution of final goods (Strange and Zucchella, 2017). Kano et al. (2020) found a flexible relationship for possible local adaptation to perform the desired level of customization. However, to date, there has been little focus on how GVCs can support CE across geographically dispersed business operations. This should not necessarily be surprising, given that GVCs have been designed to support more traditional linear economic production systems. One common approach focuses on GVC governance and upgrading (Coe and Yeung, 2019; Gereffi, 2019). Governance reflects the authority and power structure in the relationship (Kano et al., 2020). Our review highlights that value-added activities such as product design and product development are often

embedded in institutions and their interaction with governance structures.

Despite the scholarly research gains on GVC, scholars have highlighted whether the adoption of I4.0 anticipates and shapes future customer demands (Strange and Zucchella, 2017) and is linked to low carbon technology and the recycling economy (Wang et al., 2020). GVCs' success is often a function, in part, of the bottom-up governance perspective, which focuses on how regions, countries, and economic actors integrated into leveraging unskilled or low-cost labor to strengthen their competitive position worldwide (Gereffi et al., 2005). Upgrading is often a part of production value creation activities, the flow of knowledge, and improved technical knowledge and skills (De Marchi et al., 2020). A vast part of the literature also identifies the institutional role in the development of international collaboration with global suppliers, other points upgrading by fostering close interaction and collaboration to the successful cultivation of knowledge resources and technological capabilities (Golini et al., 2016). Therefore, by linking these literatures and drawing insights from our review, we provide future research opportunities for global business management scholars to explore how to I4.0 and CE shape and change GVCs.

4.2. Research stream 1: GVC governance and I4.0

Our findings reveal that firms must understand how to implement GVC governance decisions amid the transformative wave of I4.0. The digital transformation of I4.0 brings profound changes, and conventional GVCs are no longer fit for global information where artificial intelligence, big data governance, and predictive analytics create holistic solutions and uproot existing paradigms. Our findings indicate that I4.0-associated technologies will likely enhance GVC coordination and minimize information exchange errors. In this vein, industry restructuring led by I4.0 could reshape GVCs and change both the scope and geographies of GVC activities. This can have particular implications on GVC governance, potentially creating new types of governance structures and shifting the power relationships and authority within the chains from more traditional firms to new GVC players. In fact, Strange and Zucchella (2017) report that the new digital technologies driven by I4.0 have considerable potential to disrupt how and where activities are located and organized within GVCs and who captures the value-added within those chains. Accordingly, a growing body of literature recognizes the potential impact of I4.0 on GVCs and examines the mechanisms by which such influence is manifested.

Literature evidence that I4.0 and CE play a vital role in productivity, product quality, and customer satisfaction (Ma et al., 2020). As Pietrobelli and Rabellotti (2011) describe, information systems positively impact supplier learning and innovation. The governance mechanism is particularly important to share, transfer, and combine knowledge when suppliers lack tacit and market knowledge. A promising opportunity for GVC research is the monitoring and control mechanisms of dominant buyers in the pursuit of transitioning towards CE with the support of I4.0 (Awan et al., 2021).

Despite extensive research on GVCs, existing research on how I4.0 may help optimize processes, new products, and ultimately value generated from the resources still lacks in the empirical investigation (Strange and Zucchella, 2017). Our review reveals that a few articles explain the importance of I4.0 tools, such as IoT, big data and analytics, and additive manufacturing, to realize the benefits of GVCs in advancing new products and services to improve productivity (Strange and Zucchella, 2017). To date, research on GVCs has not fully considered the reality of the new digitalization technology of I4.0 (such as big data analytics, IoT, cyber-physical system) and how such interface may either enhance or impair network linkages across region and country level. In contrast, our review detailed a handful of research studies that have considered how I4.0-CE interface shapes GVCs.

4.3. Research stream 2: Impact of digitalization on upgrading and CE strategy in GVCs

Our literature review further reveals that understanding CE within the socio-economic perspective of development and developing countries is necessary to enable sustainable change in GVCs, such as lean automation. It leads to product and process design upgrading for marketing, sale, and services to enhance value creation at GVCs. The literature further reveals that to understand enabling lean automation, the understanding of CE socio-economic perspective of development and developing countries is necessary to upgrade the product and process design for marketing, sale, and services to enhance value creation GVC.

GVCs leads to green growth in the manufacturing industry and more environmentally sustainable production systems (Qu et al., 2020). Technological tools are claimed to significantly impact CE, such as designing out waste at processing stages, selecting specialist material, and extending the product life through predictive maintenance (McKinsey, 2019). As a result of big data cloud computing, the topic of big data and its effect on CE has gained attention from researchers. Our literature review reveals key challenges and opportunities in applying big data analytics and adopting CE capabilities.

The evidence reviewed also highlights that the cyber-physical system (CPS) focuses on multiple sensors and actuators for information exchange between connected objects (Monostori et al., 2016). Results suggest that adaption towards CE activities triggered by applications of a cyber-physical system ease task completion easy, as ongoing activities among partners are completed through feedback and adapt to the new conditions. Several previous studies have found evidence of the effects of CPS as a way to support the development of new services and management of product life cycle, particularly for the repair and maintenance (Rosa et al., 2020). However, results for managing and replacing physical resources tend not to affect understanding the effective utilization of tasks and processing time.

4.4. Research stream 3: Firm's network structure and location advantage

The operationalization of the sustainable CE model requires a paradigm shift from creating new value networks that allow products returned from customers to manufacturers to perform CE activities, such as reuse, recycling, and repair. Previous work on GVCs emphasizes that production activities in different regions are positively associated with the outsourcing partner and firm-specific coordination and information exchange strategies. GVC networks are socially constructed and locally integrated (Gereffi and Korzeniewicz, 1994). These networks included micro, macro, and meso levels, such as firm-level actors, governmental, and consumer groups.

Evidence suggests that network structure (multi-actor or dyadic) can affect operational performance (Golini et al., 2016), and external supply chain integration (Amendolagine et al., 2019). However, there is no consensus whether upgrading within the network relationships changes the technical competencies and enhances sourcing efficiency (Amendolagine et al., 2019). The firms' short-term and long-term strategies are likely to be shaped by their broader ecosystem (Dallas, 2015). There is substantial evidence to support a positive relationship between institutional policy and co-evolutionary learning and capability building (Dallas, 2015).

I4.0-CE interface is central to transaction cost economies because I4.0 technologies improve information exchange, minimizing cost through feedback and adaption. IoT is a new paradigm that consists of embedded devices, communication technologies, sensor networks, and applications (Ingemarsdotter et al., 2020). In reaction to this growing interest in IoT in supporting CE, research on CE has remarkably increased, particularly in management and engineering outlets. Most previous research has focused on the interface of I4.0 and CBM or I4.0 (de Sousa Jabbour et al., 2018) and GVCs (Strange and Zucchella, 2017). Consequently, research on embedded firms in networks, network

structure, and location advantage concerning I4.0 and CE remains fragmented. It entails further research that is laid out in the next section.

4.5. Research stream 4: Home and host environmental characteristics

Our review revealed interesting insights into the home and host environmental characteristics of GVCs vis-à-vis I4.0 and CE. An emerging and growing field of research on transition management provides a way to “articulate and structure what such frontrunners are doing and provides a framework to attempt to translate their approach into a more general and transferable methodology” (Loorbach and Wijsman, 2013, p. 24). These networks included micro, macro, and meso levels, such as firm-level actors, governmental levels, and consumer groups. Literature remains limited in how network actors may reconfigure their GVCs and consequently create and capture value across countries, regions, and industries (Kano et al., 2020). Specifically, research adopting the network dependence theory examines how different networks create opportunities within specific regional economies to upgrade the infrastructure (Coe and Yeung, 2019). Likewise, research has considered the networks’ role in leveraging and managing firm-specific activities to enhance resource acquisition and knowledge combination to enhance performance outcomes. In this vein, the transition management approach helps determine the right path for adopting and implementing CE practices (Loorbach and Wijsman, 2013).

The studies by Gereffi (2019) and Laplume et al. (2016) are particularly important in this field. Furthermore, Dachs et al. (2019) have argued that research on the digitalization control mechanism in GVCs has evolved and changed power relationships in network structure. However, there is still a lack of research that considers the development of GVCs in the domain of CE. Such research shortage is particularly pronounced concerning issues that revolve around the role of home and host environmental characteristics embedded across GVC locations in the evolution of I4.0 and CE. This study offers some critical perspectives and insights that can serve as reference points for future research investigation issues around the I4.0 and CE in relation to environmental factors embedded in GVCs.

5. Future research agenda

We develop a future research agenda that draws from and builds on the literature review findings. Future research is also organized around the four emergent themes identified and elaborated in the findings. Table 1 lays out relevant potential research questions across each theme and offers key references supporting these issues.

5.1. GVC governance and I4.0

Despite the wealth of research on GVC governance and I4.0, much remains to be discovered. For example, following Gereffi and Lee (2012), future research may benefit from how recent economic crises may shift the market and regional GVC structure to create and capture value through new technologies related to I4.0. In line with this inquiry, from the perspective of I4.0 and CE, manufacturers are concerned about whether they can maintain or gain the product and sales capabilities needed to develop low-cost and high-tech products.

Previous research in GVC has mainly focused on a mix of governance structures at different levels of the supply chain. Furthermore, little is known about the influence of recent organizational structures that may impact the development of I4.0. Several scholars have highlighted that I4.0 can restructure the global and regional value chains. Future research may benefit from a more in-depth study on network structure and the firm potential to develop local and regional value chains (Gereffi, 2019). However, what becomes apparent is that fewer studies that examine I4.0 focused on GVCs governance and activities. As such, a promising future avenue for research would be to explore whether or how a digital governance mechanism may influence organizational

Table 1
Future research questions.

| Key Research Themes | Future research questions/topics | Exemplary citation (s) |
|---|--|---|
| GVC governance and I4.0 | What are the implications of I4.0 for manufacturing industry structure, and how does it impact productivity performance? How do hybrid governance mechanisms complement the emerging digital technologies and create a new locational advantage? What is the impact of digital technologies on GVC governance, and how does it reduce the transaction costs? How do evolving I4.0 technologies change the governance landscape of technological upgrading? How do digital platforms affect ownership structure, location, and internationalization to transform value across borders with added flexibility and efficiency? What is the effect of the digital platform on inward or outward customer and supplier collaboration in varying industries? | Dachs et al. (2019) McWilliam et al. (2020) Nambisan et al. (2019) |
| Impact of digitalization on upgrading and CE strategy in GVCs | Does digitalization reduce the barriers to infrastructure up-gradation and facilitate the end customers? What is the effect of investment in I4.0 technologies on relocating manufacturing activities back to the home country? What locational advantage is associated with the utilization of I4.0? How does the home institutional environment accelerate inter-firm network structure? Examine the influence of I4.0 technologies on governance effectiveness. How can I4.0 exploit the production advantage while retaining the control on exchanging information across partners and cultivate a culture of knowledge combination, creation of specialized learning, and formulation of organizational CE strategies across GVCs? Examine the I4.0 and adoption of artificial intelligence interface in the context of business-to-business marketing with a focus on individual managers or firms engaged in CE implementation in GVC. | Dachs et al. (2019) Awan et al. (2021) Fisher et al. (2020) |
| Embedded firms in networks, network structure, and location advantage | How does the implementation of 3D technology and additive manufacturing in GVCs, such as basic metals, chemicals, paper products, and textiles, affect the control of raw material suppliers? How do different organizational resources and | Laplume et al. (2016) Hannibal and Knight (2018) Castelo-Branco et al. (2019) Dachs et al. (2019) McWilliam et al. (2020) |

(continued on next page)

Table 1 (continued)

| Key Research Themes | Future research questions/topics | Exemplary citation(s) |
|---|---|---|
| Home and host environmental characteristics | technology capabilities significantly impact the network structure? Does internalizing new capabilities and resources at distant locations needed to successfully safeguard the existing and new capabilities in an international environment? Examine why some firms can achieve higher levels of upgrading (process and functional) than others in the same industry? Does proximity to global network production matter in the era of I4.0? How does I4.0 affect the structure of GVCs at the regional, local, and industry level and promotes the circularity of products? | McWilliam et al. (2020) (Laplume et al., 2016) (Hannibal and Knight, 2018) |
| | How do contextual constraints (geographically, institutional context) hinder or support additive manufacturing, virtual reality, and modular assembly leveraging knowledge flows within GVCs to build CE capacity (i.e., product and process design, functional design, and social design strategies)? How does the host institutional environment reshape GVCs in some industries and does not in others? How do institutions better enact CE policies for product traceability? | |

change and how digital strategy may affect upgrading firm digital transformation at the regional value chain level.

Likewise, less attention has been paid to explicitly examining recent technological wave and their impact on reshaping the GVC. Future research may benefit from a more in-depth study on network structure and firm potential to develop GVCs (Gereffi, 2019). Other GVC factors such as location decisions, choice of network partners, flexibility and adaptability, and how firms reconfigure their resources and capabilities in meeting the demands of upgrading and diversification through digital technology enable plate-formalization as the basis for offering value (Nambisan et al., 2019). For example, the question of how GVC networks could shape governance mechanisms to design new products and services using big data analytics for effective decision-making to support CE may lead to interesting insights. Therefore, scholars are encouraged to delve deeper into the interplay between GVC governance and I4.0 and explore how I4.0 and GVC governance shape each other.

5.2. Digitization of CE strategy in GVCs

Our findings highlight that digitalization profoundly impacts upgrading and CE strategy in GVCs. However, insights into the mechanisms by which the impact of digitalization on upgrading and CE strategy in GVCs remain limited and fragmented. For example, evidence suggests that the product-service systems (lease and sharing model) connect users and equipment to improve equipment utilization by implementing I4.0 technologies (Wang et al., 2020). Different studies have also highlighted their contribution to local job creation. However, there is limited research exploring the relationship between industrial

digital technologies and the design of CE (Fisher et al., 2020), support for remanufacturing and upgrading infrastructure (Kerin and Pham, 2019), supply chain design to achieve sustainable development goals and intelligent manufacturing (Ma et al., 2020). It appears that future research may benefit from the GVC perspective to underlying what I4.0 technologies could bring advantageous upgrading or implement CE practices at the design and development stages. Big data analytics can improve the design specification when there is little change in the design process (Fisher et al., 2020). Kerin and Pham (2019) provide evidence that organizations need to focus on business intelligence to adapt quickly to identify areas that need improvement and monitor business trends. A few studies address artificial intelligence and organizational structure and their influence on CE. The research gap arises because extant research is limited to understanding the degree of adoption of the technologies that support the I4.0 concept within the production process (Castelo-Branco et al., 2019).

Likewise, there is substantial evidence of big data analytics and data-driven insights (Ghasemaghaei and Calic, 2019), as data-driven insights are dependent on big data analytics. However, there is little research on how global integration of knowledge may moderate the relationship between organizational big data analytics capabilities and decision-making quality. Therefore, big data analytics and CE capabilities are additional directions for future research focused to drive sustainable manufacturing. This evidence provides support for big data analytics as intervening variables linking the application of data management capabilities and CE performance. Based on our literature review, it appears that big data analytics is a salient predictor of CE. However, prior research in this area has given less focus on its role in decision making for CE. While there exists substantial evidence on big data analytics and data-driven insights (Ghasemaghaei and Calic, 2019). Consequently, there is ample room for future research on the issues around the use of business intelligence and CE-driven value creation in GVCs and big data analytics and decision making in GVCs.

Furthermore, concerning the link between I4.0 and manufacturer operational performance, it may be fruitful to consider how I4.0 can exploit the production advantage while retaining the control over information exchange across partners and cultivate knowledge combination, specialized learning, and organizational CE strategy formulation across GVCs. Following Gereffi and Lee (2012), future research may benefit from recent economic crises shifting the market and regional value chain structure to create and capture value. In line with this inquiry, from the perspective of I4.0 and CE, manufacturers are concerned about whether they can maintain or gain the product and sales capabilities needed to develop low-cost and high-tech products. The future research stream can guide future researchers in understanding how local and global manufacturers can support the production efficiencies in GVCs.

Finally, there is a lack of consensus on whether CPS decentralization is necessary to implement production facilities. A relatively small number of studies examine the relationship between a centralized system for virtual production monitoring and product design initiatives through interactive dashboards and data from various sources. Centralization and cloud system are unavoidable components within I4.0. A possible future opportunity for the question of how firms may implement a cloud computing strategy for developing trust and collaboration for agility and lean manufacturing. Likewise, scholars can address the question of how cloud computing can reshape and promote CE initiatives in GVC. In this way, it is possible to contribute to achieving environmental and social sustainability goals in line with the United Nations Sustainable Development Goals by integrating sustainability through the lens of CE into GVC research (Awan and Sroufe, 2022).

5.3. Firm's network structure and location advantage

There is still much to be learned about how global production network places and locations led to creating value (Coe and Yeung,

2019). Beyond being embedded in their respective GVCs, firms are embedded in various business networks according to their activity domain, products, and geographical locations. Thus, their behaviors, including technology and business model adoption, are shaped by different networks and network structures within the networks. There is substantial evidence of a potential positive link between institutional policy and co-evolutionary learning and capability building within networks (Dallas, 2015). However, future researchers should explore how different markets and CSR-driven approaches could accelerate the social and economic upgrading of developing economy firms in GVCs (Gereffi and Lee, 2016). This line of inquiry provides evidence that there is another future avenue of research to examine firm-level infrastructure facilitating the upgrading of lower-level firms at the regional value stream activities. Therefore, a promising future research opportunity is to investigate how firms with less market power can apply competencies to upgrade their processes, products, and functions within their GVC networks (Pietrobelli and Rabellotti, 2011).

Indeed (Dachs et al., 2019) have argued that research on the digitalization control mechanism in the domain of GVC has evolved and changed power relationships in network structure. There is little research on how the manufacturing industry should transform from production upgrading and structure upgrading to achieve efficiencies at the product design and production assembly level in the GVC governance (Qu et al., 2020). According to Hannibal and Knight (2018). The global factor is likely to shift the centralized production system, and “the logistics function will tend to simplify as more consumables are produced in individual households and nearby facilities” (p.1127). Further, (Strange and Zucchella, 2017) provide an assessment of “how the widespread adoption of new digital technologies (i.e. the Internet of things, big data and analytics, robotic systems and additive manufacturing) might affect the location and organization of activities within global value chains”(p.174).

As evident from our review, the vast majority of the literature evidence suggests that I4.0 is a vital set of technologies that can be utilized to increase the circularity of material flow with minimizing waste through the adoption of superior design approaches for infrastructure up-gradation (Chiappetta Jabbour et al., 2020). Thus, another fruitful research avenue is to conduct quantitative studies that would examine the I4.0 and adoption of artificial intelligence interface in business-to-business marketing, focusing on individual managers or firms engaged in CE implementation. For example, it would be interesting to examine whether and how manufacturing firms overcome the challenges of implementing CE initiatives using artificial intelligence in network structure. A much-debated question is whether internalizing new capabilities and resources at distant locations is needed to successfully safeguard the existing and new capabilities in an international environment. This implies that the scholar must focus on the specific capabilities and resources needed to internalize and transfer to understand how cross-border firms or strategic alliances adapt to value-adding activities. Therefore, capacity building varies in frequency and consequences when adapting to value-adding activities. Promising future research regarding the distant crafting of CE strategy and capabilities could be to investigate how relocation and specific modes of governance affect the material efficiency and design of the product-service system.

5.4. Home and host environmental characteristics

Despite growing attention to the role of home and host environmental characteristics in GVCs, I4.0, and CE, the research remains focused on a cursory treatment of a limited set of environmental characteristics, such as complexity, uncertainty, and dynamism. Therefore, it requires further research on how overlooked home and host environmental characteristics influence I4.0 and CE in GVCs. What characterizes a global innovation system vis-à-vis home and host environmental characteristics has been insufficiently reflected in the transnational context (Pietrobelli and Rabellotti, 2011). There remains a research gap

in how collaboration affects the implementation of I4.0 technology to achieve efficiency and effectiveness in production and how home and host environmental characteristics shape this linkage.

There is also little research on how the manufacturing industry should transform from production upgrading and structure upgrading to achieve efficiencies at the product design and production assembly level in GVC governance (Qu et al., 2020). Researchers are encouraged to address the issue of how digitalization affects firm-specific production activities and alter the mode of information sharing and exchange to minimize waste, material efficiency, and better product and process design. There is still much to be learned about how GVC locations lead to value creation (Coe and Yeung, 2019). There have been few studies that explain the implementation of CE depends on policy incentives and regulatory decisions, financial gains over the supply chain through reduction of material cost (Field and Sroufe, 2007), and remanufacturing gaining interest among firms (Govindan and Hasanagic, 2018). However, relevant questions abound.

As it is evident in our review, there is a positive association between the home institutional environment and the implementation of CE initiatives. A company's ability to move away from a traditional business model can be demonstrated by developing production and management capacities and technical advancements (Awan and Sroufe, 2022). A transition to embedding a close-loop-supply model to customer end-of-life products and collection is also a major new frontier for CE (Awan and Sroufe, 2022). However, the questions of how institutional stakeholders play an essential role in planning decision-making, what interests are represented, and how they affect manufacturing enterprises remain unanswered. Evidence suggests that material collection, reuse, and recycling have not yet fully been implemented (EllenMacArthur Foundation, 2013). Since unsustainable consumption patterns pose a serious threat to the environment, challenges remain for firms to increase close-loop productivity and improve consumption efficiency. In this study, the viable system model (VSM) is used as a theoretical lens to establish a framework to assist enterprises or organizations in restructuring GVC activities in the interface of I4.0 and CE. VSM comprises several components centered on the system functioning and specifies the distinct positioning of theoretical contributions (Dominici and Palumbo, 2013). In our developed framework, the impact of digitalization on upgrading CE strategy (input) interacts with different firms embedded in networks and takes locational advantage (output). In this way, VSM characterizes the relationship between various firm digitization initiatives and accrued restructuring of networks. Specifically, the governance structure of I4.0 and home and host institution environment may directly increase or decrease the impact of digitalization of CE on the network structure. Fig. 2 shows the theoretical model.

6. Concluding remarks

This paper reviewed the literature about I4.0 and CE in relation to GVCs. Drawing on the GVC perspective, we expanded and identified various research streams. This systematic literature review reveals linkages between the I4.0 and CE literature streams and that GVC research remains underdeveloped as the GVC gained little importance in

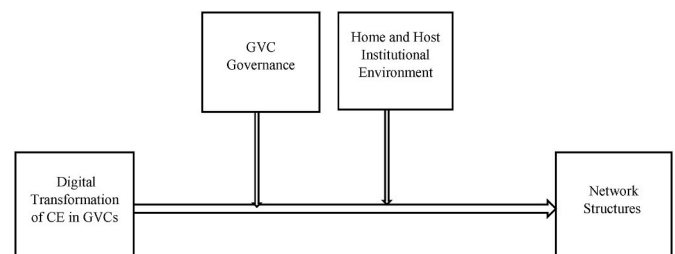


Fig. 2. Theoretical framework.

I4.0 and CE studies. Our findings are congruent with previously published studies, which recognize the importance of GVC research in generating a rich body of knowledge, mainly from a governance perspective in operations management, SCM, and international business.

Scholars have just started to pay attention to bringing I4.0 and CE to the fore of the GVC research, particularly as digital transformation and environmental issues sustainability gradually gain traction within the GVC literature. That is not to say that previous literature has not contributed to the development of the field. However, there is still a lack of research that considers the development of GVCs in operations management. We observe that much remains to be done in bringing both I4.0 and CE themes to the fore of GVCs. Connecting these research streams can lead to important, mutually beneficial insights into respective literature streams. We identified four areas that are central to the agenda for the future research, (1) GVC governance and I4.0, (2) the impact of digitalization on upgrading and CE strategy in GVCs, (3) embedded firms in networks, network structure, and location advantage, and (4) home and host environmental characteristics.

Though we have discussed the vast body of literature on GVCs, this study has some notable limitations. Our data includes peer-review articles from Scopus and the Web of Science database only, thus demonstrating comprehensive coverage. However, because we followed strict inclusion and exclusion criteria, our review does not include book reviews, working papers, and conference proceedings, which has some inbuilt limitations. Second, we acknowledge the decision to undertake a literature review from a business management perspective. We expect that this could have an advantage to the scholarly debate on the topic of GVC.

This systematic literature review draws attention to the important factors in transforming the GVC from production and structural link upgradation and seizes the opportunity to implement CE initiatives in GVC. Our study makes managers and policymakers aware of the clarity of having linkages between CE and GVC. Managers and other network actors need enhanced training in becoming aware of the importance of this growing area and are looking for new ways to improve competitive production capacities, improve human capital, and implement institutional policies by increasing digitalization.

CRediT authorship contribution statement

Usama Awan: Conceptualization, Methodology, Writing – original draft, Writing – review & editing. **Ismail Gölgeci:** Writing – original draft, Project administration, Writing – review & editing. **Dilshod Makhmadshoev:** Writing – review & editing. **Nishikant Mishra:** Supervision.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Appendix A. Supplementary data

Supplementary data to this article can be found online at <https://doi.org/10.1016/j.jclepro.2022.133621>.

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