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Early evidence on how Industry 4.0 reshapes MNEs' global value chains: The role of value creation versus value capturing by headquarters and foreign subsidiaries

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Abstract
In anticipation of the upcoming changes and turbulence caused by Industry 4.0, in which digital integration connects all value chain members, managers at leading multinational enterprises (MNEs) are scrambling to predict the associated changes in the market. This pioneering study advances our understanding by investigating the impact of an MNE's Industry 4.0 orientation on the globalization of its value chain network. Identifying two types of value-generation activities as potential moderators, namely value creation and value capturing, we compare the moderation effects when these activities are conducted by headquarters versus foreign subsidiaries. We test the proposed model using a panel dataset comprising 5572 subsidiary-year observations from 358 Korean MNEs from 2011 to 2019. The results show that an MNE's Industry 4.0 orientation leads to a more rapid expansion of its distribution network than of its supplier network. Furthermore, value creation by headquarters has a stronger positive impact on the globalization of its distribution network than that of its supplier network, whereas value creation by subsidiaries has a stronger positive impact on the globalization of its supplier network than that of its distribution network. However, value capturing has a stronger impact on the globalization of the MNE's distribution network than that of its supplier network when performed by both locations. This study concludes by discussing the theoretical and managerial implications.
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INTRODUCTION

The term "globalization" has been drawing attention in the literature for decades. However, many industry experts predict that true globalization is yet to be realized in the form of revolutionary moves of industries through integrating multiple processes and systems among value chain members across countries, enabling them to exchange information in real-time by combining all value chain members (Hofmann & Rüsch, 2017; Lee, Kao, & Yang, 2014). Riding the trend, the term "Industry 4.0" is piquing the interest of researchers, managers, and policymakers and is expected to trigger a series of radical innovations in the production and distribution of goods and services, leading to global disruptions across sectors (Lasi, Fettke, Kemper, Feld, & Hoffmann, 2014). Business leaders at the forefront of industrial innovations are consequently emphasizing the importance of staying ahead of the competition to pre-occupy the transformed market that will emerge from Industry 4.0.

Given the scale of the market and the investments required, Industry 4.0 firm activities are typically carried out at the global market level to justify the associated R&D costs and synergistic benefits from the various technologies emerging across countries. Indeed, the markets of most countries are too small to justify the costs and effort, and thus, Industry 4.0 initiatives usually demand a firm's attention at the global level. Supporting this, Luo (2022: 354) asserts that "[d]igitization symbolizes the fourth industrial revolution. While digital connectivity may vary across countries ... To a large extent, digital connections are country (or location) agnostic … allows companies to market their digitally-enabled products and services globally with ease."

In the face of macro-level industrial changes coupled with digital connectivity at the global level, one of the most important decisions for firms with Industry 4.0 orientation is its membership in a technology group and value chain (Hofmann & Rüsch, 2017), as the synergetic benefits from Industry 4.0 largely depend on the structure of technological leadership in industrial networks embedded in the global value chain (Götz & Jankowska, 2017). While the outcomes of smart factories, the Internet of Things (IoT), connected communications, artificial intelligence, machine learning, and big data are still evolving, the outcomes of Industry 4.0 hinge on global coordination among global value chain (GVC) members and their contributions to forward-looking technological innovations. Furthermore, on the downstream side of the GVC, Industry 4.0 may lead to decentralization. Specifically, the key downstream characteristics of an Industry 4.0 value chain, network-connected production, and distribution, are likely to force global businesses to consider automated mass customization to remain close to customers, expediting decentralization in the downstream value chain of multinational enterprises (MNEs) and, thereby, expanding their presence in the global market (Bogers, Hadar, & Bilberg, 2016; Strange & Zucchella, 2017).

With the level of integration among the GVC participants required by Industry 4.0 according to its emerging technological needs, its influence on the global restructuring and expansion of the supply chain or distribution network is inevitable (Götz & Jankowska, 2017). Even so, the impact of a firm's orientation toward Industry 4.0 on the restructuring of its GVC as an associated outcome has remained largely unexplored in the literature, with only a few works examining Industry 4.0 as a firm's new orientation. Most of these works are exploratory and limited in scope. For instance, the literature explores the adoption (Müller, Kiel, & Voigt, 2018) and potential application models of Industry 4.0 (Hofmann & Rüsch, 2017; Wilkesmann & Wilkesmann, 2018), and its resulting market strategies and growth opportunities (Baldassarre, Ricciardi, & Campo, 2017; Strange & Zucchella, 2017). However, even these aspects are explored only conceptually, lacking empirical verifications.

Given the anticipated impacts of a firm's Industry 4.0 orientation, this study explores Industry 4.0 as a firm's orientation and the resulting outcomes in its GVC, including those concerning the restructuring of its global supply chain and distribution network. In doing so, we seek the following four important contributions, filling the research gap in the literature. First, we investigate the potential benefits of Industry 4.0 for MNEs through the lens of resource dependence theory (RDT) by exploring how the network connectedness facilitated by Industry 4.0 among global value chain members impacts the globalization of its upstream (supplier network) and downstream (distribution network) value chain activities at the subsidiary level. Specifically, we contend that an MNE with a strong Industry 4.0 orientation will experience increased sales and purchase intensities within its GVC due to enhanced interfirm connectivity and business opportunities as well as the chance to specialize in its core activities while outsourcing activities with a low profit margin to its GVC partners. With its results, this pioneering empirical study identifies early evidence of the benefits of an MNE's Industry 4.0 orientation regarding various types of performance-related efficiencies, namely market expansion, value-adding position, and enhanced opportunities for in-house production.

Second, we further expect the impact to be stronger on sales intensity than purchase intensity. An MNE with a stronger Industry 4.0 orientation possesses fundamental and widely applicable knowledge resources that will make it more attractive to other partners in the GVC, increasing their dependence on it. This will allow the MNE to secure a technological leadership role and occupy a more advantageous and profitable position within the GVC, reducing the relative weight of purchases from suppliers in the final goods or services sold, given the sales amount. Furthermore, Industry 4.0 facilitates broader opportunities for in-house production, potentially instigating the disintermediation of supply chains, and allowing an MNE to reduce its dependence on suppliers by performing certain activities hitherto undertaken by external service providers. Thus Industry 4.0 orientation helps its subsidiaries increase their sales intensity to a greater extent than their purchase intensity.

Third, our comparison of the value-creation and value-capturing efforts of an MNE's headquarters and its foreign subsidiaries has implications for the allocation of organizational resources. The interactions between these distinct strategies and an MNE's Industry 4.0 orientation are expected to impact network globalization, with the results helping managers make informed decisions on organizational structure and resource allocation (Dellestrand, Kappen, & Lindahl, 2020).

Finally, this study makes important methodological contributions, too. Most notably, we conduct the first empirical test of a theoretical framework on the impacts of Industry 4.0 orientation, in contrast to the exploratory nature of relevant prior studies. In addition, we measure a firm's Industry 4.0 orientation by its "actions" rather than its "intentions" toward Industry 4.0 inputs. Given the scarcity of publicly available data, we believe that Industry 4.0 orientation is a useful measure of a firm's actions on Industry 4.0 and accurately reflects its strategic direction. This study is organized as follows. The next section introduces our theoretical framework, reviews the literature on the Industry 4.0 phenomenon, and lays out the hypotheses. Then, we describe our methods and explain the data sources and analytical details. Finally, we discuss the results and offer implications for scholars and managers.

THEORETICAL FRAMEWORK AND HYPOTHESIS DEVELOPMENT

Industry 4.0 and Global Value Chains

Industry 4.0 is an industrial macro-trend (Reischauer, 2018) related to the emergence and diffusion of a range of radical digital technologies. More specifically, Industry 4.0 consists of network-connected intelligent systems (Kovács & Kot, 2016) that heavily depend on digital transformation – requiring both products and processes to be "smart" and industry partners to be integrated. It also necessitates a rearrangement of the dynamics among MNEs and their GVC partners, vendors, and distributors (Luo, 2021). While Industry 3.0 relied on individual firms' computer systems, factory automation, and digitalization, Industry 4.0 pursues autonomous decision-making (e.g., cyber-physical systems) by interconnecting the entire value chain and signaling a fundamental paradigm shift from Industry 3.0 (Yin, Stecke, & Li, 2018).

The key advantage in the Industry 4.0 era lies in the synergies created by a group of value chain members with a technology leader in the coordinating position (Götz & Jankowska, 2017). Firms must hereby strategically choose their membership in a specific technology group or value chain (Hofmann & Rüsch, 2017). However, given that Industry 4.0 is a relatively recent phenomenon, scholarly research on its impact on firms and their global presence has thus far remained limited. Most extant studies explore how an Industry 4.0 orientation may confer a general advantage by unlocking opportunities and reducing transaction costs for firms across the GVC (Brun, Gereffi, & Zhan, 2019; Williamson, 1975, 1985). While both upstream and downstream activities of a firm can leverage the benefits Industry 4.0 offers, our understanding of the actual mechanisms through which Industry 4.0 is restructuring value chain activities and the associated opportunities, remains limited. Filling the void in the literature, our study offers a conceptual model of the effects of an MNE's Industry 4.0 orientation on its GVC reconfiguration.

Industry 4.0 Orientation of MNEs: New Market Creation Within and Across GVCs

We define an MNE's Industry 4.0 orientation as actions to develop radical innovations or core technologies that use network-connected industrial integrations aimed at improving the efficiency of its business activities. This study explores the impact of Industry 4.0 orientation using RDT (Pfeffer & Salancik, 1978), which posits that firms with unique resources can exert power over exchange partners that have come to depend on these unique resources (Kreiser & Marino, 2002; Ulrich & Barney, 1984). We begin by asserting that an MNE with a strong Industry 4.0 orientation is more likely to create various new market opportunities that help its subsidiaries boost sales- and purchase-related activities within the GVC.

An MNE with a strong Industry 4.0 orientation proactively makes intentional changes, rather than simple as-needed adjustments, enabling it to gain a competitive edge in the market (Hughes & Morgan, 2007). An MNE that embraces Industry 4.0 is likely to elevate its commitment, strategic decision-making, and innovation, leading to enhanced business performance (Eisenhardt, 1989; Hughes & Morgan, 2007) and technological leadership in the development of products, services, and processes (Han, Kim, & Srivastava, 1998; Hult & Ketchen, 2001). Therefore, a strong Industry 4.0 orientation allows an MNE to pursue new business opportunities in both new and existing markets.

More importantly, a strong Industry 4.0 orientation enables the MNE to expand its market more efficiently through increased interfirm connectivity. A firm with a highly connected digital architecture incurs low costs for both external information searches (Autio, Mudambi, & Yoo, 2021) and internal coordination (Cantwell, 2009; Luo, 2021). For instance, Uber can expand its market more efficiently than its traditional competitors because its core technology is more easily adapted to other countries. Through the early adoption of digitalization and new technologies, a strong Industry 4.0 orientation may enable an MNE to seize new market opportunities (Kache & Seuring, 2017), explore new possibilities, and exploit market intelligence through technological leadership, ultimately improving its market expansion efficiency (Han et al., 1998; Hult & Ketchen, 2001). In addition, as consumers increasingly favor digital channels (Ghauri, Strange, & Cooke, 2021), digitalization can increase the global customer reach (Luo, 2021) and improve product launching and marketing efficiency. Similarly, MNEs can exploit social media to expose their products to countless potential consumers, even in remote markets.

While capturing various new business opportunities across markets, MNEs with a strong Industry 4.0 orientation can lead the design of new business models because they can control the information needed to pave frictionless paths to new markets (Sturgeon, 2021), which is likely to increase sales and purchase intensities within the GVC. These MNEs can not only improve their services to existing customers but also create new customer pools based on converging knowledge and business models (e.g., Uber may attract riders who previously used only public transportation; Airbnb may appeal to guests who previously traveled infrequently due to accommodation-related restrictions). In addition, the increased modularity across GVCs may reduce contractual and operational friction (Luo, 2021), consequently reducing the cost of market expansion (e.g., Apple and Google aim to launch electronic vehicles without making substantial investments in manufacturing facilities).

According to RDT, firms facing market turbulence often strive to achieve stability by employing adaptive strategies such as engaging in coalition activities (Pfeffer & Salancik, 1978) and establishing or strengthening relationships with influential exchange partners in the value chain (Provan, Beyer, & Kruytbosch, 1980). In fact, platforms help firms derive power from network effects as the platform's utility increases with the growing number of participants (Kenney & Zysman, 2016). Platforms such as Amazon's offline grocery service or Tesla's self-driving vehicle system rely heavily on Industry 4.0 features, including the IoT, cloud computing, big data analytics, and artificial intelligence, all of which increase modularity and scalability (Sturgeon, 2021). As a result, network effects grow exponentially, potentially resulting in oligopolistic "winner-take-most" markets (Cuypers, Hennart, Silverman, & Ertug, 2021; Sturgeon, 2021). As only few firms become increasingly dominant, other value chain members voluntarily adopt the new business model (Soh, 2010), which facilitates the dominant firm's market expansion (e.g., the expansion of Google's Android-based app market), leading to improved sales and purchase intensities within the GVC.

Industry 4.0 can, therefore, positively influence an MNE's ability to efficiently expand its market through the GVC. Thus, we expect an MNE's stronger Industry 4.0 orientation to increase its subsidiary's sales intensity within the GVC (Knight & Kim, 2009) as the increased interfirm connectivity and greater reach will promote new business and wealth-creation opportunities. Furthermore, we also expect an MNE's stronger Industry 4.0

orientation to increase its subsidiary's purchase intensity within the GVC as, due to market expansion efficiency, the firm can further specialize in its core activities and outsource activities with smaller profit margins to GVC partners. Hence, we propose the following hypotheses.

Hypothesis 1a: An MNE's Industry 4.0 orientation *positively* impacts its subsidiary's sales intensity within the GVC.

Hypothesis 1b: An MNE's Industry 4.0 orientation *positively* impacts its subsidiary's purchase intensity within the GVC.

MNE Industry 4.0 Orientation and New Appropriation Regimes in GVCs

Although we expect the impact of Industry 4.0 to be positive on both subsidiary's sales and purchase intensities within the GVC, we argue that the impact is likely to be stronger on the former. A strong Industry 4.0 orientation offers an MNE considerable power and fundamental and widely applicable knowledge resources; these, in turn, enable the MNE to reconfigure positions and roles within/across the GVC to improve its appropriation regimes, thereby reaping higher returns from knowledge resources. We further argue that this improvement in appropriation regimes can involve two types of performance-related efficiencies: a value-adding position and enhanced opportunities for in-house production.

First, regarding the value-adding position, an MNE with a stronger Industry 4.0 orientation can hold a more central and advantageous position in the value chain architecture (Gulati & Singh, 1998). As Industry 4.0 encompasses the unprecedented convergence of multiple radical innovations across industries and technological domains (Sung, 2018), it is likely to introduce disruption and uncertainty into existing value-adding systems. During the transition period, the existing standards for products and production/distribution processes will be either disrupted or challenged (Oh & Rhee, 2008), and strong platform leaders will come to dominate these newly emerging standards (Sturgeon, 2021). According to the RDT perspective, an MNE that owns unique and core knowledge resources is likely to have a power advantage in its interfirm relationships (Xiao, Petkova, Molleman, & van der Vaart, 2019), allowing it to capture the most substantial share of the value created within its GVC (Autio et al., 2021; Mudambi, 2008).

Building on this perspective, we argue that MNEs with a stronger Industry 4.0 orientation are more likely to gain foundational and widely applicable knowledge on products and services, such as standardized hardware systems and the software environment in the GVC. Hence, they are likely to become core leaders, occupying more advantageous and profitable positions. They also gain architectural control over collaboration networks (Autio & Thomas, 2014; Teece, 2007), enable other firms to pursue complementary innovations (Gawer & Cusumano, 2014), and alleviate the pressure from environmental uncertainty by solving major industrial challenges (Adner & Kapoor, 2010). For example, because Amazon has access to profit-related data, it can appropriate economic rent from sellers on its platform by replacing their products with Amazon's own products (Cuypers et al., 2021; Zhu & Liu, 2018). Uber has gained more power and control than typical franchisors because Uber monitors its drivers via navigation systems, prevents them from cheating riders through smart payment systems, and avoids the need for physical inspections by using in-car cameras. The advantageous position stemming from technological leadership and architectural control in the industry is expected to help MNEs with a strong Industry 4.0 orientation capture a disproportionate share of the value created within their GVCs. Furthermore, this enhanced value creation implies that MNEs with a strong Industry 4.0 orientation will rely less on purchases from GVC suppliers given their sales level. In sum, an MNE with a strong Industry 4.0 orientation helps gain a central, advantageous position, and increased connectivity. As a result of these enhanced value-adding activities, the relative weight of purchases from suppliers in the final goods or services sold will be lower given the sales amount. In other words, the improved efficiency in the value-adding process enables an MNE to generate more sales given the quantum of purchases from external suppliers (Cantwell, 2009).

Second, the literature has also highlighted key advantages related to the enhanced opportunities for in-house production stemming from firm digitalization (Ancarani, Di Mauro, & Mascali, 2019). Thus, a higher degree of digitalization as a consequence of Industry 4.0 orientation is expected to lead to the disintermediation of supply chains, allowing an MNE to reduce its dependence on various suppliers by performing certain activities previously conducted by external service providers. As Brun et al., (2019: 47) note, "digitization can change the firm's decision from 'buy' to 'make' resulting in shorter supply chains." In fact, one of the main benefits of digitalization in GVCs is the expected increase in productivity due to the automation of production and the substitution of labor with capital (or the readjusting of the activities performed by labor), making in-house production more viable (Ancarani, Mauro Di, & Mascali, 2019).

In the same vein, digitalization is enabling increased servicification, which allows the conversion of capital expenditure on equipment into operational expenditure (Baur & Wee, 2015; Porter & Heppelmann, 2014). By doing so, firms may explore the practice of flexible manufacturing without owning the production equipment, relying instead on "pay-by-use" or subscription models with equipment manufacturers who own and maintain the equipment (Brun et al., 2019). Finally, Industry 4.0 can also make the role of certain suppliers more redundant as it opens the door to manufacturing in smart factories that rely on efficient networks wherein resources and products are registered, tracked, and located immediately. This could reduce coordination costs and allow firms to save on warehouse costs (Deloitte, 2015). Thus, although Industry 4.0 may increase an MNE's dependence on specific providers critical to the functioning of these smart factories, its dependence on various traditional suppliers is likely to reduce significantly. This is particularly the case with certain components that become critical or sensitive with an MNE's emphasis on Industry 4.0 and, consequently, the need to be manufactured in-house as a part of efforts to reduce its dependence on existing suppliers. For example, in September 2020, Tesla announced its plan to produce its own batteries, thereby potentially reducing the cost of its electric vehicles significantly. Before this announcement, Tesla relied on manufacturing partners like LG and Panasonic.[1]

In sum, while the benefits of Industry 4.0 described in H1a and H1b apply to both sales and purchase intensities, we expect the overall impact on purchases to be offset by the additional advantages in manufacturing. Thus, we argue that a strong Industry 4.0 orientation enables MNEs to gain more power over their customers while reducing their dependence on suppliers, helping their subsidiaries increase their sales intensity more than their purchase intensity. This leads to a stronger effect on the subsidiary's sales intensity than on its purchase intensity:

Hypothesis 1c: An MNE's Industry 4.0 orientation has a *stronger positive* impact on its subsidiary's sales intensity within the GVC *than* on its subsidiary's purchase intensity within the GVC.

Value Creation and Value Capturing in the Global Value Chain

The notions of exploration and exploitation in the seminal work of March (1991) have been widely applied to explicate a firm's strategic activities in the value chain (Lavie & Rosenkopf, 2006; Lepak, Smith, & Taylor, 2007; Mizik, & Jacobson, 2003; Rothaermel & Deeds, 2004). As Lepak et al., (2007: 192) explain, "March (1991) has suggested that there is a need for scholars to understand the relationship between the exploration of new ideas, which connects well with value creation, and the exploitation of ideas, which connects with value capture." That is, explorational activities (e.g., R&D) are conducive to value creation, while exploitative activities (e.g., marketing) are conducive to value capturing. As a result, the concepts of value creation and value capturing have also been applied to the study of innovations among MNEs (e.g., Cantwell & Mudambi, 2011). Building on these insights from the literature, we define value creation as an MNE's efforts to develop innovative knowledge for the GVC, and value capturing as the MNE's efforts to maximize the value from the knowledge produced in the GVC.

Moderating Roles of Value Creation by Headquarters and Subsidiaries

The innovation process relies on the combination of basic research and applied research. Basic research seeks core knowledge (Cassiman, Perez-Castrillo, & Veugelers, 2002) which is a primary contributor to the essential quality of technological resources (Henard & McFadyen, 2005) and increases the radical nature of an MNE's innovation capability (Makri & Lane, 2007). Accordingly, basic research can strengthen the MNE's potential influence on its business networks and industries. However, developing core knowledge requires a firm to persist with investments under highly uncertain conditions and ensure effective knowledge accumulation (Henafrd & McFadyen, 2005). Supporting this, the literature from various domains, including strategy, international business (IB), and innovation, has argued that R&D centered at the corporate headquarters is more efficient for conducting basic research because it can minimize the internal transaction costs across multiple R&D units (Argyres & Silverman, 2004) and effectively protect core knowledge (Gassmann & von Zedtwitz, 1999). In a similar vein, Awate, Larsen and Mudambi (2015: 64) argue that "the root technology is created in the home country – often at a central R&D unit co-located with headquarters – and the foreign subsidiary mainly exploits its parents' competencies." Given that Industry 4.0 involves concurrently managing new technologies from diverse domains, efficient and well-protected R&D activities are critical to securing an advantageous position in the market. This is especially true as core knowledge of Industry 4.0 is often a key national interest of many governments and is associated with institutional regulations across countries.

When MNEs prioritize technological leadership, as occurs with a strong Industry 4.0 orientation, their headquarters tend to focus on developing core technologies that are more widely applicable and radically advanced (Argyres & Silverman, 2004; Novelli, 2010). Therefore, the core technologies of Industry 4.0 (e.g., cloud computing and big data) can be viewed as "upstream technologies" that can facilitate the advancement of many other associated applications (Maine & Garnsey, 2006). Especially as Industry 4.0 involves the convergence of various emerging technologies, high-quality basic research is a key knowledge resource for attracting potential users and value chain partners. As RDT emphasizes, firms that are attractive in this regard are expected to gain power in interfirm relationships and mitigate external risks (Xiao et al., 2019) such as technological uncertainty. That is, the influential technological resources derived from strong basic research (e.g., computer science), coupled with core technologies of Industry 4.0, will enable the firm to hold a superior position and gain more power over competitors in the market. In turn, greater power in interfirm relationships and partners' increased dependence will help strengthen the positive influence of a value-adding position and market expansion on sales intensity within the GVC.

On the other hand, while these core technologies from value creation can also strengthen the positive effect of market expansion on the purchase-related side, as explained in the previous section, these activities may concurrently suffer from the offset effect caused by the enhanced opportunities for in-house production. As the increased need to protect the core technologies emanating from the firm's value-creation efforts advocates in-house production (Beneito, 2006; Gil, Bong, & Lee, 2003), we expect the positive moderating impact on purchases to be attenuated. Hence, we propose that:

> **Hypothesis 2a:** Value creation at the MNE's headquarters has a *stronger positive* moderating impact on the relationship between the MNE's Industry 4.0 orientation and its subsidiary's sales intensity within the GVC *than* on the relationship between the MNE's Industry 4.0 orientation and its subsidiary's purchase intensity within the GVC.

While headquarter-level basic research tends to focus on core technologies, subsidiary-level applied research is more likely to capitalize on such core technologies in the form of product- or process-related knowledge to serve the needs of local or regional markets (Awate et al., 2015; Glass, 2003) rather than to seek acceptance in the global market. An MNE's knowledge resources lead to the dependence of others in the value chain, to the extent that these resources are marketable and, thus, attractive. Core technologies foster the development of complementary technologies customized for products and services in diverse countries and markets (Youtie, Iacopetta, & Graham, 2008). Often, the foreign subsidiaries of an MNE are responsible for rendering finished products (Figueiredo, 2011; Ryan, Giblin, Andersson, & Clancy, 2018; Yamin & Otto, 2004), which they can accomplish by forming their own networks with local partners (Yamin & Otto, 2004) and developing local or regional standards for their products (Figueiredo, 2011). Therefore, subsidiary-level applied research provides the focal subsidiary with the knowledge to create new collaboration opportunities with local partners, leading to an increase in the subsidiary's sales and purchases in the GVC.

However, while applied research may positively strengthen the impact of Industry 4.0 on both the sales and purchase sides through local network expansion, the sales side may concomitantly suffer from an offset effect due to poor global applicability (Gassmann & von Zedtwitz, 1999). Thus, as locally applied research tends to need more localized product adaption, especially compared to the headquarters' research outputs, which have a more global orientation, subsidiaries probably need to explore locally optimized alternatives and engage in more purchase activities from local providers to meet localized expectations (Birkinshaw, 1997; Delany, 2000; Un & Rodríguez, 2018). In contrast, the positive effect on the increase of sales in the host country will be, at least to some degree, offset by the reduced sales abroad due to lower global applicability. We argue that while foreign subsidiaries with high levels of value creation increase the applicability of core technologies by adapting to local markets, the overall global attractiveness of the subsidiaries within the GVC may decrease because these adaptations have poor global applicability. That is, given the same level of inputs, the products that result from subsidiaries' value-creation efforts may not be adopted on as large a scale as the products of headquarters' value-creation efforts, reducing the efficiency of the MNE's value-adding activities. For instance, in 2013, Apple launched the iPhone 5C, which was customized for the low-end market segment, primarily the Chinese market.[2] This adapted product required the subsidiaries in China to conduct additional R&D and purchase materials and components specifically for this model, resulting in a relatively lower adoption rate worldwide, relative to the incremental investment.

In sum, the subsidiaries of an MNE with a strong Industry 4.0 orientation often conduct applied research focusing on local specificity rather than basic research, which tends to be less applicable to other partners in the GVC. Thus, subsidiaries' value creation is less effective than headquarters' value creation at strengthening the positive impact on the attractiveness of the MNE within the GVC, reducing the participation and dependence of other partners. In fact, subsidiaries that pursue applied research might sometimes become *more* dependent on (at least some of) their providers because the inputs are less likely to be offered by multiple suppliers. Hence, we propose that:

Hypothesis 2b: Value creation by an MNE's subsidiary has a *stronger positive* moderating impact on the relationship between the MNE's Industry 4.0 orientation and its subsidiary's purchase intensity within the GVC *than* on the relationship between the MNE's Industry 4.0 orientation and its subsidiary's sales intensity within the GVC.

Moderating Roles of Value Capturing by Headquarters and Subsidiaries

Value capturing in the marketplace is closely related to market-oriented activities for commercializing innovations (Mizik & Jacobson, 2003), which can enhance a firm's competitive position by exploiting new technologies (Rothaermel, 2001) and preventing new entrants (Shane, 2001). If a firm cannot fully capture newly created value, it loses the advantages of proactive, albeit risky, investment in innovations. Hence, the importance of value capturing has been well addressed in various literature domains (Dutta, Narasimhan, & Rajiv, 1999; Nelson, 2006; Ofek & Sarvary, 2003; Swaminathan, Murshed, & Hulland, 2008; Teece, 1986).

The potential of core technologies in the market primarily relies on the subsequent development of complementary innovations, which in turn requires compatibility with external partners' knowledge. An MNE's value-capturing efforts are typically designed to enhance its technology's compatibility by increasing the likelihood of matching the key features of its core technologies and market opportunities with those of potential partners and customers (Maine & Garnsey, 2006). Considering that Industry 4.0 comes with uncertainties about the convergence of new technologies, an MNE can secure more compatible partners in its distribution network by putting more effort into value-capturing activities (Iansiti & Levien, 2004), which will help local partners stably and efficiently link their knowledge assets to emerging upstream knowledge. As value capturing with advanced IT enables firms to create interactive, personalized, and addressable environments (Kalaignanam, Kushwaha, & Varadarajan, 2008), MNEs that pursue significant value-capturing efforts with a strong Industry 4.0 orientation can create a high degree of compatibility that is unique and valuable resources, increasing the dependence of value chain members. For example, KaKao, the third-most valuable company in Korea after Samsung Electronics and SK Hynix, has smoothly expanded its business operations to the taxi, bank, food delivery, and gift markets with numerous external partners thanks to not only social media service (SNS) technologies but also its accumulated market intelligence. Furthermore, the increased power and industry position associated with a core technology allows an MNE to design a more profitable business model. For instance, in 2020, Google enforced a 30% commission on in-app purchases without making additional investments in its Android platform – a platform it initially provided to offer highly compatible (even open) core technologies that reduced the risks for external partners.

While compatibility is the key element to creating an ecosystem in new business areas, RDT expects that an MNE will become more attractive and derive more power through the compatibility obtained from value-capturing activities (Kreiser & Marino, 2002; Ulrich & Barney, 1984). RDT further notes that customers who recognize the power of an MNE as a resource owner tend to become more dependent on that MNE network (Pfeffer & Salancik, 1978). In other words, value-capturing activities, as a means to communicate an MNE's Industry 4.0 orientation to the market, help reinforce the advantages of the central position within the GVC, strengthening the positive effect of a value-adding position on sales intensity within the GVC. Such benefits of increased power and partner dependence associated with a high Industry 4.0 orientation are less prominent in an MNE's purchase activities, as an MNE with a strong value-capturing capability will focus on leveraging its market intelligence to efficiently and globally increase rents. For instance, based on its recommendation system, which efficiently captures the diverse interests of customers across countries, Amazon achieved a 29% sales increase during its second fiscal quarter in 2015[3] and also launched new Amazon global stores through cooperation with local partners.[4]

Hypothesis 3a: Value capturing by an MNE's headquarters has a *stronger positive* moderating impact on the relationship between the MNE's Industry 4.0 orientation and its subsidiary's sales intensity within the GVC *than* on the relationship between the MNE's Industry 4.0 orientation and its subsidiary's purchase intensity within the GVC.

Hypothesis 3b: Value capturing by an MNE's subsidiaries has a *stronger positive* moderating impact on the relationship between the MNE's Industry 4.0 orientation and its subsidiary's sales intensity within the GVC *than* on the relationship between the MNE's Industry 4.0 orientation and its subsidiary's purchase intensity within the GVC.

METHODS

Research Context

In the present study, we focus on Industry 4.0 and the GVCs of South Korean (hereafter, Korean) MNEs for three reasons. First, Korea is one of the leaders in country-level innovation, making Industry 4.0 particularly salient among Korean MNEs. The Korean government and presidential committee of Industry 4.0 have prioritized the preparedness and competitiveness of Korea's Industry 4.0 efforts. Furthermore, Korea's leading information and communication technology companies, such as Samsung, LG, and SK, have made huge investments in Industry 4.0 capabilities. These efforts are reflected in some notable rankings: Korea ranked first on the Bloomberg Global Innovation Index in 2019 and 2021, second for R&D intensity and value-added manufacturing, and fourth for high-tech density. In 2019, Korea tied with Japan for third place in the world's high-tech rankings (including Industry 4.0) compiled by *The* Nikkei (2020), the holding company of *The Financial Times*.

Second, Korean MNEs have extensive experience with subsidiary-level sales and purchases within their GVC networks "due to their accumulated age and diverse foreign direct investments (FDIs) across all realms of the globe" (Lee, Jiménez, Yang, & Song, 2020: 451). Historically, Korean MNEs have concentrated on the advantages offered by both internal value chains and GVCs, yet their organizational strategies have recently expanded to include external suppliers and customers within their GVC networks.[5] Thus, Korean MNEs leverage tangible and intangible resources through both domestic and foreign suppliers and customers to obtain "upgraded technological and process management skills," "distinctive capabilities," and "internationalization knowledge" (Lee et al., 2020: 452).

Finally, in 2019, Korea's FDI outflow of USD 36 billion was the 9th largest in the world, according to the World Investment Report 2020 by the United Nations Conference on Trade and Development (UNCTAD, 2020). All of the above suggest that Korea is an ideal country for the study of Industry 4.0 and its impact on MNEs' globalization.

Data and Sample

We tested our hypotheses using a dataset of 5572 foreign subsidiary-year observations from 358 Korean MNEs[6] publicly listed on the Korea Stock Exchange from 2011 to 2019. We collected the longitudinal panel data from multiple sources, including the Korean Ministry of Economy and Finance databases, the Data Analysis, Retrieval, and Transfer (DART) system provided by the Korean

Financial Supervisory Service (KFSS), the Korea Listed Companies Association, KISVALUE, and FnGuide. We also collected longitudinal Korean patent data from the KIPRIS database and longitudinal MNE-level corporate governance score data from the Thomson Reuters ASSET4 database. Finally, we collected supplementary information on foreign subsidiaries from each MNE's homepage, LEXIS/NEXIS, and the corporate information provided by the *Chosun Ilbo* newspaper company.

Main Variables

Dependent variables

Our dependent variables are (1) *subsidiary sales intensity within the GVC* and (2) *subsidiary purchase intensity within the GVC*. We measured the subsidiary's sales intensity as the percentage of a specific subsidiary's external sales outside its MNE (including external sales to home-country, here Korea, host-country, and third-country customer firms) in a particular year to the total sales (interfirm plus intrafirm sales) of the subsidiary in the same year. We measured the subsidiary's purchase intensity as the percentage of a specific subsidiary's external purchases outside its MNE (including external purchases from home-country, host-country, and third-country suppliers) in a particular year to the total purchases (interfirm plus intrafirm purchases) of the subsidiary in the same year. Both variables range from 0 to 100. Although the Economics literature has used country- or industry-level GVC measures (e.g., Wang, Wei, Yu, & Zhu, 2017) or *indirect* exporting firm-level measures (e.g., the ratio of foreign value added to total exports; Lu, Shi, Luo, & Liu, 2018), to the best of our knowledge, this is the first study to use such a fine-grained measurement of foreign-subsidiary-level GVC intensity in the international business (IB) and any other relevant literature.

Independent and moderating variables

Industry 4.0 orientation. Our independent variable, *Industry 4.0 orientation*, is measured annually at the MNE level as an MNE's actions. Although Industry 4.0 orientation can be quantified by surveying senior managers, such measures often lack applicability and generalizability outside their respective contexts. Moreover, not all participants may subscribe to the same conceptual definition of Industry 4.0 orientation. We addressed these concerns by conducting a content analysis of annual reports. We chose this method because it (1) is applicable across a broad range of industries, (2) covers a large number of MNEs across relatively long periods, and (3) encompasses a diverse scope of MNE actions.

We based the operational definition of Industry 4.0 on reports from three sources: (1) the World Economic Forum (*The Global Risks Report 2017 12th Edition*),[7] (2) the National Intelligence Council (*Global Trend 2030 report*),[8] and (3) the McKinsey Global Institute report (*Disruptive technologies: Advances that will transform life, business, and the global economy*).[9] We extracted quotes pertaining to the conceptual constructs/sub-dimensions of Industry 4.0, namely "Industry 4.0, the Fourth (4th) Industrial Revolution (4IR), digital transformation, Cyber-Physical Systems (CPS), smart factory, 3D printing, artificial intelligence (AI), next-generation genomics, robotics, blockchain, the Internet of Things (IoT), Virtual Reality (VR), Augmented Reality (AR), cloud computing, big data, self-driving/autonomous driving, and next-generation nanotechnology." Note that this operationalization of Industry 4.0 orientation is based on an MNE's *actions* rather than its *intentions,* as the latter have different conceptualizations and repercussions. Industry 4.0 orientation as actions signals that an MNE has already committed resources/actions to developing Industry 4.0 technology and applications, whereas Industry 4.0 orientation as intentions refers to Industry 4.0 as something that an MNE needs/plans to do, likely due to a shortfall relative to aspirations.[10]

This study relied on the human-based open-language coding method to assess an MNE's Industry 4.0 orientation, our independent variable, as this method enables us to differentiate actions from intentions in conditions that machine-learning algorithms could not fathom. While the literature within similar research context employs two different computer-assisted coding methods, closed-language and novel open-language (Harrison, Thurgood, Boivie, & Pfarrer, 2019, 2020; Krippendorff, 1980; Tetlock, Saar-Tsechansky, & Macskassy, 2008; Uotila, Maula, Keil, & Zahra, 2009), the novel open-language approach is superior to closed-language methods (Park et al., 2015) as it utilizes "a more comprehensive collection of the features of the language being analyzed, such as how often the text features single, uncategorized words, sentence length, multiword phrases, and other features" (Harrison et al., 2019: 1318) rather than predefined words or categories. Yet, the method requires "a separate, psychometrically validated measure of a given construct for a subset of observations in order to train prediction models" (Harrison et al., 2019: 1319) making the tool unsuitable for new concepts like Industry 4.0 orientation in our study (Herrmann & Nadkarni, 2014; Nadkarni & Herrmann, 2010). To overcome this weakness of the machine-learning-based open-language approach, this study relied on the human-based open-language coding method as the literature indicates that humans perform similarly, across all patterns, to machines (e.g., Kühl et al., 2020). Even so, the human-based open language approach is independent of the domain of training, helping solve problems related to unforeseen domains that a machine cannot (e.g., Kao & Venkatachalam, 2021).

To conduct our human-based open-language coding analysis, we gathered textual data in the form of annual reports made public by KFSS's DART database. The textual data from DART were analyzed by the first author, who counted the number of terms for Industry 4.0 orientation relating to the actions of each MNE appearing in its annual reports for each firm-year. Then, the variable for the Industry 4.0 orientation of each MNE was calculated by dividing the number of terms for the Industry 4.0 orientation action of each MNE by the MNE's total number of employees per firm-year to weight firm size. Each MNE was coded by another rater using the same coding sheet (Ostergard Jr., 2000). The interrater reliability between the two raters was 0.93, reflecting a 93% agreement between them on all coded terms, indicating very good interrater agreement in the coding process.

Headquarters value creation and value capturing. The moderating variables for Hypotheses 2A and 3A are *headquarters value creation* and *headquarters value capturing*, respectively. Following the literature (Mizik & Jacobson, 2003; Mowery, Sampat, & Ziedonis, 2002), *headquarters value creation* was measured using the natural logarithm of the total number of applied patents, and *headquarters value capturing* was measured using the advertising intensity (i.e., advertising and marketing expenditures as a proportion of total sales).[11] Mizik and Jacobson (2003: 63) argue that a firm's resource allocations involve the "two fundamental processes of creating value (i.e., innovating, producing, and delivering products to the market) and appropriating [capturing] value (i.e., extracting profits in the marketplace)." Mizik and Jacobson (2003: 65) further claim that "it is the innovations resulting from R&D that have received the most attention as a cornerstone of value creation." In other words, the total number of applied patents, as a proxy for innovation quantity or capacity, is closely related to the firm's basic research activities (Mowery, Sampat, & Ziedonis, 2002) and thus is an appropriate measure of value creation in our study. Meanwhile, a firm's advertising capability is a crucial characteristic that governs branding and marketing strategies and differentiates a firm's offerings from those of its rivals (Chamberlin, 1933). Brand-based differentiation can augment a firm's advantage and is often employed as "an entry deterrence strategy" (Bunch & Smiley, 1992), although advertising can also separate market leaders from market followers based on whether they can maintain their advantages (Golder, 2000). Therefore, our proxies for the total number of applied patents and advertising intensity are in line with the practices in the literature.

Subsidiary value creation and value capturing. The moderating variables for Hypotheses 2B and 3B are *subsidiary value creation* and *subsidiary value capturing*. In line with our operationalizations in the previous section, we define *subsidiary value creation* as the R&D intensity (i.e., the ratio of the number of engineers and R&D personnel to the total number of employees) of each subsidiary and *subsidiary value capturing* as the advertising intensity (i.e., the ratio of advertising and marketing expenditures to total sales) of each subsidiary. While R&D at the headquarter-level involves basic research (Awate et al., 2015; Glass, 2003), foreign-subsidiary-level R&D focuses on extended or applied research and has a relatively short-term investment perspective (Henard & McFadyen, 2005). Thus, while we employed an accounting-based proxy for headquarters value creation, we focused on human resources (HR) for subsidiary value creation. Meanwhile, a foreign subsidiary can also increase its advertising expenditure in the local market to facilitate its value-capturing activities, as many subsidiaries have indeed been doing.

Control variables
We controlled for various factors that are also expected to affect a subsidiary's sales and purchase intensities within the GVC. First, we controlled for a set of subsidiary-level variables: subsidiary age, size, ownership mode, vertical diversification, R&D international joint venture (IJV) subsidiary status, and headquarters' knowledge transfer regarding value creation and value capturing. We included *subsidiary age*, operationalized as the natural logarithm of the years between its establishment and the focal year (Chung, Park, Lee, & Kim, 2015),

because it is more urgent for younger subsidiaries to capture value through the GVC, focusing on sales to external customers (Day, 2011; Mizik & Jacobson, 2003). Meanwhile, older subsidiaries are likely to focus on purchases from external suppliers within the GVC, since value creation through applied R&D is more important to them (Awate et al., 2015; Glass, 2003). We included *subsidiary size*, operationalized as the natural logarithm of the subsidiary's total assets (Chung et al., 2015), because larger subsidiaries tend to have more external relational capital and joint strategies with GVC partners; thus, they are more likely to depend on their GVC network (Kano, Tsang, & Yeung, 2020). We included the *subsidiary ownership mode* because the GVC itself is more likely to succeed when the subsidiary ownership is in the form of a joint venture (JV) rather than a wholly owned subsidiary (WOS) as alliance governance is more efficient at facilitating operational activities in the GVC network. In line with the IB literature (Hennart, 1991; Makino & Neupert, 2000), we coded the subsidiary ownership mode as 1 if a parent firm owned 95% or more of equity (WOS) and a value of 0 otherwise (JV).

We included *vertical diversification*, measured as the subsidiary-level intrafirm trade between the headquarters and its subsidiaries divided by the total trade of each subsidiary, because vertical diversification should increase the tendency of an MNE's subsidiaries to sell/buy from each other rather than externally. Furthermore, we controlled for the impact of *R&D IJV subsidiary status* (a dummy variable set to 1 if the subsidiary is an IJV with an R&D function) because such subsidiaries are more likely to seek radical innovations to learn superior Industry 4.0 practices, especially in developed countries. Finally, we controlled for knowledge transfer between the headquarters and subsidiaries, which may influence the benefits reaped from an Industry 4.0 orientation in terms of value creation and value capturing, especially in highly dynamic environments (see footnote 7). Specifically, we used the ratio of parent country nationals (PCN) to the engineers and R&D personnel of each subsidiary as a proxy for *headquarters' knowledge transfer in value creation* and the ratio of PCN to each subsidiary's salespersons as a proxy for *headquarters' knowledge transfer in value capturing*.

Second, we controlled for a set of MNE-level variables: MNE size, international experience (depth), host country number (breadth), geographic diversification, and governance. We controlled for *MNE size,* operationalized as the natural logarithm of total assets (Chung et al., 2015), because larger MNEs are less likely to depend on their GVCs for selling intermediate goods to external partners since they have enough tangible and intangible resources to internalize. Larger MNEs also are more likely to outsource their intermediate goods and components from external suppliers to make their production more efficient and diversified. In contrast, more internationally experienced MNEs are likely to strategically focus on their subsidiaries' purchases of intermediate goods and components from external partners, and these more internationally experienced MNEs are likely to sell their intermediate goods and components to external customers. This is because they have abundant internationalization experience, facilitating their production of intermediate goods to sell to GVC members. As a result, they are more dependent on internal value chains than on GVCs for their purchases of intermediate goods to enhance their operational flexibility and efficiency (Kano et al., 2020; Lanz & Miroudot, 2011; Lee et al., 2020; Lee, Shin, & Lee, 2015). In addition, an MNE that operates in many host countries is expected to have greater scope for both headquarters' divisions and foreign subsidiaries to engage in value-creating and value-capturing activities. To reflect these in the study, we measured *MNE international experience* (depth) by calculating the natural logarithm of months since the MNE established its first foreign subsidiary and *MNE host country number* (breadth) by calculating the natural logarithm of the number of host countries where each MNE entered (Magnusson & Boggs, 2006; Magnusson, Westjohn, & Boggs, 2009).

We controlled for *geographic diversification* because it should increase the stability of the MNE's supply and/or distribution. We adopted the following entropy measure from the literature (e.g., Delios, Xu, & Beamish, 2008):

$$\text{Geographic diversification} = \sum_{i=1}^{N} P_i \ln\left(\frac{1}{P_i}\right)$$

where P_i is the percentage share of the ith geographic segment (the MNE's subsidiaries located in country i) in the MNE's total subsidiaries in the focal year. Finally, we controlled for *MNE governance*, measured as the firm-level corporate governance score from the Thomson Reuters ASSET4 database (Cheng, Ioannou, & Serafeim, 2014), because an MNE is more likely to make related party transactions for tax purposes or to prop up poorly-performing subsidiaries if it is operating under weak governance.

Third, we controlled for a set of host country effects, namely political stability/risk, cultural distance, market size and growth, institutional distance, R&D intensity, technological change, local competition intensity, and asset-augmentation FDI. We defined the *political stability* of the host country using the Business Environment Risk Intelligence (BERI) political risk index, in which a higher score denotes less political risk (i.e., greater stability). Following the literature, we measured *cultural distance* via the Euclidean distance formula (Pattnaik & Lee, 2013; Shenkar, 2001), which overcomes certain limitations of Kogut and Singh's (1988) cultural distance index. We reason that political stability can be a good market signal through which local subsidiaries can safely sell and/or purchase intermediate goods or components to or from external customers or suppliers, driving a higher sales/purchase intensity (Lee et al., 2020). Meanwhile, a larger cultural distance should increase the cost of foreignness (Jean & Kim, 2021), thereby increasing the likelihood that local subsidiaries' transactions will be internalized, resulting in a reduced sales/purchase intensity. We controlled for *market size* (the logarithm of the country's gross domestic product or GDP) and *market growth* (the GDP annual growth rate) because both factors reflect local advantages and growth opportunities that can enable MNEs to conduct transactions in the external market, thereby increasing the sales/purchase intensity.

We controlled for the institutional distance between the home and host countries because a greater distance instigates information search costs that may deter transactions within the GVC (Jean & Kim, 2021). We included two dimensions of institutional distance: the difference between the general legal environment (*legal environment distance*) of the two countries, operationalized as the six dimensions of the World Bank WGI index (Slangen & van Tulder, 2009), and the difference in intellectual property (IP) protections between the two countries (*IP protection distance*), operationalized as the three sub-dimensions (protection of intellectual property rights, patent protection, and copyright piracy) of the Americans for Tax Reform Foundation/Property Rights Alliance's composite index.

We controlled for the host country's *R&D intensity* (operationalized as the percentage of the country's R&D expenditures divided by its GDP, per the World Bank's World Development Indicators) because the local R&D environment naturally influences a subsidiary's sales and purchase intensities (i.e., the dependent variables) as well as value creation and value capturing (i.e., the moderating variables). Specifically, a higher R&D intensity likely represents steep local competition for the MNE's subsidiary, which may decrease its sales intensity; at the same time, a higher R&D intensity could represent sources of abundant high-quality technologies and components, which may increase the subsidiary's purchase intensity. We controlled for the host country's *technological change,* operationalized as the year-to-year percentage change in the host country's R&D intensity, as it may be a broad indicator of the Industry 4.0 environment of the host country. By including this control variable, we account for the variability in country-level differences and barriers to the applicability and adoption of MNE Industry 4.0 by each MNE's foreign subsidiaries. We included the host country's *local competition intensity*, operationalized as the World Economic Forum's Global Competitiveness Index or GCI, as it may affect the outcomes of an MNE's Industry 4.0 orientation. In addition, we controlled for *asset-augmentation FDI* (Cui, Meyer & Hu, 2014), operationalized as a dummy variable by assigning "1" if the Global Innovation Index (GII) score of a host country is higher than Korea while assigning "0" if this GII score of a host country is lower than Korea. The sources of GII are Cornell University, INSEAD, and the World Intellectual Property Organization (WIPO), and GII is computed based on two sub-indices of the innovation input (with five pillars, e.g., market sophistication) and output (with two pillars, e.g., knowledge and technology outputs). If the motive of FDI is asset-augmentation FDI (or strategic asset-seeking FDI) in the host countries where innovation levels are higher, MNEs are more likely to learn their superior Industry 4.0 practices.[12]

Finally, we included region, industry, and year dummies. Extending from the UN's 10 geographic regions, our region dummies are the 11 dummies of Northern Africa (baseline), Sub-Saharan Africa, South-Eastern Asia, Eastern Asia, Southern Asia, Western Asia (Middle East), Europe, Latin America and Caribbean, Northern America, Oceania, and Commonwealth of Independent States (CIS). These region dummies are added to reflect the potential cross-region differences in our study. For industry dummies, we employed the OECD Industrial Classification code to reflect the potential effects of unobserved dissimilarities in competition or capital intensity related to differences in industrial features. We included year dummies to control for the impacts of temporal changes in demand, market growth, and external uncertainties across countries (Feinberg & Gupta, 2009).

Estimation methods

We tested our hypotheses with a random-intercept[13] multilevel Tobit model with double-censoring (Emery, 2013; Greene, 2003; Rabe-Hesketh & Skrondal, 2012; Stata, 2017), given the three key characteristics of our data discussed next. First, since some foreign subsidiaries in the sample did not have any transactions within the GVC, our dependent variable contains some zeroes; this was addressed using a Tobit estimator (Baggs & Brander, 2006). Second, our dependent variables are percentages, ranging from 0 to 100; thus, they are double-censored, which can bias the results if not controlled (Greene, 2003). Finally, our dataset has a hierarchical structure (level three: parent firm; level two: (host) country; level one: foreign subsidiary), which must be considered to minimize the risk of underestimating the standard errors (Hox, 1995, 2010; Rabe-Hesketh & Skrondal, 2012).

Moreover, there could be a potential endogeneity issue in the study's model as Industry 4.0 orientation may be endogenous due to potential reverse causality, simultaneity, and omission bias (Jean, Deng, Kim, & Yuan, 2016; Reeb, Sakakibara, & Mahmood, 2012). To address this potential issue, we employed the control function approach (Jean, Kim, Zhou, & Cavusgil, 2021; Petrin & Train, 2010). This approach adds an excluded variable to the regression equation to account for the potentially adverse effect of unknown sources of endogeneity, such that the independent variable is no longer correlated with the error term in the regression equation. This helps retain the assumption of independence between Industry 4.0 orientation and the error term in the equation (Jean et al., 2021; Wang et al., 2017). We chose the average of Industry 4.0 orientation for each sector as the excluded variable, consistent with previous studies employing the "sector-average" as the instrumental variable (e.g., Birhanu, Gambardella, & Valentini, 2016; Liu, Yang, & Augustine, 2018). This variable meets both the relevance and exogeneity requirements of the excluded variable (Wooldridge, 2010) because the sectoral pressures to mimetize are likely to influence Industry 4.0 orientation, while at the same time the variable also exhibited a non-significant correlation with the error term of the model ($r = 0.02$, $p = 0.26$). In addition, we tested for a weak instrument by evaluating the Cragg-Donald statistics of 15.63, which is greater than the commonly recognized threshold (i.e., 7.77) in the literature. Thus, the null hypothesis of a weak instrument is rejected (Stock & Yogo, 2005). Given the quality of the instrumental variable, we regressed Industry 4.0 orientation on the sector-average of Industry 4.0 orientation and generated the predicted residuals, which work as an effective control variable to address potential endogeneity concerns (Wooldridge, 2010). Thus, we added the predicted residuals as an additional explanatory variable for a subsidiary's sales and purchase intensities within the GVC, the dependent variables in our study, in order to control for the potential endogeneity in the model (Wooldridge, 2010).

Furthermore, following previous studies (e.g., Dinh, Calabrò, Campopiano, & Basco, 2021), we utilized lagging variables, including the independent and moderating variables. This was done to address potential reverse causality in our study, in addition to the control function approach (Jean et al., 2021; Petrin & Train, 2010). Specifically, while the dependent variables were measured at t, all of the independent and moderating variables, as well as the control variables, were lagged at $t-1$, and headquarters' value creation (total number of applied patents) was measured at $t-2$ to minimize reverse causality in the model. Measuring headquarters' value creation at $t-2$ is widely acknowledged in the innovation literature given the time lag between applied and granted patents (e.g., Hall, Jaffe & Trajtenberg, 2001; Choi, Kumar, & Zambuto, 2016). In sum, these statistical/empirical methods help the current study alleviate concerns about potential reverse causality in our model.

RESULTS

Table 1 presents the descriptive statistics and a Pearson correlation matrix of the variables employed in the random-intercept multi-level Tobit model analysis. The mean of the subsidiary's sales intensity within the GVC is 66.62% of the subsidiary's total sales, while the mean of the subsidiary's purchase intensity within the GVC is 36.55% of the subsidiary's total purchases, meaning that these two dependent variables include both

Table 1 Descriptive statistics and correlation matrix

	M	SD	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
1 Subsidiary sales intensity within the GVC (%)	66.62	42.53																		
2 Subsidiary purchase intensity within the GVC (%)	36.55	42.32	0.11																	
3 Subsidiary size = log (subsidiary assets)	23.47	1.82	0.03	0.05																
4 Subsidiary age = log (years since establishment)	1.62	1.07	− 0.04	0.10	0.36															
5 Vertical diversification (vertical integration)	0.24	0.30	− 0.41	− 0.22	− 0.01	0.06														
6 R&D IJV subsidiaries	0.02	0.14	0.04	0.04	0.06	0.04	0.01													
7 Headquarters' knowledge transfer in value creation	0.01	0.08	− 0.02	− 0.01	− 0.05	− 0.04	0.01	0.03												
8 Headquarters' knowledge transfer in value capturing	0.01	0.06	− 0.05	− 0.00	0.08	0.10	0.02	− 0.03	0.04											
9 Subsidiary value creation (R&D forces) (ratio)	0.07	0.04	− 0.26	0.21	− 0.04	− 0.05	0.20	0.17	0.11	− 0.17										
10 Subsidiary value capturing (advertising intensity) (ratio)	0.03	0.05	0.12	0.05	− 0.29	− 0.17	− 0.05	− 0.04	0.04	− 0.01	− 0.11									
11 Ownership mode dummy (WOS = 1 vs JV = 0)	0.77	0.41	− 0.07	− 0.06	− 0.14	− 0.04	0.15	− 0.27	− 0.01	0.05	− 0.01	− 0.02								
12 Political stability	50.81	17.88	0.01	0.02	− 0.01	− 0.02	0.01	− 0.01	0.01	0.05	− 0.01	0.08	0.04							
13 Cultural Euclidean distance	62.23	20.62	− 0.03	− 0.02	− 0.02	0.03	− 0.01	− 0.02	0.02	0.08	− 0.11	0.07	0.08	0.42						
14 Host country GDP = log (host country GDP)	6.96	1.79	− 0.02	− 0.01	− 0.05	− 0.01	− 0.01	− 0.01	0.03	0.06	− 0.09	0.13	0.06	0.42	0.11					
15 Host country GDP growth	6.71	3.62	− 0.19	0.10	− 0.19	− 0.22	0.15	0.03	− 0.01	− 0.14	0.39	− 0.08	− 0.04	0.01	− 0.14	− 0.07				
16 Host country R&D intensity (%)	1.35	0.84	− 0.11	0.04	0.00	0.05	− 0.07	− 0.05	0.02	0.13	− 0.27	0.17	0.08	0.42	0.47	0.48	− 0.37			
17 Host country technological change (%)	3.11	5.72	− 0.08	0.06	0.01	− 0.07	0.09	0.03	0.00	− 0.06	0.16	− 0.05	− 0.05	0.10	0.08	0.14	0.31	− 0.03		
18 Host country market competitive environment	5.50	0.44	− 0.04	0.01	0.05	0.03	0.01	− 0.02	0.01	0.07	− 0.10	0.05	0.05	0.50	0.47	0.40	− 0.09	0.69	0.21	
19 Legal environment distance	0.74	0.50	− 0.08	0.06	− 0.03	− 0.04	0.07	0.03	0.01	− 0.08	0.21	− 0.06	− 0.09	− 0.22	− 0.29	− 0.21	0.31	− 0.35	0.25	− 0.21
20 IP protection distance	4.22	1.75	− 0.02	0.00	0.08	0.05	0.01	0.01	− 0.04	− 0.09	0.05	− 0.14	− 0.06	− 0.34	− 0.43	− 0.51	0.01	− 0.52	− 0.06	− 0.41
21 Asset-augmentation FDI	0.26	0.44	0.16	0.09	0.08	0.15	− 0.11	− 0.04	0.00	0.13	− 0.06	0.07	0.07	0.11	0.47	0.35	− 0.46	0.49	− 0.21	0.35
22 MNE size = log (firm assets)	25.78	4.66	− 0.01	0.03	0.02	0.04	0.00	0.00	0.00	0.02	0.02	0.02	0.02	0.12	0.41	0.40	0.03	0.24	0.12	0.32
23 MNE international experience (depth) (log)	7.26	2.53	0.05	− 0.06	0.03	0.11	− 0.05	− 0.03	− 0.03	0.04	− 0.18	− 0.01	0.08	− 0.14	− 0.21	− 0.22	− 0.33	− 0.07	− 0.27	− 0.26
24 MNE host country number (log)	3.80	3.35	0.11	− 0.08	0.15	0.07	− 0.09	− 0.02	− 0.02	0.06	− 0.26	− 0.02	0.03	− 0.12	− 0.24	− 0.29	− 0.34	− 0.08	− 0.21	− 0.22
25 MNE governance	16.93	6.87	− 0.04	− 0.04	0.00	0.00	0.01	0.02	− 0.01	− 0.02	0.09	− 0.02	0.01	0.30	0.32	0.09	0.10	0.00	0.12	0.17
26 MNE geographic diversification	0.52	0.35	0.03	0.04	− 0.07	− 0.05	− 0.07	− 0.02	− 0.02	0.02	− 0.01	0.00	0.07	− 0.13	− 0.23	− 0.26	− 0.02	− 0.18	− 0.28	− 0.29
27 MNE Industry 4.0 orientation (weighted by employees)	0.01	0.04	0.13	0.04	− 0.02	− 0.02	− 0.02	− 0.01	− 0.01	− 0.01	− 0.04	0.03	0.00	− 0.17	− 0.13	− 0.13	− 0.10	− 0.03	− 0.09	− 0.17
28 HQ value creation = log (applied patents)	6.39	1.43	0.05	0.03	0.06	0.05	− 0.06	− 0.01	− 0.01	0.05	− 0.08	0.03	0.04	0.39	0.45	0.26	− 0.19	0.25	0.04	0.36
29 HQ value capturing (advertising intensity) (ratio)	0.03	0.01	0.04	− 0.03	− 0.15	− 0.01	0.01	− 0.01	0.04	− 0.01	0.04	0.10	0.07	0.12	0.11	0.12	0.06	0.11	− 0.12	0.04

	M	SD	19	20	21	22	23	24	25	26	27	28
20 IP protectiondistance			0.23									
21 Asset-augmentation FDI	0.26	0.44	− 0.41	− 0.33								
22 MNE size = log (firm assets)	25.78	4.66	− 0.12	− 0.27	0.08							
23 MNE international experience (depth) (log)	7.26	2.53	− 0.03	0.22	0.11	− 0.15						
24 MNE host country number (log)	3.80	3.35	− 0.05	0.29	0.06	− 0.21	0.49					
25 MNE governance	16.93	6.87	0.14	0.00	− 0.22	0.42	− 0.08	− 0.17				
26 MNE Geographic diversification	0.52	0.35	− 0.05	0.16	− 0.14	− 0.18	0.46	0.43	− 0.02			
27 MNE Industry 4.0 orientation (weighted by employees)	0.01	0.04	0.03	0.08	0.01	− 0.69	0.10	0.09	− 0.14	0.12		
28 HQ value creation = log (applied patents)	6.39	1.43	− 0.13	− 0.16	0.12	0.67	− 0.01	− 0.04	0.36	0.00	0.07	
29 HQ value capturing (advertising intensity) (ratio)	0.03	0.01	− 0.06	− 0.06	− 0.01	0.16	0.08	− 0.02	0.06	0.14	0.01	0.12

Coefficients above 0.03 and below − 0.03 are significant at $p < 0.05$, and those above 0.04 and below − 0.04 are significant at $p < 0.01$.

subsidiaries undertaking sales and purchases within the GVC and those within the internal value chain.

We assessed the possibility of multicollinearity by checking the variance inflation factor (VIF) for each variable. For our explanatory variables, the highest VIF was 2.39, well below the recommended threshold of 10, demonstrating that multicollinearity is unlikely to have influenced our results (Chatterjee, Hadi, & Price, 2000).

The results of our multilevel Tobit model analysis obtained using Stata 15 are shown hierarchically in Table 2 (Hox, 1995, 2010; Raudenbush & Bryk, 2002). Models 1–5 of Table 2 display the analytical results of the multilevel Tobit models for the factors that influence the subsidiary's sales intensity within the GVC, whereas Models 6–10 present the analytical results of the multilevel Tobit models for the factors that influence the subsidiary's purchase intensity within the GVC.[14]

Models 1 and 6 include only the control variables. Models 2 and 7 include the independent variable (i.e., Industry 4.0 orientation) and four moderating variables (i.e., headquarters value creation and value capturing; subsidiary value creation and capturing) along with the control variables. Models 3 and 8 include each pair of two MNE/headquarter-level interaction terms between Industry 4.0 orientation and headquarters' value creation versus value capturing. Models 4 and 9 include each pair of two cross-level interaction terms between Industry 4.0 orientation and subsidiary value creation versus value capturing. Finally, Models 5 and 10 are full models with all the variables and interaction terms.

Hypothesis 1a predicts that an MNE's Industry 4.0 orientation has a positive impact on its subsidiary's sales intensity, and Hypothesis 1b predicts that an MNE's Industry 4.0 orientation has a positive impact on its subsidiary's purchase intensity. Meanwhile, Hypothesis 1c claims that MNE-level Industry 4.0 orientation has a stronger positive impact on sales intensity than on purchase intensity. In Models 2 and 7, Industry 4.0 orientation has a significant positive relationship with both the subsidiary's sales intensity (Model 2) and its purchase intensity (Model 7), but the regression coefficient is larger for the former (Model 2: $b = 94.87$, $p = 0.00$; Model 7: $b = 41.17$, $p = 0.04$). These findings are replicated in the other model pairs, including the full models (Model 5: $b = 194.98$, $p = 0.00$; Model 10: $b = 61.54$, $p = 0.04$), supporting Hypotheses 1A and 1B. Further, we tested the difference with the Wald test for the equality of regression coefficients (Jayachandran, Kalaignanam, & Eilert, 2013; Luo & Homburg, 2008), which rejected the null hypothesis that the regression coefficients are equal in Models 5 and 10 ($F_{\text{difference}} = 5.90$, $p = 0.02$), supporting Hypothesis 1c.

Hypothesis 2a predicts that headquarters value creation is a stronger positive moderator of the relationship between Industry 4.0 orientation and the subsidiary's sales intensity than between Industry 4.0 orientation and the subsidiary's purchase intensity. In Models 3 and 8, the interaction term between Industry 4.0 orientation and headquarters value creation is positively and significantly related to both the sales intensity and purchase intensity, but the regression coefficient of the interaction term is larger in Model 3 than in Model 8 (Model 3: $b = 24.57$, $p = 0.00$; Model 8: $b = 13.70$, $p = 0.05$). These findings are replicated in the other model pairs, including the full models (Model 5: $b = 20.65$, $p = 0.00$; Model 10: $b = 13.14$, $p = 0.07$). According to the Wald test result, the coefficient difference is statistically significant at the 1% level ($F_{\text{difference}} = 6.49$, $p = 0.01$). Therefore, Hypothesis 2a is supported.

Hypothesis 2b contends that subsidiary value creation is a stronger positive moderator of the relationship between Industry 4.0 orientation and the subsidiary's purchase intensity than between Industry 4.0 orientation and the subsidiary's sales intensity. In Model 4, the interaction term between Industry 4.0 orientation and subsidiary value creation is negatively, but not significantly, related to the subsidiary's sales intensity ($b = -414.04$, $p = 0.22$), whereas, in Model 9, the interaction term is positively and significantly related to the subsidiary's purchase intensity ($b = 869.96$, $p = 0.02$). These findings are replicated in the full models (Model 5: $b = -398.99$, $p = 0.24$; Model 10: $b = 747.43$, $p = 0.04$). According to the Wald test, the coefficient difference between Models 5 and 10 is statistically significant ($F_{\text{difference}} = 5.47$, $p = 0.02$). Thus, Hypothesis 2b is supported.

Hypothesis 3a predicts that headquarters value capturing is a stronger positive moderator of the relationship between Industry 4.0 orientation and the subsidiary's sales intensity than between Industry 4.0 orientation and the subsidiary's purchase intensity. In Model 3, the interaction term between Industry 4.0 orientation and headquarters value capturing is positively and significantly related to the subsidiary's sales intensity ($b = 3175.49$, $p = 0.01$), but the interaction term is negatively

Table 2 Results of multilevel Tobit model for supplier GVC versus customer GVC

DV: Subsidiary sales intensity within the GVC (%)	Hypo.	Model 1			Model 2			Model 3		
Variables		Coef.	SE	Sig.	Coef.	SE	Sig.	Coef.	SE	Sig.
Fixed effects										
Intercept		82.69	11.71	0.00	101.58	12.28	0.00	107.32	12.83	0.00
Subsidiary level										
Subsidiary size = log (subsidiary assets)		0.08	0.30	0.80	0.17	0.31	0.58	0.15	0.31	0.63
Subsidiary age = log (years since establishment)		– 1.53	0.50	0.00	– 1.75	0.50	0.00	– 1.76	0.50	0.00
Ownership mode dummy (WOS = 1 vs JV = 0)		– 1.12	1.27	0.38	– 0.48	1.27	0.70	– 0.51	1.27	0.69
Vertical diversification (vertical integration)		– 66.42	1.69	0.00	– 65.81	1.68	0.00	– 65.66	1.69	0.00
R&D IJV subsidiaries		1.49	3.74	0.69	1.15	3.72	0.76	1.27	3.72	0.73
Headquarters' knowledge transfer in value creation		– 5.04	5.75	0.38	– 0.03	5.77	1.00	– 0.16	5.77	0.98
Headquarters' knowledge transfer in value capturing		– 23.94	8.66	0.01	– 17.50	8.67	0.04	– 17.67	8.67	0.04
Subsidiary value creation (R&D forces) (ratio)					– 94.07	16.40	0.00	– 95.27	16.41	0.00
Subsidiary value capturing (advertising intensity) (ratio)					45.68	9.65	0.00	46.09	9.65	0.00
(Host) country level										
Political stability		0.07	0.04	0.09	0.09	0.04	0.05	0.09	0.04	0.05
Cultural Euclidean distance		– 0.15	0.05	0.00	– 0.14	0.05	0.00	– 0.13	0.05	0.00
Host country GDP = log (host country GDP)		– 1.16	0.61	0.06	– 0.96	0.63	0.13	– 1.07	0.64	0.09
Host country GDP growth		– 0.74	0.22	0.00	– 0.70	0.23	0.00	– 0.71	0.24	0.00
Host country R&D intensity (%)		– 1.53	1.61	0.34	– 1.52	1.67	0.36	– 1.46	1.67	0.38
Host country technological change (%)		– 0.00	0.10	0.99	– 0.01	0.10	0.95	– 0.00	0.10	0.99
Host country market competitive environment		– 3.68	1.90	0.05	– 2.81	1.97	0.15	– 2.91	1.97	0.14
Legal environment distance		– 1.04	1.15	0.37	– 1.20	1.15	0.30	– 1.35	1.15	0.24
IP protection distance		– 0.12	0.75	0.87	– 0.21	0.77	0.78	– 0.25	0.78	0.75
Asset-augmentation FDI		7.56	1.97	0.00	5.87	1.98	0.00	5.55	1.99	0.01
MNE/HQ level										
MNE size = log (firm assets)		– 0.00	0.13	0.98	– 0.26	0.22	0.24	– 0.48	0.26	0.07
MNE international experience (depth)		0.99	0.30	0.00	0.90	0.30	0.00	0.82	0.30	0.01
MNE host country number		0.75	0.23	0.00	0.48	0.24	0.04	0.44	0.24	0.06
MNE governance		– 0.06	0.10	0.53	– 0.03	0.11	0.76	– 0.02	0.11	0.86
MNE Geographic diversification		0.79	1.74	0.65	0.10	1.78	0.96	0.13	1.78	0.94
MNE Industry 4.0 orientation (weighted by employees)	**H1**				94.87	18.08	0.00	207.82	55.40	0.00
HQ value creation = log (applied patents)					1.45	0.62	0.02	1.78	0.64	0.01
HQ value capturing (advertising intensity) (ratio)					123.08	48.27	0.01	139.10	53.20	0.01
MNE/HQ level interactions										
Industry 4.0 orientation × HQ value creation	**H2A**							24.57	6.45	0.00
Industry 4.0 orientation × HQ value capturing	**H3A**							3175.49	1199.96	0.01
Cross-level interactions										
Industry 4.0 orientation × subsidiary value creation	**H2B**									
Industry 4.0 orientation × subsidiary value capturing	**H3B**									
Predicted residuals from stage 1		– 0.03	0.01	0.02	– 0.02	0.01	0.12	– 0.02	0.01	0.10
Eastern Asia		13.48	7.77	0.08	15.03	7.76	0.05	14.03	7.89	0.08
Southern Asia		23.65	8.75	0.01	21.51	8.72	0.01	19.20	9.23	0.04
Western Asia		22.08	11.25	0.05	15.66	11.08	0.16	16.78	11.18	0.13
Chemicals excluding pharmaceuticals		0.77	2.15	0.72	0.84	2.24	0.71	0.93	2.25	0.68
Pharmaceuticals		0.12	9.02	0.99	3.57	8.81	0.69	3.72	8.83	0.67
Rubber and plastics products		3.49	3.53	0.32	0.04	3.54	0.99	0.10	3.55	0.98
Other non-metallic mineral products		0.14	2.95	0.96	0.94	3.00	0.75	1.01	3.01	0.74
Basic metals and fabricated metal products		1.31	3.22	0.68	2.37	3.26	0.47	2.47	3.28	0.45
Radio, TV, communications equipment and computing machinery		4.81	1.78	0.01	7.79	1.95	0.00	7.90	1.96	0.00
Electrical machinery and apparatus, n.e.c.		11.30	3.19	0.00	11.07	3.24	0.00	11.10	3.24	0.00
Motor vehicles, trailers and semi-trailers		0.21	2.02	0.92	0.56	2.17	0.80	0.63	2.17	0.77
Random effects										
MNE/HQ Level		0.26	0.10	0.01	0.33	0.12	0.00	0.40	0.13	0.00

Table 2 (*Continued*)

DV: Subsidiary sales intensity within the GVC (%)	Hypo.	Model 1			Model 2			Model 3		
Variables		Coef.	SE	Sig.	Coef.	SE	Sig.	Coef.	SE	Sig.
(Host) Country Level		0.30	0.13	0.02	0.36	0.14	0.01	0.45	0.15	0.00
σ_u		8.57	2.67	0.00	8.72	2.83	0.00	8.74	2.85	0.00
σ_e		35.71	0.34	0.00	35.51	0.34	0.00	35.50	0.34	0.00
Log-likelihood		− 27861.91			− 27797.05			− 27785.35		

DV: Subsidiary sales intensity within the GVC (%)	Hypo.	Model 4			Model 5		
Variables		Coef.	SE	Sig.	Coef.	SE	Sig.
Fixed effects							
Intercept		102.01	12.34	0.00	107.47	12.84	0.00
Subsidiary level							
Subsidiary size = log (subsidiary assets)		0.16	0.31	0.61	0.13	0.31	0.67
Subsidiary age = log (years since establishment)		− 1.73	0.50	0.00	− 1.74	0.50	0.00
Ownership mode dummy (WOS = 1 vs JV = 0)		− 0.53	1.27	0.67	− 0.56	1.27	0.66
Vertical diversification (vertical integration)		− 65.82	1.68	0.00	− 65.67	1.69	0.00
R&D IJV subsidiaries		1.16	3.72	0.76	1.28	3.72	0.73
Headquarters' knowledge transfer in value creation		− 0.01	5.77	1.00	− 0.17	5.77	0.98
Headquarters' knowledge transfer in value capturing		− 17.57	8.67	0.04	− 17.73	8.67	0.04
Subsidiary value creation (R&D forces) (ratio)		− 89.93	16.73	0.00	− 91.44	16.75	0.00
Subsidiary value capturing (advertising intensity) (ratio)		44.92	9.85	0.00	44.70	9.85	0.00
(Host) country level							
Political stability		0.08	0.04	0.06	0.08	0.04	0.06
Cultural Euclidean distance		− 0.14	0.05	0.00	− 0.13	0.05	0.00
Host country GDP = log (host country GDP)		− 0.99	0.63	0.11	− 1.11	0.64	0.09
Host country GDP growth		− 0.69	0.23	0.00	− 0.71	0.24	0.00
Host country R&D intensity (%)		− 1.57	1.67	0.35	− 1.50	1.67	0.37
Host country technological change (%)		− 0.00	0.10	0.98	− 0.00	0.10	0.98
Host country market competitive environment		− 2.62	1.98	0.19	− 2.75	1.98	0.17
Legal environment distance		− 1.18	1.15	0.30	− 1.34	1.15	0.24
IP protection distance		− 0.26	0.78	0.74	− 0.29	0.78	0.71
Asset-augmentation FDI		5.98	1.98	0.00	5.66	1.99	0.00
MNE/HQ level							
MNE size = log (firm assets)		− 0.25	0.22	0.27	− 0.46	0.26	0.08
MNE international experience (depth)		0.87	0.30	0.00	0.79	0.30	0.01
MNE host country number		0.46	0.24	0.05	0.43	0.24	0.07
MNE governance		− 0.05	0.11	0.68	− 0.03	0.11	0.80
MNE Geographic diversification		0.15	1.78	0.93	0.17	1.78	0.92
MNE Industry 4.0 orientation (weighted by employees)	**H1**	103.03	33.60	0.00	194.98	61.82	0.00
HQ value creation = log (applied patents)		1.50	0.62	0.02	1.87	0.64	0.00
HQ value capturing (advertising intensity) (ratio)		133.51	48.27	0.01	138.40	53.20	0.01
MNE/HQ level interactions							
Industry 4.0 orientation × HQ value creation	**H2A**				20.65	6.61	0.00
Industry 4.0 orientation × HQ value capturing	**H3A**				3118.85	1201.35	0.01
Cross-level interactions							
Industry 4.0 orientation × subsidiary value creation	**H2B**	− 414.04	336.82	0.22	− 398.99	337.16	0.24
Industry 4.0 orientation × subsidiary value capturing	**H3B**	453.98	154.23	0.00	396.57	157.02	0.01
Predicted residuals from stage 1		− 0.02	0.01	0.09	− 0.02	0.01	0.07
Eastern Asia		15.29	7.78	0.05	14.05	7.89	0.08
Southern Asia		21.62	8.80	0.01	18.72	9.26	0.04
Western Asia		14.49	11.13	0.19	15.76	11.20	0.16
Chemicals excluding pharmaceuticals		0.76	2.24	0.73	0.92	2.26	0.68

Table 2 (*Continued*)

DV: Subsidiary sales intensity within the GVC (%)	Hypo.	Model 4			Model 5		
Variables		Coef.	SE	Sig.	Coef.	SE	Sig.
Pharmaceuticals		3.44	8.81	0.70	3.71	8.82	0.68
Rubber and plastics products		0.08	3.54	0.98	0.04	3.55	0.99
Other non-metallic mineral products		0.78	3.00	0.79	0.91	3.01	0.76
Basic metals and fabricated metal products		2.24	3.26	0.49	2.42	3.28	0.46
Radio, TV, communications equipment and computing machinery		7.72	1.95	0.00	7.87	1.96	0.00
Electrical machinery and apparatus, n.e.c.		10.99	3.25	0.00	11.05	3.25	0.00
Motor vehicles, trailers and semi-trailers		0.49	2.17	0.82	0.59	2.18	0.79
Random effects							
MNE/HQ Level		0.44	0.13	0.00	0.41	0.14	0.00
(Host) Country Level		0.45	0.15	0.00	0.43	0.15	0.01
σ_u		8.81	2.83	0.00	8.92	2.85	0.00
σ_e		35.51	0.34	0.00	35.50	0.34	0.00
Log-likelihood		− 27789.32			− 27776.63		

DV: Subsidiary purchase intensity within the GVC (%)	Hypo.	Model 6			Model 7			Model 8		
Variables		Coef.	SE	Sig.	Coef.	SE	Sig.	Coef.	SE	Sig.
Fixed effects										
Intercept		15.90	13.13	0.23	− 8.87	13.50	0.51	− 1.00	14.11	0.94
Subsidiary level										
Subsidiary size = log (subsidiary assets)		0.74	0.33	0.03	0.65	0.34	0.06	0.62	0.34	0.07
Subsidiary age = Log (years since establishment)		5.49	0.56	0.00	5.82	0.55	0.00	5.83	0.55	0.00
Ownership mode dummy (WOS = 1 vs JV = 0)		− 0.32	1.42	0.82	− 0.73	1.39	0.60	− 0.74	1.39	0.59
Vertical diversification (vertical integration)		− 38.87	1.89	0.00	− 40.38	1.85	0.00	− 40.15	1.86	0.00
R&D IJV Subsidiaries		0.80	4.19	0.85	0.23	4.09	0.96	0.07	4.09	0.99
Headquarters' knowledge transfer in value creation		− 7.79	6.45	0.23	− 5.48	6.35	0.39	− 5.41	6.35	0.39
Headquarters' knowledge transfer in value capturing		− 13.29	9.71	0.17	− 31.21	9.53	0.00	− 31.12	9.53	0.00
Subsidiary value creation (R&D forces) (ratio)					289.81	18.02	0.00	288.95	18.02	0.00
Subsidiary value capturing (Advertising Intensity) (ratio)					50.89	10.61	0.00	50.45	10.61	0.00
(Host) Country level										
Political stability		0.10	0.05	0.05	0.05	0.05	0.35	0.05	0.05	0.33
Cultural Euclidean distance		− 0.03	0.05	0.53	− 0.05	0.05	0.35	− 0.03	0.05	0.57
Host country GDP = Log (host country GDP)		− 1.08	0.68	0.11	− 0.47	0.69	0.49	− 0.36	0.70	0.60
Host country GDP growth		1.02	0.25	0.00	1.12	0.25	0.00	1.03	0.26	0.00
Host country R&D intensity (%)		0.31	1.80	0.87	3.79	1.83	0.04	3.79	1.83	0.04
Host country technological change (%)		0.16	0.11	0.14	0.09	0.11	0.40	0.10	0.11	0.36
Host country market competitive environment		1.72	2.13	0.42	0.06	2.17	0.98	0.13	2.17	0.95
Legal environment distance		1.91	1.29	0.14	1.31	1.26	0.30	1.49	1.26	0.24
IP protection distance		− 0.65	0.84	0.44	1.11	0.85	0.19	1.18	0.85	0.17
Asset-augmentation FDI		6.53	2.21	0.00	2.52	2.17	0.25	2.87	2.18	0.19
MNE/HQ Level										
MNE size = Log (Firm assets)		0.12	0.15	0.42	0.03	0.24	0.90	− 0.28	0.29	0.34
MNE international experience (depth)		− 0.38	0.33	0.25	− 0.23	0.33	0.48	− 0.30	0.33	0.36
MNE host country number		− 0.86	0.26	0.00	− 0.26	0.26	0.32	− 0.30	0.26	0.25
MNE governance		− 0.04	0.11	0.71	− 0.09	0.12	0.48	− 0.10	0.12	0.42
MNE geographic diversification		4.39	1.95	0.02	5.82	1.95	0.00	5.70	1.95	0.00
MNE Industry 4.0 orientation (weighted by employees)	**H1**				41.17	19.89	0.04	52.57	27.40	0.06
HQ value creation = Log (applied patents)					1.24	0.68	0.07	0.66	0.70	0.35
HQ value capturing (advertising intensity) (ratio)					− 95.45	53.02	0.07	− 75.33	58.43	0.20
MNE/HQ level Interactions										
Industry 4.0 orientation × HQ value creation	**H2A**							13.70	7.09	0.05

Table 2 (*Continued*)

DV: Subsidiary purchase intensity within the GVC (%)	Hypo.	Model 6			Model 7			Model 8		
Variables		Coef.	SE	Sig.	Coef.	SE	Sig.	Coef.	SE	Sig.
Industry 4.0 orientation × HQ value capturing	**H3A**							– 894.28	1124.64	0.43
Cross-level Interactions										
Industry 4.0 orientation × subsidiary value creation	**H2B**									
Industry 4.0 orientation × subsidiary value capturing	**H3B**									
Predicted residuals from stage 1		– 0.02	0.01	0.08	– 0.03	0.01	0.02	– 0.03	0.01	0.01
Sub-Saharan Africa		30.32	11.70	0.01	32.80	11.60	0.01	30.13	11.77	0.01
Southern Asia		14.24	8.80	0.11	20.64	8.84	0.02	16.51	9.36	0.08
Europe		15.49	7.79	0.05	16.95	7.96	0.03	14.81	8.18	0.07
Northern America		15.17	7.92	0.06	15.71	8.03	0.05	14.68	8.23	0.08
Chemicals excluding pharmaceuticals		9.82	2.15	0.00	9.32	2.26	0.00	9.21	2.28	0.00
Pharmaceuticals		0.14	9.07	0.99	2.19	8.93	0.81	2.00	8.94	0.82
Rubber and plastics products		10.24	3.54	0.00	10.91	3.58	0.00	10.87	3.59	0.00
Other non-metallic mineral products		9.25	2.95	0.00	7.97	3.03	0.01	7.90	3.04	0.01
Basic metals and fabricated metal products		3.99	3.24	0.22	2.95	3.30	0.37	2.83	3.32	0.39
Radio, TV, communications equipment and computing machinery		9.84	1.79	0.00	10.11	1.97	0.00	9.93	1.98	0.00
Electrical machinery and apparatus, n.e.c.		13.62	3.21	0.00	10.70	3.30	0.00	10.63	3.30	0.00
Motor vehicles, trailers and semi-trailers		8.12	2.04	0.00	5.92	2.20	0.01	5.78	2.21	0.01
Random effects										
MNE/HQ level		17.86	5.73	0.00	26.33	10.34	0.01	34.02	12.79	0.01
(Host) country level		0.30	0.10	0.00	0.28	0.11	0.01	0.29	0.10	0.01
σ_u		4.83	1.94	0.01	5.45	1.65	0.00	5.47	1.65	0.00
σ_e		39.73	0.44	0.00	38.67	0.43	0.00	38.66	0.43	0.00
Log-likelihood		– 28479.89			– 28330.16			– 28318.35		

DV: Subsidiary purchase intensity within the GVC (%)	Hypo.	Model 9			Model 10		
Variables		Coef.	SE	Sig.	Coef.	SE	Sig.
Fixed effects							
Intercept		– 7.49	13.56	0.58	– 0.85	14.12	0.95
Subsidiary level							
Subsidiary size = log (subsidiary assets)		0.63	0.34	0.06	0.61	0.34	0.08
Subsidiary age = Log (years since establishment)		5.81	0.55	0.00	5.82	0.55	0.00
Ownership mode dummy (WOS = 1 vs JV = 0)		– 0.67	1.39	0.63	– 0.69	1.39	0.62
Vertical diversification (vertical integration)		– 40.35	1.85	0.00	– 40.15	1.86	0.00
R&D IJV Subsidiaries		0.25	4.09	0.95	0.10	4.09	0.98
Headquarters' knowledge transfer in value creation		– 5.48	6.35	0.39	– 5.43	6.35	0.39
Headquarters' knowledge transfer in value capturing		– 31.13	9.53	0.00	– 31.05	9.53	0.00
Subsidiary value creation (R&D forces) (ratio)		286.12	18.38	0.00	285.29	18.40	0.00
Subsidiary value capturing (Advertising Intensity) (ratio)		47.47	10.83	0.00	47.81	10.83	0.00
(Host) Country level							
Political stability		0.05	0.05	0.31	0.05	0.05	0.30
Cultural Euclidean distance		– 0.05	0.05	0.37	– 0.03	0.05	0.57
Host country GDP = Log (host country GDP)		– 0.40	0.69	0.56	– 0.31	0.70	0.66
Host country GDP growth		1.10	0.25	0.00	1.03	0.26	0.00
Host country R&D intensity (%)		3.75	1.83	0.04	3.75	1.83	0.04
Host country technological change (%)		0.09	0.11	0.41	0.10	0.11	0.38
Host country market competitive environment		0.05	2.17	0.98	0.00	2.18	1.00
Legal environment distance		1.33	1.26	0.29	1.49	1.26	0.24
IP protection distance		1.16	0.85	0.17	1.22	0.85	0.15
Asset-augmentation FDI		2.65	2.18	0.22	2.96	2.19	0.18
MNE/HQ Level							

Table 2 (*Continued*)

DV: Subsidiary purchase intensity within the GVC (%)	Hypo.	Model 9			Model 10		
Variables		Coef.	SE	Sig.	Coef.	SE	Sig.
MNE size = Log (Firm assets)		– 0.05	0.24	0.85	– 0.30	0.29	0.29
MNE international experience (depth)		– 0.20	0.33	0.54	– 0.27	0.33	0.42
MNE host country number		– 0.24	0.26	0.35	– 0.28	0.26	0.28
MNE governance		– 0.09	0.12	0.46	– 0.10	0.12	0.40
MNE geographic diversification		5.76	1.95	0.00	5.66	1.96	0.00
MNE Industry 4.0 orientation (weighted by employees)	**H1**	48.16	22.16	0.03	61.54	30.58	0.04
HQ value creation = Log (applied patents)		1.20	0.68	0.08	0.69	0.70	0.33
HQ value capturing (advertising intensity) (ratio)		– 93.99	53.02	0.08	– 75.65	58.43	0.20
MNE/HQ level Interactions							
Industry 4.0 orientation × HQ value creation	**H2A**				13.14	7.26	0.07
Industry 4.0 orientation × HQ value capturing	**H3A**				– 828.14	1125.95	0.46
Cross-level Interactions							
Industry 4.0 orientation × subsidiary value creation	**H2B**	869.96	370.07	0.02	747.43	370.47	0.04
Industry 4.0 orientation × subsidiary value capturing	**H3B**	272.38	169.54	0.11	217.78	172.61	0.21
Predicted residuals from stage 1		– 0.03	0.01	0.01	– 0.03	0.01	0.01
Sub-Saharan Africa		32.21	11.62	0.01	30.21	11.77	0.01
Southern Asia		20.54	8.93	0.02	17.40	9.39	0.06
Europe		16.50	7.99	0.04	15.03	8.19	0.07
Northern America		15.30	8.06	0.06	14.90	8.24	0.07
Chemicals excluding pharmaceuticals		9.20	2.26	0.00	9.15	2.28	0.00
Pharmaceuticals		2.00	8.93	0.82	1.90	8.94	0.83
Rubber and plastics products		10.74	3.58	0.00	10.76	3.59	0.00
Other non-metallic mineral products		7.73	3.03	0.01	7.71	3.04	0.01
Basic metals and fabricated metal products		2.76	3.30	0.40	2.71	3.32	0.41
Radio, TV, communications equipment and computing machinery		9.99	1.98	0.00	9.83	1.98	0.00
Electrical machinery and apparatus, n.e.c.		10.59	3.30	0.00	10.52	3.30	0.00
Motor vehicles, trailers and semi-trailers		5.81	2.21	0.01	5.69	2.21	0.01
Random effects							
MNE/HQ level		27.41	11.45	0.02	38.79	14.69	0.01
(Host) country level		0.29	0.11	0.01	0.35	0.11	0.00
σ_u		5.38	1.67	0.00	5.41	1.66	0.00
σ_e		38.67	0.43	0.00	38.66	0.43	0.00
Log-likelihood		– 28311.86			– 28297.41		

$N = 5572$. Unstandardized coefficients are reported. The *p* values are based on two-tailed tests. Null models are analyzed, and region, industry and year dummies are estimated, but only significant region dummies are reported and year dummies are not reported here.

and insignificantly related to the subsidiary's purchase intensity in Model 8 ($b = -\ 894.28$, $p = 0.43$). These findings are replicated in the full models (Model 5: $b = 3118.85$, $p = 0.01$; Model 10: $b = -\ 828.14$, $p = 0.46$). According to the Wald test, the coefficient difference is statistically significant ($F_{\text{difference}} = 7.28$, $p = 0.01$). Hence, Hypothesis 3a is supported.

Finally, Hypothesis 3b contends that subsidiary value capturing is a stronger positive moderator of the relationship between Industry 4.0 orientation and the subsidiary's sales intensity than between Industry 4.0 orientation and the subsidiary's purchase intensity. In Model 4, the interaction term between Industry 4.0 orientation and subsidiary value capturing is positively and significantly related to the sales intensity ($b = 453.98$, $p = 0.00$), but the interaction term is positively yet insignificantly related to the purchase intensity in Model 9 ($b = 272.38$, $p = 0.11$). The findings are replicated in the full models (Model 5: $b = 396.57$, $p = 0.01$; Model 10: $b = 217.78$, $p = 0.21$). According to the Wald test, the coefficient difference is statistically significant ($F_{\text{difference}} = 4.79$, $p = 0.03$). Therefore, Hypothesis 3b is supported.

Effect Sizes

With a censored dependent variable like in our models, the economic effect size of an explanatory variable of interest on a dependent variable should be influenced by not only a coefficient of the explanatory variable of interest but also all the values of the covariate variables and parameters (variance of error term) as a type of "adjusting factor" (Wooldridge, 2010). In addition to other influences on the economic effect size, nonlinearity triggered by a censored dependent variable can contribute to the dependence of the economic effect size on the chosen covariate variables. To address these issues, we report the economic effects using the average partial (marginal) effect (APE or AME), which is obtained by "averaging the individual partial effects across the sample", as recommended by Wooldridge (2016: 531–532).

In Model 5, a unit increase in an MNE's Industry 4.0 orientation leads to an increase in its subsidiary's sales intensity within the GVC by 194.63 as APE, with all else being equal. In Model 10, a unit increase in an MNE's Industry 4.0 orientation leads to an increase in its subsidiary's purchase intensity within the GVC by 61.02 as APE, with all else being equal. In both cases, the APE of the independent variables of interest in Models 5 and 10 are less than the corresponding coefficients of the independent variables, respectively (194.98 in Model 5 and 61.54 in Model 10), which is consistent with the fact that "the adjustment factor is strictly between zero and one" ($194.98–194.63 = 0.35$ in Model 5 and $61.54–61.02 = 0.52$ in Model 10) (Wooldridge, 2016: 539). These results show that Hypotheses 1A and 1B both have valid managerial implications.

When comparing the economic effect size of an MNE's Industry 4.0 orientation on its subsidiary's sales intensity within the GVC with that of an MNE's Industry 4.0 orientation on its subsidiary's purchase intensity, we find that the effect size of the former is much larger than that of the latter ($194.63 > 61.02$), as shown by the results above. This result supports the policy implication of our Hypothesis 3.

In Model 5, a unit increase in Industry 4.0 orientation in an interaction term leads to an increase in the subsidiary's sales intensity by 20.61 while the headquarters value creation changes. In addition, a unit increase in headquarters value creation leads to an increase in the subsidiary's sales intensity by 20.57 while Industry 4.0 orientation changes. Meanwhile, in Model 10, a unit increase in Industry 4.0 orientation in an interaction term leads to an increase in the subsidiary's purchase intensity by 13.13 while the headquarters value creation changes. In addition, a unit increase in headquarters value creation leads to an increase in the subsidiary's purchase intensity by 13.08 while Industry 4.0 orientation changes. Therefore, Hypothesis 2a is still supported.

In Model 10, a unit increase in Industry 4.0 orientation in an interaction term leads to an increase of the subsidiary's purchase intensity by 746.04 while subsidiary value creation changes. In addition, a unit increase in subsidiary value creation leads to an increase in the subsidiary's purchase intensity by 747.12 while Industry 4.0 orientation changes. Meanwhile, in Model 5, when we calculate the economic effect size for an interaction term, sometimes even with an insignificant result, there can be some minimal economic effect size (Ai & Norton, 2003). Hence, we calculate the economic effect size for the interaction term between Industry 4.0 orientation and subsidiary value creation, and the result shows that there is comparatively a minimal effect size. Hence, Hypothesis 2b is supported.

In Model 5, a unit increase in Industry 4.0 orientation in an interaction term leads to an increase in the subsidiary's sales intensity by

3113.67 while the headquarters value capturing changes. In addition, a unit increase in headquarters value capturing leads to an increase in the subsidiary's sales intensity by 3109.86 while Industry 4.0 orientation changes. Meanwhile, in Model 10, like our above explanation, sometimes even with an insignificant result, there can be some minimal economic effect size. Thus, we calculate the economic effect size for the interaction term between Industry 4.0 orientation and headquarters value capturing, and the result exhibits that there is a relatively much smaller effect size. Hence, Hypothesis 3a is supported as well.

Finally, in Model 5, a unit increase in Industry 4.0 orientation in an interaction term leads to an increase in the subsidiary's sales intensity by 395.12 while the headquarters value capturing changes. In addition, a unit increase in subsidiary value capturing leads to an increase in the subsidiary's sales intensity by 394.58 while Industry 4.0 orientation changes. Meanwhile, in Model 10, we calculate the economic effect size for the interaction term between Industry 4.0 orientation and subsidiary value capturing, and the result presents that there is a comparably much smaller effect size. Hence, Hypothesis 3b is also supported. In sum, the economic effect sizes of interaction terms are similar to, but a little less than, those of the coefficients of the interaction terms in Models 5 and 10.

Robustness Tests

We conducted several robustness tests. First, recent studies indicate that a simple word count analysis of corporate news stories or scoring word frequencies can capture organizational attributes that are otherwise difficult to quantify (Tetlock et al., 2008; Uotila et al., 2009). Thus, we conducted computer-assisted closed-language coding using a computer-aided text analysis (CATA) program to count the appearance of those related terms related to Industry 4.0 orientation to replace our measure for Industry 4.0 orientation for the first robustness test. Second, instead of drawing on the total number of employees to standardize Industry 4.0 orientation, we used an MNE's total assets and total sales to standard Industry 4.0 orientation as our independent variable in the second robustness test. For the third robustness test, we used the ratio of R&D expenditure to total sales instead of the logarithm of the number of applied patents as the measure for headquarters value creation. In our fourth robustness test, we replaced the ratio of advertising and marketing expenditures to total sales with the ratio of advertising and marketing expenditures to total assets as the measure for headquarters value capturing. For our fifth robustness test, we used the ratio of the number of salespersons to the total number of employees instead of the ratio of advertising and marketing expenditures to total sales as the measure for subsidiary value capturing. For our sixth robustness test, we used a larger sample by following the traditional definition of an MNE as "an enterprise that engages in foreign direct investment (FDI) and owns or controls value-adding activities in more than one country" (Dunning & Lundan, 1993: 3). Those six additional model and sample estimations yielded results that were statistically the same as the results of our analyses, including similar *p* values and coefficient sizes as well as similar F-differences in the Wald tests.

Seventh, the importance of Industry 4.0 orientation on upstream and downstream value chain activities can vary significantly by industry. Thus, we re-estimated our models using split samples including (1) the two subsamples of high- versus low-tech industries[15] and (2) only the subsample of the knowledge-intensive industries that are widely acknowledged in the innovation and management literature (Cohen, Nelson, & Walsh, 2000; Hagedoorn & Duysters, 2002; Heeley, Matusik, & Jain, 2007; Prud'homme, 2016; Zaheer, Hernandez, & Banerjee, 2010). The estimation results for the high-tech and the knowledge-intensive industries yielded stronger support for our main and moderating effects in terms of *p* value and coefficients, as well as F-differences in the Wald tests, whereas the results with the low-tech industries yielded statistically unsupported estimations. The subsample tests indicate that the study model holds better in the high-tech and knowledge-intensive industries, which is in line with the core arguments in our study in the context of Industry 4.0.

Eighth, given that our key explanatory variables are at the MNE level while our outcomes are at the subsidiary level, there is a potential issue resulting from an MNE's Industry 4.0 orientation not fully transferred to, or equally accessible by, all foreign subsidiaries. Although we included several control variables in the main analyses to control for this effect to a certain extent, we conducted a robustness test in which we aggregated the data to create proxies of our dependent variables at the MNE level using the information available for this study (e.g., a subset of mostly major MNEs in Korea with their strategically important subsidiaries). According to the MNE level analysis, all of the testable hypotheses at the MNE level (i.e., Hypotheses 1A, 1B, and 1C) are supported as in the main analyses.

Finally, the effects of MNEs' Industry 4.0 orientation and value creation/capturing, as the main and moderator variables, could also vary across countries/regions. So, we compared the study model with those estimated with subsamples from China only and India only as the two largest emerging economies in Asia by including a China dummy versus an India dummy in the model for the three-way interactions of our variables of interest. The results indicate that the main and moderating effects are much stronger in China than in India, and Hypothesis 1b is supported only in China. These results provide valuable insight into country differences in the effects of Industry 4.0 orientation and value creation/capturing for both parents and foreign subsidiaries.[16]

DISCUSSION

As pioneering research on Industry 4.0, this study used a panel dataset to conduct an empirical analysis of the effects of globalization on MNEs' business activities. As far as we know, this is the first empirical study to use firm-level data to test a comprehensive model regarding the effects of Industry 4.0 on firm globalization, and the results offer rich theoretical and managerial implications. This study is timely given the recent rise of Industry 4.0 in the global market and the scarcity of empirical evidence on its outcomes.

The literature offers a preliminary conceptual understanding of the globalization potential of Industry 4.0 (Strange & Zucchella, 2017). A firm with a stronger Industry 4.0 orientation becomes more globally connected within its internal and external networks, resulting in an advanced global organization that serves the market more efficiently (Hofmann & Rüsch, 2017). We advance this conceptual discussion through an empirical investigation into the expansion of the GVC of an MNE's foreign subsidiaries as the outcome of its Industry 4.0 orientation. The results indicate a positive relationship between Industry 4.0 orientation and GVC expansion that is stronger for distribution network globalization than for supplier network expansion. Hence, Industry 4.0 orientation promotes market-based globalization over supply-network globalization by inducing more dependence by downstream value chain members, as anticipated by RDT. This result is in line with our expectations – we reasoned that an MNE with a strong Industry 4.0 orientation is more likely to pre-occupy the market, and that radical innovations and enhanced opportunities for in-house production are likely to encourage firms to retain unique resources within the organization for active market expansion rather than share them with suppliers (Wilkesmann & Wilkesmann, 2018), thereby strengthening downstream value chain members' dependence.

Theoretical Implications

The rapid emergence of Industry 4.0 in various industries raises questions about the future of MNEs' internalization of value-adding activities versus their externalization through integration with external value chain partners worldwide. By considering the intensity of GVC sales (downstream) versus that of GVC purchases (upstream) as the outcome variables – rather than internal transactions – this study offers a snapshot of future GVC relationships under Industry 4.0. As pioneering empirical research, this study recognizes that Industry 4.0, as a bundle of innovations targeting human-less decision-making, is likely to have positive, albeit differential, impacts on the expansions of downstream and upstream GVCs through enhanced market expansion, a value-adding position, and enhanced opportunities for in-house production. Specifically, downstream GVCs will expand faster than upstream GVCs because integrated global partners remain interdependent within the network, while the efficiencies of value-adding and manufacturing activities will be enhanced by Industry 4.0. This will be partly accomplished by the internalization of value-adding activities within the MNE's upstream network, ensuring that core technological resources are retained within the network and leading to disintermediation in some supply chains.

This study contributes to the literature by comparing the functions of headquarters and subsidiaries in realizing an MNE's Industry 4.0 orientation as these often have distinctive roles that affect the allocation of resources between them (Dellestrand, Kappen, & Lindahl, 2020). For a typical MNE, the network of subsidiaries plays a critical role in new product development, manufacturing, and distribution of goods and services. As Industry 4.0 may cause decentralization (Wilkesmann & Wilkesmann, 2018), our findings suggest that headquarters and subsidiaries play different roles in expanding the MNE's presence in the global market.

The study makes a unique contribution to the literature by comparing and contrasting the moderating effects of value creation by headquarters versus subsidiaries. We find that headquarters' value creation leads to the globalization of the distribution network more than that of the supplier network, while subsidiary value creation leads to the expansion of the global supplier network more than that of the distribution network. The results most likely reflect the value of resources generated by the entire MNE network. In line with RDT, we reason that value creation makes an association with an MNE more attractive for other value chain members, which enhances their dependence on it, especially when value creation reflects the MNE's central effort by its headquarters (which has advantages in location and coordination) rather than the decentralized, sporadic efforts by its subsidiaries (Pfeffer & Salancik, 1978). By contrast, the effect of value capturing does not seem to vary between the headquarters and subsidiaries, as most value-capturing activities that exploit the resources generated by Industry 4.0 aim to expand the market through distribution network globalization.

This study also makes unique contributions to the corporate strategy and innovation literature by recognizing the strategic yet innovative nature of Industry 4.0 in the context of Korean MNEs. An MNE and its value chain members can gain unique and unprecedented benefits from the disruptive and hard-to-imitate nature of radical innovations as well as the subsequent synergistic effect of the bundled innovations associated with Industry 4.0. Specifically, the benefits from Industry 4.0 are likely to be far greater than the sum of the potential benefits from individual innovations; however, upstream and downstream value chain members are likely to experience different effects depending on how an MNE arranges its activities.

Our paper uses an RDT lens to clarify how an MNE's Industry 4.0 orientation increases or decreases its reliance on its GVC, thereby addressing the theoretical question of how Industry 4.0 is affecting dependence relationships – the key argument of RDT (Pfeffer & Salancik, 1978; Xia, Ma, Lu, & Yiu, 2014). Specifically, this study pinpoints how the value-adding position and market-expansion advantages conferred by an Industry 4.0 orientation improve an MNE's appropriation regimes within its GVC while leading other firms to depend more heavily on it, expanding the scope of RDT to the emerging phenomenon of Industry 4.0. We believe that this study makes an important theoretical contribution by bridging the stream of RDT literature to the edge of industrial innovations that are emerging globally.

Managerial Implications

Our study offers multiple managerial implications regarding the role of a firm's Industry 4.0 orientation. First, we show that an MNE's Industry 4.0 orientation affects its globalization. A GVC comprises a supplier network (upstream) and a distribution network (downstream), and an MNE's Industry 4.0 orientation has a stronger influence on the globalization of its distribution network (and, therefore, on its global market expansion) than on that of its supplier network. This suggests that by emphasizing Industry 4.0, an MNE can expand its market more effectively and strengthen its market presence. Drawing on RDT, we argue that a firm's visibility, as manifested in its technological leadership in Industry 4.0, can attract more distributors that develop enhanced dependence, allowing it to effectively reach every corner of the global market (Pfeffer & Salancik, 1978; Xia et al., 2014). Also, a strong Industry 4.0 orientation should not dramatically increase the focal MNE's reliance on additional suppliers as doing so would diminish the value of the resources associated with Industry 4.0 orientation.

According to our results, the outcomes of an MNE's Industry 4.0 orientation depend on the roles played by both its headquarters and foreign subsidiaries and, thus, the success of an Industry 4.0 initiative requires commitment from both parts of the MNE. MNE managers should note, however, that the impacts of a value-creation strategy differ between the headquarters and subsidiaries; thus, they should choose a strategic locus of value creation based on whether the MNE wishes to prioritize the globalization of its distribution or supply chain network. If the objective of a value-creation strategy is to strengthen the supplier network, the value creation should be carried out by the subsidiaries. However, if the MNE is more interested in globalizing its distributor network while materializing its Industry 4.0 orientation, value creation should be centralized at the headquarters. The difference is relevant to decisions about resource allocation and the design of organizational structures related to GVC expansion. Meanwhile, unlike value creation, the effect of value capturing does not seem to differ between headquarters and subsidiaries; hence, the location of value capturing between headquarters and subsidiaries does not affect the impact of Industry 4.0 orientation on firm globalization.

Our study results indicate that Industry 4.0 will have differential effects on upstream and downstream value chain activities, thus offering several implications for partnership decisions. A strong Industry 4.0 orientation seems to promote the expansion of the upstream partnership network less than it does the expansion of downstream distribution channels within the GVC for two reasons: First, an Industry 4.0 orientation confers an advantage only to the extent that the MNE can retain core technological knowledge inside its organization and partnership network, thereby strengthening the dependence of its network partners. Therefore, managers should be wary of large upstream networks in which core technological knowledge is shared and the partners' dependence is consequently weakened. Second, an MNE can retain a competitive edge by working with the best partners in the global network. On the downstream side, the connectivity that comes with a strong Industry 4.0 orientation should make it easier, faster, and less costly to expand the distribution network without leaking core technologies to the members, thereby retaining a high level of partner dependence. Collectively, these factors offer different partnership opportunities and implications for potential upstream and downstream GVC members.

Limitations and Future Research Directions

While the current study makes important contributions to the literature, there are opportunities to extend its results. First, this study did not consider the interlinkage between an MNE's GVC and its internal value chain or between an MNE's interfirm and intrafirm trade (although GVCs are closely linked to internal value chains). Furthermore, the differing impact of Industry 4.0 on an MNE's domestic vs. international value chain activities is another promising area of inquiry for IB managers and scholars alike. We hope that future research will consider testing these linkages and impacts if relevant data are available.

Second, this study focused on Industry 4.0 orientation at the MNE level. Therefore, our results cannot answer broader questions about how Industry 4.0 will transform the basic governance structure of the GVC (Foster, Graham, Mann, Waema, & Friederici, 2018). We leave it to future research to investigate the transformation of the GVC governance structure by platform MNEs.

Third, while it is not feasible for one study to evaluate all possible dependent variables of interest, we focused on the subsidiary's sales and purchase intensities. We hope that future research will test other GVC-related variables such as GVC network performance, which is "an indication of (GVC) governance efficiency" (Kano et al., 2020: 615). Moreover, our measurements did not explicitly consider the risk (uncertainty) associated with diversification. Although this study considered an MNE's vertical diversification and geographic diversification to control for their effects in the model, those issues related to diversification across regions/countries warrant future in-depth research.

Fourth, in this study, we focused on subsidiary-level GVC activities. Given that MNE-level GVC ratios cannot reflect the heterogeneity of each subsidiary, subsidiary-level performance measures used in the study helped explore the impact of Industry 4.0 orientation on subsidiary performance. However, future studies could explore the phenomenon using an MNE-level GVC measure to reveal more MNE-level implications. We also encourage future studies to validate our study results using subsidiary-level Industry 4.0 orientation data by employing other potential methodological approaches (e.g., survey or a mixed approach) as such approaches, coupled with strict validation (e.g., reliability and validity assessments), might help identify additional strategic implications of Industry 4.0.

Fifth, our moderators (i.e., value creation and value capturing by headquarters and subsidiaries) did not consider the possibility of external shocks such as the COVID-19 pandemic. External shocks disrupt value chains, and "this disruption is best understood as the interplay between many legitimate actors and a dramatically transformed overall context" (Pananond, Gereffi, & Pedersen, 2020: 435), potentially revealing a GVC's weaknesses (O'Leary, 2020) and its resilience (O'Neil, 2020). We hope that future research can take advantage of the data generated during the COVID-19 pandemic or a similar empirical opportunity. In addition, we operationalized value creation by the headquarters and the subsidiary slightly differently (i.e., the number of applied patents for the headquarters versus the PCN ratio of engineers and R&D personnel for the subsidiary) because of the nature of the data this study relied on. Readers are advised to interpret the results with this in mind.

Finally, in this study, we focused on Korea as the home country of the MNEs, given our study's scope and the characteristics of the home country we described. To generalize and enrich our findings, future research may consider a mixed approach with a sample of MNEs from multiple home countries, including a mix of less-developed and developed economies with diverse cultural and institutional environments. In addition, Korea is well known for its technology-intensive industries (e.g., microelectronics), with its firms highly competitive in international markets. Given their competitive strength in particular industries, Korean MNEs are more likely to realize both value-creation and value-capturing effects by adopting Industry 4.0 as it helps both parents and foreign subsidiaries compete more effectively against their foreign counterparts in host-country markets. Future studies may consider comparing Korean MNEs with those from other countries (e.g., Japan) in the same industry to reveal how the industry composition across countries exerts a difference in accruing the benefits from Industry 4.0 and MNEs' value-creation and value-capturing activities.

CONCLUSION

This study represents a first step toward understanding the trajectory of Industry 4.0 by exploring the effects of an MNE's Industry 4.0 orientation on its globalization outcomes. To scholars and managers, Industry 4.0 is a digitally connected industrial revolution that is driving change and uncertainty (Baldassarre, Ricciardi, & Campo, 2017). As the study results indicate, a strong Industry 4.0 orientation leads to the expansion of an MNE's downstream value chain network more than its upstream network, and the effect is moderated by the location (headquarters vs. subsidiaries) of the two value-generation activities (value creation vs. value capturing). We hope that this study sparks future research that can help managers, value chain members, and consumers prepare for the arriving fourth industrial revolution and its accompanying disruption.

In anticipation of the upcoming changes and turbulence caused by Industry 4.0, in which digital integration connects all value chain members, managers at leading multinational enterprises (MNEs) are scrambling to predict the associated changes in the market. This pioneering study advances our understanding by investigating the impact of an MNE's Industry 4.0 orientation on the globalization of its value chain network. Identifying two types of value-generation activities as potential moderators, namely value creation and value capturing, we compare the moderation effects when these activities are conducted by headquarters versus foreign subsidiaries. We test the proposed model using a panel dataset comprising 5572 subsidiary-year observations from 358 Korean MNEs from 2011 to 2019. The results show that an MNE's Industry 4.0 orientation leads to a more rapid expansion of its distribution network than of its supplier network. Furthermore, value creation by headquarters has a stronger positive impact on the globalization of its distribution network than that of its supplier network, whereas value creation by subsidiaries has a stronger positive impact on the globalization of its supplier network than that of its distribution network. However, value capturing has a stronger impact on the globalization of the MNE's distribution network than that of its supplier network when performed by both locations. This study concludes by discussing the theoretical and managerial implications.

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NOTES

[1]Please see the following article: https://www.inverse.com/innovation/tesla-cheaper-electric-battery.

[2]Please see two news articles: (1) https://nypost.com/2013/09/07/apple-expected-to-sell-iphone-5c-only-in-china/ and (2) https://www.eetimes.com/china-is-the-only-reason-the-iphone-5c-matters.

[3]Please refer to the following analysis report: https://www.rejoiner.com/resources/amazon-recommendations-secret-selling-online.

[4]Please refer to the following analysis report: https://press.aboutamazon.com/news-releases/news-release-details/amazon-and-11st-launch-new-amazon-global-store-korea/.

[5]In this paper, the "internal value chain" is the MNE's internal network, including its subsidiaries and the business units involved in the production and distribution of its products at the global level. The "GVC" is the MNE's global network of external business partners, such as its suppliers and distributors (Gereffi & Fernandez-Stark, 2011: 4).

[6]We used the sample of Korean MNEs (and their foreign subsidiaries only) that must report overseas operations to the Export-Import Bank of Korea, the public organization directly under the Korean Ministry of Economy and Finance. Our dataset includes the list of worldwide investments made by only Korean MNEs, with operations in at least six countries (UNCTAD), and with at least 30% of sales (excluding exports from their home country parents) derived from overseas markets. These Korean MNEs have their foreign subsidiaries located across multiple countries, ranging from a minimum of six countries to a maximum of 82 countries, together covering 84 countries.

[7]http://www3.weforum.org/docs/GRR17_Report_web.pdf.

[8]https://www.files.ethz.ch/isn/159368/global-trends-2030-nic-lo.pdf.

[9]https://www.mckinsey.com/~/media/McKinsey/Business%20Functions/McKinsey%20Digital/Our%20Insights/Disruptive%20technologies/MGI_Disruptive_technologies_Full_report_May2013.pdf.

[10]We thank the anonymous reviewers for their insightful comments on these issues.

[11]For the total number of applied patents, we used non-consolidated data. For advertising intensity, our data sources did not offer non-consolidated data; thus, we used a close proxy by excluding the overseas data for the foreign subsidiaries' advertising and marketing expenditures and total sales from the original consolidated data. We thank an anonymous reviewer for their thoughtful comment on this issue.

[12]We thank an anonymous reviewer's insightful comment on this issue.

[13]Although many models typically offer the possibility of testing whether fixed vs. random effect models work better, econometric manuals (see, for instance, Stata manuals13 at https://www.stata.com/manuals13/xtxttobit.pdf) point out that only parametric (as our sample follows a normal distribution) random effects Tobit models can be estimated reliably. The reasons are i) there does not exist a sufficient statistic allowing the fixed effects to be conditioned out of the likelihood, and ii) unconditional fixed-effects estimates are biased (Wooldridge, 2019).

[14]Table 2 does not report the results of the unconditional models, although we include them in our original estimations.

[15]Following the innovation and management literature (e.g., Heeley, Matusik, & Jain, 2007; Zaheer, Hernandez, & Banerjee, 2010) and OECD Classification of manufacturing industries based on R&D intensities, we categorized high-tech industries as the following manufacturing industries: aircraft and spacecraft, pharmaceuticals, office, accounting and computing machinery, radio, TV, and communications equipment, and medical, precision and optical instruments; meanwhile, we categorized low-tech industries with other manufacturing industries.

[16]We thank an anonymous reviewer for their insightful comments on this issue.

REFERENCES

Adner, R., & Kapoor, R. 2010. Value creation in innovation ecosystems: How the structure of technological interdependence affects firm performance in new technology generations. *Strategic Management Journal,* 31(3): 306–333.

Ai, C., & Norton, E. C. 2003. Interaction terms in logit and probit models. *Economics Letters,* 80: 123–129.

Ancarani, A., Di Mauro, C., & Mascali, F. 2019. Backshoring strategy and the adoption of Industry 4.0: Evidence from Europe. *Journal of World Business,* 54(4): 360–371.

Argyres, N. S., & Silverman, B. S. 2004. R&D, organization structure, and the development of corporate technological knowledge. *Strategic Management Journal,* 25(8–9): 929–958.

Autio, E., Mudambi, R., & Yoo, Y. 2021. Digitalization and globalization in a turbulent world: Centrifugal and centripetal forces. *Global Strategy Journal,* 11(1): 3–16.

Awate, S., Larsen, M. M., & Mudambi, R. 2015. Accessing vs sourcing knowledge: A comparative study of R&D internationalization between emerging and advanced economy firms. *Journal of International Business Studies,* 46(1): 63–86.

Baggs, J., & Brander, J. A. 2006. Trade liberalization, profitability, and financial leverage. *Journal of International Business Studies,* 37(2): 196–211.

Baldassarre, F., Ricciardi, F., & Campo, R. 2017. *The advent of Industry 4.0 in manufacturing industry: Literature review and growth opportunities.* Dubrovnik: University of Dubrovnik.

Baur, C., & Wee, D. 2015. Manufacturing's next act. *McKinsey & Company, 6.*

Beneito, P. 2006. The innovative performance of in-house and contracted R&D in terms of patents and utility models. *Research Policy,* 35(4): 502–517.

Birhanu, A. G., Gambardella, A., & Valentini, G. 2016. Bribery and investment: Firm-level evidence from Africa and Latin America. *Strategic Management Journal,* 37: 1865–1877.
Birkinshaw, J. M. 1997. Entrepreneurship in multinational corporations: The characteristics of subsidiary initiatives. *Strategic Management Journal,* 18(3): 207–229.
Bogers, M., Hadar, R., & Bilberg, A. 2016. Additive manufacturing for consumer-centric business models: Implications for supply chains in consumer goods manufacturing. *Technological Forecasting and Social Change,* 102: 225–239.
Brun, L., Gereffi, G., & Zhan, J. 2019. The "lightness" of Industry 4.0 lead firms: implications for global value chains. In *Transforming industrial policy for the digital age*. Edward Elgar Publishing.
Bunch, D. S., & Smiley, R. 1992. Who deters entry? Evidence of the use of strategic entry deterrence. *Review of Economics and Statistics,* 3: 509–521.
Cantwell, J. 2009. Innovation and information technology in the MNE. *In The Oxford Handbook of International Business (2 ed.).* Oxford University Press.
Cantwell, J. A., & Mudambi, R. 2011. Physical attraction and the geography of knowledge sourcing in multinational enterprises. *Global Strategy Journal,* 1(3–4): 206–232.
Cassiman, B., Perez-Castrillo, D., & Veugelers, R. 2002. Endogenizing know-how flows through the nature of R&D investments. *International Journal of Industrial Organization,* 20(6): 775–799.
Chamberlin, E. 1933. *The theory of monopolistic competition*. Cambridge, MA: Harvard University Press.
Chatterjee, S., Hadi, A. S., & Price, B. 2000. *Regression analysis by example 3*. New York, NY: John Wiley & Sons Inc.
Cheng, B., Ioannou, I., & Serafeim, G. 2014. Corporate social responsibility and access to finance. *Strategic Management Journal,* 35(1): 1–23.
Choi, B., Kumar, M. V. S., & Zambuto, F. 2016. Capital structure and innovation trajectory: The role of debt in balancing exploration and exploitation. *Organization Science,* 27(5): 1183–1201.
Chung, C. C., Park, H. Y., Lee, J. Y., & Kim, K. 2015. Human capital in multinational enterprises: Does strategic alignment matter? *Journal of International Business Studies,* 46(7): 806–829.
Cohen, W. M., Nelson, R. R., & Walsh, J. P. 2000. Protecting their intellectual assets: Appropriability conditions and why US manufacturing firms patent (or not) (No. w7552). National Bureau of Economic Research.
Cui, L., Meyer, K. E., & Hu, 2014. What drives firms' intent to seek strategic assets by foreign direct investment? A study of emerging economy firms. *Journal of World Business*, 49(4): 488–501.
Cuypers, I. R., Hennart, J. F., Silverman, B. S., & Ertug, G. 2021. Transaction cost theory: Past progress, current challenges, and suggestions for the future. *Academy of Management Annals,* 15(1): 111–150.
Delany, E. 2000. Strategic development of the multinational subsidiary through subsidiary initiative-taking. *Long Range Planning,* 33(2): 220–244.
Delios, A., Xu, D., & Beamish, P. W. 2008. Within-country product diversification and foreign subsidiary performance. *Journal of International Business Studies,* 39: 706–724.
Dellestrand, H., Kappen, P., & Lindahl, O. 2020. Headquarter resource allocation strategies and subsidiary competitive or cooperative behavior: Achieving a fit for value creation. *Journal of Organizational Design,* 9(6): 66.
Deloitte, I. 2015. 4.0: Challenges and solutions for the digital transformation and use of exponential technologies. *Report, Deloitte AG*.
Dinh, T. Q., Calabrò, A., Campopiano, G., & Basco, R. 2021. The impact of politically connected CEOs and boards of directors on firm performance: A study of Vietnamese family and nonfamily firms. *Entrepreneurship Theory and Practice*. https://doi.org/10.1177/1042258720985477.
Dunning, J. H., & Lundan, S. M. 1993. *Multinational enterprises and the global economy*. Wokingham: Addison-Wesley.
Dutta, S., Narasimhan, O., & Rajiv, S. 1999. Success in high-technology markets: Is marketing capability critical? *Marketing Science,* 18(4): 547–568.
Emery, T. 2013. Intergenerational transfers and European families: Does the number of siblings matter? *Demographic Research,* 29(10): 247–274.
Eisenhardt, K. M. 1989. Making fast strategic decisions in high-velocity environments. *Academy of Management Journal,* 32(3): 543–576.
Feinberg, S. E., & Gupta, A. K. 2009. MNC subsidiaries and country risk: Internalization as a safeguard against weak external institutions. *Academy of Management Journal,* 52(2): 381–399.
Foster, C., Graham, M., Mann, L., Waema, T., & Friederici, N. 2018. Digital control in value chains: Challenges of connectivity for East African firms. *Economic Geography,* 94(1): 68–86.
Figueiredo, P. N. 2011. The role of dual embeddedness in the innovative performance of MNE subsidiaries: evidence from Brazil. *Journal of Management Studies,* 48(2): 417–440.
Gassmann, O., & Von Zedtwitz, M. 1999. New concepts and trends in international R&D organization. *Research Policy,* 28(2–3): 231–250.
Gawer, A., & Cusumano, M. A. 2014. Industry platforms and ecosystem innovation. *Journal of Product Innovation Management,* 31(3): 417–433.
Gereffi, G., & Fernandez-Stark, K. 2011. *Global value chain analysis: A primer. Center on Globalization, Governance & Competitive-ness (CGGC)*. Duke University, Durham, North Carolina.
Gil, Y., Bong, S., & Lee, J. 2003. Integration model of technology internalization modes and learning strategy: globally late starter Samsung's successful practices in South Korea. *Technovation,* 23(4): 333–347.
Golder, P. N. 2000. Historical method in marketing research with new evidence on long-term market share stability. *Journal of Marketing Research,* 37: 156–172.
Götz, M., & Jankowska, B. 2017. Clusters and Industry 4.0 – do they fit together? *European Planning Studies,* 25: 1633–1653.
Greene, W. H. 2003. *Econometric analysis* (5th ed.). Prentice-Hall: Upper Saddle River, NJ.
Hagedoorn, J., & Duysters, G. 2002. External sources of innovative capabilities: The preference for strategic alliance or mergers. *Journal of Management Studies,* 39(2): 177–188.
Hall, B. H., Jaffe, A. B., & Trajtenberg, M. 2001. The NBER patent citation data file: Lessons, insights and methodological tools. *NBER Working Paper 8498.*
Han, J. K., Kim, N., & Srivastava, R. K. 1998. Market orientation and organizational performance: Is innovation a missing link? *Journal of Marketing,* 62(4): 30–45.
Harrison, J. S., Thurgood, G. R., Boivie, S. B., & Pfarrer, M. D. 2019. Measuring CEO personality: Developing, validating, and testing a linguistic tool. *Strategic Management Journal,* 40(8): 1316–1330.
Harrison, J. S., Thurgood, G. R., Boivie, S. B., & Pfarrer, M. D. 2020. Perception is reality: How CEOs' observed personality influences market perceptions of firm risk and shareholder returns. *Academy of Management Journal,* 63(4): 1166–1195.
Heeley, M. B., Matusik, S. F., & Jain, N. 2007. Innovation, appropriability, and the underpricing of initial public offerings. *Academy of Management Journal,* 50(1): 209–225.
Henard, D. H., & McFadyen, M. A. 2005. The complementary roles of applied and basic research: A knowledge-based perspective. *Journal of Product Innovation Management,* 22(6): 503–514.
Hennart, J.-F. 1991. The transaction costs theory of joint ventures: An empirical study of Japanese subsidiaries in the United States. *Management Science,* 37(4): 483–497.

Herrmann, P., & Nadkarni, S. 2014. Managing strategic change: The duality of CEO personality. *Strategic Management Journal,* 35(9): 1318–1342.
Hofmann, E., & Rüsch, M. 2017. Industry 4.0 and the current status as well as future prospects on logistics. *Computers in Industry,* 89: 23–34.
Hox, J. J. 1995. *Applied multilevel analysis* (2nd ed.). Amsterdam: TT-Publikaties.
Hox, J. J. 2010. *Multilevel analysis: Techniques and applications* (2nd ed.). New York, NY: Routledge Taylor & Francis Group.
Hughes, M., & Morgan, R. E. 2007. Deconstructing the relationship between entrepreneurial orientation and business performance at the embryonic stage of firm growth. *Industrial Marketing Management,* 36(5): 651–661.
Hult, G. T. M., & Ketchen, D. J., Jr. 2001. Does market orientation matter? A test of the relationship between positional advantage and performance. *Strategic Management Journal,* 22(9): 899–906.
Iansiti, M., & Levien, R. 2004. Strategy as ecology. *Harvard Business Review,* 82(3): 68–78.
Jayachandran, S., Kalaignanam, K., & Eilert, A. M. 2013. Product and environmental social performance: Varying effect on firm performance. *Strategic Management Journal,* 34(10): 1255–1264.
Jean, R. J. B., & Kim, D. 2021. Signalling strategies of exporters on internet business-to-business platforms. *Journal of Management Studies,* 58(7): 1869–1898.
Jean, R.-J.B., Kim, D., Zhou, K. Z., & Cavusgil, S. T. 2021. E-platform use and exporting in the context of Alibaba: A signaling theory perspective. *Journal of International Business Studies,* 52: 1501–1528.
Jean, R., Deng, Z., Kim, D., & Yuan, X. 2016. Assessing endogeneity issues in international marketing research. *International Marketing Review,* 33(3): 483–512.
Kache, F., & Seuring, S. 2017. Challenges and opportunities of digital information at the intersection of Big Data Analytics and supply chain management. *International Journal of Operations & Production Management,* 37(1): 10–36.
Kalaignanam, K., Kushwaha, T., & Varadarajan, P. 2008. Marketing operations efficiency and the Internet: An organizing framework. *Journal of Business Research,* 61(4): 300–308.
Kano, L., Tsang, E. W., & Yeung, H. W. C. 2020. Global value chains: A review of the multi-disciplinary literature. *Journal of International Business Studies,* 51: 577–622.
Kao, Y.-F., & Venkatachalam, R. 2021. Human and machine learning. *Computational Economics,* 57: 889–909.
Kenney, M., & Zysman, J. 2016. The rise of the platform economy. *Issues in Science and Technology,* 32(3): 61–69.
Knight, G. A., & Kim, D. 2009. International business competence and the contemporary firm. *Journal of International Business Studies,* 40(2): 255–273.
Kogut, B., & Singh, H. 1988. The effect of national culture on the choice of entry mode. *Journal of International Business Studies,* 19(3): 411–432.
Kovács, G., & Kot, S. 2016. New logistics and production trends as the effect of global economy changes. *Polish Journal of Management Studies,* 14(2): 115–126.
Krippendorff, K. 1980. *Content analysis: An introduction to its methodology*. Newbury Park, CA: Sage.
Kühl, N., Goutier, M., Baier, L., Wolff, C., & Martin, D. 2020. *Human vs. supervised machine learning: Who learns patterns faster*? Preprint submitted to arXiv. December 8, 2020.
Lanz, R., & Miroudot, S. 2011. *Intra-firm trade: Patterns, determinants and policy implications*. OECD Trade Policy Working Papers, 114: 1–76.
Lasi, H., Fettke, P., Kemper, H.-G., Feld, T., & Hoffmann, M. 2014. Industry 4.0. *Business & Information Systems Engineering,* 6(4): 239–242.
Lavie, D., & Rosenkopf, L. 2006. Balancing exploration and exploitation in alliance formation. *Academy of Management Journal,* 49(4): 797–818.
Lee, J. Y., Jiménez, A., Yang, Y. S., & Song, Y. 2020. Political risk, internal versus global value chain knowledge, and subsidiary operational integration. *Global Strategy Journal,* 10(3): 444–472.
Lee, J., Kao, H.-A., & Yang, S. 2014. Service innovation and smart analytics for Industry 4.0 and big data environment. *Procedia CIRP,* 16: 3–8.
Lee, S.-H., Shin, H.-W., & Lee, J. Y. 2015. *Operational flexibility, cultural diversity, and foreign subsidiary divestment*. Paper presented at the annual conference of Academy of Management, Vancouver, Canada.
Lepak, D. P., Smith, K. G., & Taylor, M. S. 2007. Value creation and value capture: A multilevel perspective. *Academy of Management Review,* 32(1): 180–194.
Liu, H., Yang, J. Y., & Augustine, D. 2018. Political ties and firm performance: The effects of proself and prosocial engagement and institutional development. *Global Strategy Journal,* 8: 471–502.
Lu, Y., Shi, H., Luo, W., & Liu, B. 2018. Productivity, financial constraints, and firms' global value chain participation: Evidence from China. *Economic Modelling,* 73: 184–194.
Luo, X., & Homburg, C. 2008. Satisfaction, complaint, and the stock value gap. *Journal of Marketing,* 72(4): 29–43.
Luo, Y. 2021. New OLI advantages in digital globalization. *International Business Review*, 101797.
Maine, E., & Garnsey, E. 2006. Commercializing generic technology: The case of advanced materials ventures. *Research Policy,* 35(3): 375–393.
Magnusson, P., & Boggs, D. J. 2006. International experience and CEO selection: An empirical study. *Journal of International Management,* 12(1): 107–126.
Magnusson, P., Westjohn, S. A., & Boggs, D. J. 2009. Order-of-entry effects for service firms in developing markets: An examination of multinational advertising agencies. *Journal of International Marketing,* 17(2): 23–41.
Makino, S., & Neupert, K. E. 2000. National culture, transaction costs, and the choice between joint venture and wholly owned subsidiary. *Journal of International Business Studies,* 31(4): 705–713.
Makri, M., & Lane, P. J. 2007. A search theoretic model of productivity, science and innovation. *R&D Management,* 37(4): 303–317.
Mizik, N., & Jacobson, R. 2003. Trading off between value creation and value appropriation: The financial implications of shifts in strategic emphasis. *Journal of Marketing,* 67: 63–76.
Mowery, D. C., Sampat, B. N., & Ziedonis, A. A. 2002. Learning to patent: Institutional experience, learning, and the characteristics of U.S. university patent after the Bayh-Dole Act, 1981–1992. *Management Science,* 48(1): 73–89.
Mudambi, R. 2008. Location, control and innovation in knowledge-intensive industries. *Journal of Economic Geography,* 8: 699–725.
Müller, J. M., Kiel, D., & Voigt, K.-I. 2018. What drives the implementation of Industry 4.0? The role of opportunities and challenges in the context of sustainability. *Sustainability,* 10(1): 247.
Nadkarni, S., & Herrmann, P. 2010. CEO personality, strategic flexibility, and firm performance: The case of the Indian business process outsourcing industry. *Academy of Management Journal,* 53(5): 1050–1073.
Nelson, R. R. 2006. Reflections of David Teece's "Profiting from technological innovation…." *Research Policy,* 35(8): 1107–1109.
Nikkei. 2020. *A research on the market shares of major products and services in 2019*. August 13, 2020.
Novelli, E. 2010. As you sow, so shall you reap: General technologies and entry into new product subfields in the face of technological uncertainty. In *DRUID conference*.
Oh, J., & Rhee, S. 2008. The influence of supplier capabilities and technology uncertainty on manufacturer supplier collaboration: A study of the Korean automotive industry.

International Journal of Operations & Production Management, 28(6): 490–517.
Ofek, E., & Sarvary, M. 2003. R&D, marketing, and the success of next-generation products. *Marketing Science,* 22(3): 355–370.
O'Leary, L. 2020. The modern supply chain is snapping. *The Atlantic*, March 26.
O'Neil, S. K. 2020. How to pandemic-proof globalization: Redundancy, not re-shoring, is the key to supply chain security. *Foreign Affairs*. https://www.foreignaffairs.com/articles/2020-04-01/how-pandemic-proofglobalization.
Ostergard, R. L., Jr. 2000. The measurement of intellectual property rights protection. *Journal of International Business Studies,* 31(2): 349–360.
Pananond, P., Gereffi, G., & Pedersen, T. 2020. An integrative typology of global strategy and global value chains: The management and organization of cross-border activities. *Global Strategy Journal,* 10: 421–443.
Park, G., Schwartz, H. A., Eichstaedt, J. C., Kern, M. L., Kosinski, M., Stillwell, D. J., … Seligman, M. E. P. 2015. Automatic personality assessment through social media language. Journal of Personality and Social Psychology, 108(6): 934–952.
Pattnaik, C., & Lee, J. Y. 2013. Distance and divestment of Korean MNC affiliates: The moderating role of entry mode and experience. *Asia Pacific Business Review,* 20(1): 174–196.
Petrin, A., & Train, K. 2010. A control function approach to endogeneity in consumer choice models. *Journal of Marketing Research,* 47(1): 3–13.
Pfeffer, J., & Salancik, G. R. 1978. *The external control of organizations: A resource Dependence perspective*. New York: Harper & Row.
Porter, M. E., & Heppelmann, J. E. 2014. How smart, connected products are transforming competition. *Harvard Business Review,* 92(11): 64–88.
Provan, K. G., Beyer, J. M., & Kruytbosch, C. 1980. Environmental linkages and power in resource-dependence relations between organizations. *Administrative Science Quarterly,* 25(2): 200–225.
Rabe-Hesketh, S., & Skrondal, A. 2012. *Multilevel and longitudinal modeling using Stata* (3rd ed.). STATA Press: Cambridge, MA.
Raudenbush, S. W., & Bryk, A. S. 2002. *Hierarchical linear models: Applications and data analysis methods* (2nd ed.). Sage: Thousand Oaks, CA.
Reeb, D., Sakakibara, M., & Mahmood, I. P. 2012. From the editors: Endogeneity in international business research. *Journal of International Business Studies,* 43(3): 211–218.
Reischauer, G. 2018. Industry 4.0 as policy-driven discourse to institutionalize innovation systems in manufacturing. *Technological Forecasting and Social Change,* 132: 26–33.
Rothaermel, F. T. 2001. Incumbent's advantage through exploiting complementary assets via interfirm cooperation. *Strategic Management Journal,* 22(6–7): 687–699.
Rothaermel, F. T., & Deeds, D. L. 2004. Exploration and exploitation alliances in biotechnology: A system of new product development. *Strategic Management Journal,* 25(3): 201–221.
Ryan, P., Giblin, M., Andersson, U., & Clancy, J. 2018. Subsidiary knowledge creation in co-evolving contexts. *International Business Review,* 27(5): 915–932.
Shane, S. 2001. Technology regimes and new firm formation. *Management Science,* 47(9): 1173–1190.
Shenkar, O. 2001. Cultural distance revisited: Towards a more rigorous conceptualization and measurement of cultural differences. *Journal of International Business Studies,* 32(3): 519–535.
Slangen, A. H. L., & van Tulder, R. J. M. 2009. Cultural distance, political risk, or governance quality? Towards a more accurate conceptualization and measurement of external uncertainty in foreign entry mode research. *International Business Review,* 18: 276–291.
Soh, P. H. 2010. Network patterns and competitive advantage before the emergence of a dominant design. *Strategic Management Journal,* 31(4): 438–461.
Stata. 2017. *Stata 15 user's guide*. College Station, TX: Stata Press.
Stock, J., & Yogo, M. 2005. Testing for weak instruments in linear IV regression. In D. W. K. Andrews (Ed.), *Identification and inference for econometric models*. New York: Cambridge University Press.
Strange, R., & Zucchella, A. 2017. Industry 4.0, global value chains and international business. *Multinational Business Review,* 25(3): 174–184.
Sturgeon, T. J. 2021. Upgrading strategies for the digital economy. *Global Strategy Journal,* 11(1): 34–57.
Sung, T. K. 2018. Industry 4.0: A Korea perspective. *Technological Forecasting and Social Change,* 132: 40–45.
Swaminathan, V., Murshed, F., & Hulland, J. 2008. Value creation following merger and acquisition announcements: The role of strategic emphasis alignment. *Journal of Marketing Research,* 45(1): 33–47.
Teece, D. 1986. Profiting from technological innovation: Implications for integration, collaboration. *Licensing and Public Policy. Research Policy,* 15(6): 285–305.
Teece, D. J. 2007. Explicating dynamic capabilities: The nature and microfoundations of (sustainable) enterprise performance. *Strategic Management Journal,* 28(13): 1319–1350.
Tetlock, P. C., Saar-Tsechansky, M., & Macskassy, S. 2008. More than words: Quantifying language to measure firms' fundamentals. *Journal of Finance,* 63(3): 1437–1467.
Ulrich, D., & Barney, J. B. 1984. Perspectives in organizations: Resource dependence, efficiency, and population. *Academy of Management Review,* 9(3): 471–481.
Un, C. A., & Rodríguez, A. 2018. Local and global knowledge complementarity: R&D collaborations and innovation of foreign and domestic firms. *Journal of International Management,* 24(2): 137–152.
UNCTAD 2020. *World Investment Report 2020: International production beyond the pandemic*. New York: United Nations Publications.
Uotila, J., Maula, M., Keil, T., & Zahra, S. A. 2009. Exploration, exploitation, and financial performance: Analysis of S&P 500 corporations. *Strategic Management Journal,* 30(2): 221–231.
Wang, Z., Wei, S.-J., Yu, X., & Zhu, K. 2017. *Measures of participation in global value chains and global business cycles*. National Bureau of Economic Research (NBER) Working Paper Series No. 23222: 1-34. Cambridge, MA. http://www.nber.org/papers/w23222.
Wilkesmann, M., & Wilkesmann, U. 2018. Industry 4.0 – organizing routines or innovations? Very Informal Newsletter on Library Automation. *VINE Journal of Information and Knowledge Management Systems,* 48(2): 238–254.
Williamson, O. E. 1975. *Markets and Hierarchies: Analysis and antitrust implications*. New York: Free Press.
Williamson, O. E. 1985. *The economic institutions of capitalism*. New York: Free Press.
Wooldridge, J. M. 2010. *Econometric analysis of cross section and panel data* (2nd ed.). Cambridge, MA: MIT Press.
Wooldridge, J. M. 2016. *Introductory econometrics: A modern approach* (6th ed.). Boston, MA: Cengage Learning.
Wooldridge, J. M. 2019. Correlated random effects models with unbalanced panels. *Journal of Econometrics,* 211(1): 137–150.
Xia, J., Ma, X., Lu, J. W., & Yiu, D. W. 2014. Outward foreign direct investment by emerging market firms: A resource dependence logic. *Strategic Management Journal,* 35: 1343–1363.
Xiao, C., Petkova, B., Molleman, E., & van der Vaart, T. 2019. Technology uncertainty in supply chains and supplier involvement: The role of resource dependence. *Supply Chain Management: an International Journal.,* 24(6): 697–709.

Yamin, M., & Otto, J. 2004. Patterns of knowledge flows and MNE innovative performance. *Journal of International Management,* 10(2): 239–258.
Yin, Y., Stecke, K. E., & Li, D. 2018. The evolution of production systems from Industry 2.0 through Industry 4.0. *International Journal of Production Research*, 56(1-2): 848-861
Youtie, J., Iacopetta, M., & Graham, S. 2008. Assessing the nature of nanotechnology: Can we uncover an emerging general purpose technology? *Journal of Technology Transfer,* 33(3): 315–329.
Zaheer, A., Hernandez, E., & Banerjee, S. 2010. Prior alliances with targets and acquisition performance in knowledge-intensive industries. *Organization Science,* 21(5): 1072–1091.
Zhu, F., & Liu, Q. 2018. Competing with complementors: An empirical look at Amazon.com. *Strategic Management Journal,* 39(10): 2618–2642.

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