The role of Subsidiaries from Multinational Enterprises in the digital era

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ABSTRACT

International Business theories and models that address how multinationals organize their international operations in terms of configuration, coordination and the role of their subsidiaries were generated during the third industrial revolution in the second half of the 20th century and the first decade of the 21st century. The purpose of this paper is to contribute to the understanding of Multinational Enterprises considering the Digital Transformation, or Industry 4.0. In this theory-building paper, we start with a taxonomy for plant roles from the Operations Management research field. We review the literature on international manufacturing networks and their plant roles, proceed with the Digital Transformation of Industry 4.0, and search academic and commercial literature to find its effects on Multinational Enterprises. Based on this literature review, we develop a set of propositions and an analytical model that support new modes of configuration and coordination not foreseen by frameworks built during the third industrial revolution. The paper offers a renewed taxonomy for the role of a subsidiary of a Multinational Enterprise in the digital era. We are starting to empirically test the model, its propositions and the proposed taxonomy using the case study methodology at Multinational Enterprises operating in Brazil.

Keywords: Industry 4.0, Multinational Enterprise, International Manufacturing Network, Cyber-Physical System, Digital Platform.

1 INTRODUCTION

In the International Business (IB) field the theories and models that address how multinationals organize their international operations in terms of configuration, coordination and the role of subsidiaries were generated before the advent of Digitalization and Industry 4.0 (I4.0), during the 1990s and 2000s (Bartlett & Ghoshal, 1989; Birkinshaw & Morrison, 1995; Demeter, 2017; Ferdows, 1997; Rugman, Verbeke & Yuan, 2011). A point that has been neglected so far is that digitalization/digitization may drive MNEs to reconfigure, implement novel coordination mechanisms, and redefine the role of their subsidiaries. Despite issues like backshoring (bringing back to the home country previously offshored operations), servitization (changing the strategic focus of the organizational unit from producing to servicing), and centralization (re-concentrating decision making at the headquarters or some few subsidiaries) having already been addressed in the extant literature (Brennan et al., 2015; Kinkel, 2012, 2014; Strange & Zuchella, 2017), these studies do not elucidate the impacts that digitalization/digitization and I4.0 play in the way in which MNEs may reorganize their subsidiaries' networks. This is the question that drives this study.

The taxonomies for subsidiary roles proposed in the extant literature rely on two independent factors. The first one is the strategic reason to locate a subsidiary in a specific place and the second one is the capabilities or activities carried out at each location (Bartlett & Ghoshal, 1989; Birkinshaw & Morrison, 1995; Demeter, 2017; Feldmann, Olhager, Fleet & Shi, 2013; Ferdows, 1997; Rugman et al., 2011; Vereecke & van Dierdonck, 2002). This paper investigates how and why Digital Transformation might change the above-mentioned factors, creating new configurations and coordination modes, resulting in a new taxonomy for plant roles.

In this study, we use Kasra Ferdows' taxonomy as a starting point (Ferdows, 1997), a model widely used in Operations Management (OM) (Demeter, 2017; Feldmann et al., 2013; Ferdows, 1997; Vereecke & van Dierdonck, 2002) with clear similarities in relation to Birkinshaw's model (Birkinshaw & Morrison, 1995), which is more visible to IB researchers. In this conceptual study, we start by recollecting the extant literature to synthesize the premises and the rationale attributed to multinationals as they develop their International Manufacturing Networks (IMNs): what criteria for configuration, which mechanisms for coordination and what role attributed to subsidiaries in different locations. Then we review the literature on digitalization and I4.0 to highlight their potential impacts on the roles of subsidiaries, characterized by the strategic reason to locate each subsidiary and the capabilities or activities carried out at each location. By contrasting those two bodies of knowledge, we were able to identify potential changes brought about by digitalization/digitization. Analyzing selected cases extracted from sources like academic and business literature, press releases, MNEs' websites, and reports from consulting firms, we consolidated in 5 propositions related to new forms of configuration and coordination, and a new taxonomy, derived from Ferdows' previous one.

The phenomenon of Digital Transformation, also known as Industry 4.0 (I4.0), has touched almost every aspect of human life (Schwab, 2017). In what concerns the organization and management of productive activities, digitalization/digitization creates the possibility to replicate the physical world in the virtual space, online and in real-time, thus creating new possibilities to integrate machines, men and organizations (Kagermann, Helbig, Hellinger & Wahlster, 2013; Schwab, 2017). New digital technologies are expected to enable firms to carry management and execution activities for the same operation from different physical locations in their networks, thanks to digital technologies like Cyber-Physical Systems (CPS) and digital platforms that materialize the integration of the physical and digital worlds. Before I4.0, such activities had to be carried at a single physical location, as described by Bartlett & Ghoshal (1989), Birkinshaw & Morrison (1995), Ferdows (1997), and Rugman et al. (2011). The execution of operations tends to disperse and locate closer to markets or knowledge sources, providing faster response and higher flexibility, while the management activities tend to concentrate on one or a few strategic locations. As digital technologies provide real-time synchronization between the physical and digital environments, centralized management and dispersed execution result in scale effects and better network coordination. Therefore, the traditional factors used to define plant roles, the strategic reason to locate a subsidiary and the capabilities or activities carried out at each location, may no longer be enough for that purpose. What seems to be the new rationale is that the introduction of I4.0 technologies changes the logic by which plant roles are defined by altering the possible activities carried at a subsidiary, consequently creating new types of subsidiaries not foreseen in the traditional models and dispensing other types that no longer exist in the I4.0 world. A new factor, the digital maturity of the subsidiary, is incorporated into the model in order to reflect this new reality, originating a taxonomy for plant roles in the digital era.

We are starting the empirical part by testing the propositions and new taxonomy in at least seven firms, where we expect to generate between ten and fifteen case studies. All the firms are MNEs that operate in Brazil from different countries of origin, including Brazilian MNEs. They also belong to different sectors like the Automotive Industry, Equipment and Systems Manufacturers, Fast-Moving Consumer Goods (FMCG) and the Chemical Industry. All companies are large, some of them with several operations that may turn into more than one case, given the different roles that each one assumes in their respective IMNs.

We offer the following main contributions in this article. The first one is to reconcile Global Operations Management with the undergoing Digital Transformation called Industry 4.0 (I4.0), by means of explaining how digital technologies like cyber-physical systems (CPS) and digital platforms influence the two factors that characterize plant roles, IMN configuration, and IMN coordination, in ways that were not foreseen in the original model from Ferdows (Ferdows, 1997). This contribution can also be extended to the IB research field since there are similarities between the traditional factors that determine the configuration and coordination of an IMN in OM and of an MNE network of subsidiaries in IB. The second contribution is to provide an updated plant taxonomy for MNE subsidiaries in the digital era.

The remainder of the article proceeds as follows: In Section 2 we build the literature review of global operations focusing IMNs, and I4.0 in terms of its enabling technologies; in Section 3 we analyze the intersection of both research streams in the literature, build the propositions and close with the analytical model; our discussion in Section 4 offers a new taxonomy for plant roles in the digital era; and in Section 5 we conclude the article with a discussion of the main contributions, limitations, and future research opportunities.

2 LITERATURE REVIEW

2.1 Plant role, Configuration, and Coordination of IMNs

OM approaches global operations from two perspectives: IMNs are used to study structural and infrastructural decisions at the plant level, as well as configuration and coordination issues for the network level, thus providing a firm internal perspective, while value networks fit better to analyze end-to-end supply chain decisions from a firm external perspective

(Rudberg & Olhager, 2003; Demeter, 2017). In this paper, we use the IMN perspective to analyze global operations at both the plant and network levels. We use the definition from Cheng, Farooq & Johansen (2015, p.393) for the IMN: “a coordinated aggregation (network) of intra-firm plants located in different places”. We also define manufacture activities broadly as those related to production or service delivery, Research and Development (R&D), logistics, marketing, sales, and administrative support functions, in line with Rugman et al. (2011) and Fleury & Fleury (2012). A plant may execute one or several of these activities, according to this definition. Service delivery is also included in the definition to cope with servitization, a phenomenon that will be discussed later under 3.1.2. The broader definition of manufacture activities is also useful to compare the plants described in OM to the subsidiaries from IB.

In his seminal article, Kasra Ferdows (Ferdows, 1997) proposes a framework and plant role taxonomy that is widely recognized in the OM literature (Demeter, 2017; Feldmann et al., 2013; Ferdows, 1997; Vereecke & van Dierdonck, 2002). Ferdows (1997) argues that the configuration of an International Manufacturing Network (IMN) is determined by the strategic reason for locating each of the participating plants, while the IMN coordination is determined by the competences or activities that each plant executes. Different combinations of these two factors in a single location determine the plant role within the IMN, according to the taxonomy proposed by Ferdows (1997). Several authors confirm, discuss, criticize and elaborate on Ferdows’ model, although his two factors and taxonomy remain the same (Cheng, Farooq & Johansen, 2011; Feldman et al., 2013; Meijboom & Vos, 2004; Rudberg & Olhager, 2003; Vereecke & Van Dierdonck, 2002).

The first factor addressed by Ferdows (1997) is the strategic reason for site location. Ferdows (1997) lists three main reasons that justify the location of a plant. The first one is access to the low-cost production, a major driver for offshoring operations in the second half of the 20th century (Kinkel, 2012), also described in economic-geography and International Business theories like the Product Life Cycle (Vernon, 1966) and the eclectic paradigm (Dunning, 1988, 2015). The second is the access to knowledge and capabilities, a reason that was criticized by Rugman & Nguyen (2014) but gained impulse with the dawn of emerging market multinational enterprises, since these firms lacked critical knowledge and would search for it in developed markets, either by building greenfield plants there or by merging with or acquiring companies (Cuervo-Cazurra, 2012; Dunning, 1998; Luo & Tung, 2007; Ramamurti & Singh, 2009; Williamson, Ramamurti, Fleury & Fleury, 2012). Finally, the third reason identified by Ferdows (1997) is the proximity to markets, in line with the internalization theory (Buckley & Casson, 1976, 1998, 2019), the incremental theory (Johanson & Vahlne, 1977, 2009) and the eclectic paradigm (Dunning 1988, 1998).

In comparison to the eclectic paradigm from Dunning (1998), widely used in the IB literature, which lists four locational factors: a) resource seeking; b) market seeking; c) efficiency-seeking: d) strategic asset seeking, Ferdows' classification merges resource seeking and efficiency-seeking into access-to-low-cost-production strategic reason to locate, while proximity to market matches market seeking and search for knowledge and capabilities resembles Dunning's strategic asset seeking. OM literature challenges Ferdows' (1997) strategic-reason-to-locate factor, tests it empirically and confirms its validity. Feldmann & Olhager (2013), Feldmann et al. (2013) and Vereecke & Van Dierdonck (2002) use several different drivers for site location like access to natural resources, access to energy, low-cost labor, proximity to industry clusters, proximity to suppliers or competitors, infrastructure among others, but are always able to factor them down to Ferdows' three strategic reasons for site location.

For his second independent factor that defines plant roles, Ferdows (1997) describes a hierarchy of activities that sites can execute, calling them “competences”. The lower level of activity is “production” while the upper level is “global hub for product or process knowledge”. Intermediate levels add competences like technical process, procurement, logistics, supplier’s development, process development, improvement recommendations, product development and global market supply (Ferdows, 1997). Ferdows’ hierarchy of activities is criticized in several ways. The terms “activity” and “competency” are used interchangeably; the classification lacks empirical evidence; and there are plants that retain higher responsibilities without necessarily executing lower ones (Feldmann & Olhager, 2013; Meijboom & Vos, 2004; Vereecke & Van Dierdonck, 2002). Authors favor the term “competences” to describe their hierarchy, while they clarify that it reflects actual activities of the plant, not just the existence of an in-house competency (Feldmann & Olhager, 2013; Meijboom & Vos, 2004; Vereecke & Van Dierdonck, 2002). We will use the term “activity” to describe actual tasks executed by the site, while competency will be used to describe an existing capability at the site that may be at use or at the disposal of the IMN to be used. The empirical evidence to build the hierarchy of activities is gained through interviews with academics and practitioners from actual IMNs (Feldmann & Olhager, 2013; Meijboom & Vos, 2004; Vereecke & Van Dierdonck, 2002). In common, they start at production, ascend to local management, development and close with responsibilities for the entire network (Feldmann & Olhager, 2013).

Based on the combination of the strategic reason to locate and the capabilities found in a Plant, Ferdows (1997) presents a taxonomy composed of six different roles, depicted in Figure 1. The taxonomy proposed by Ferdows (1997) remains untouched in the OM literature, although it was built during the late 1990s during the third industrial revolution.

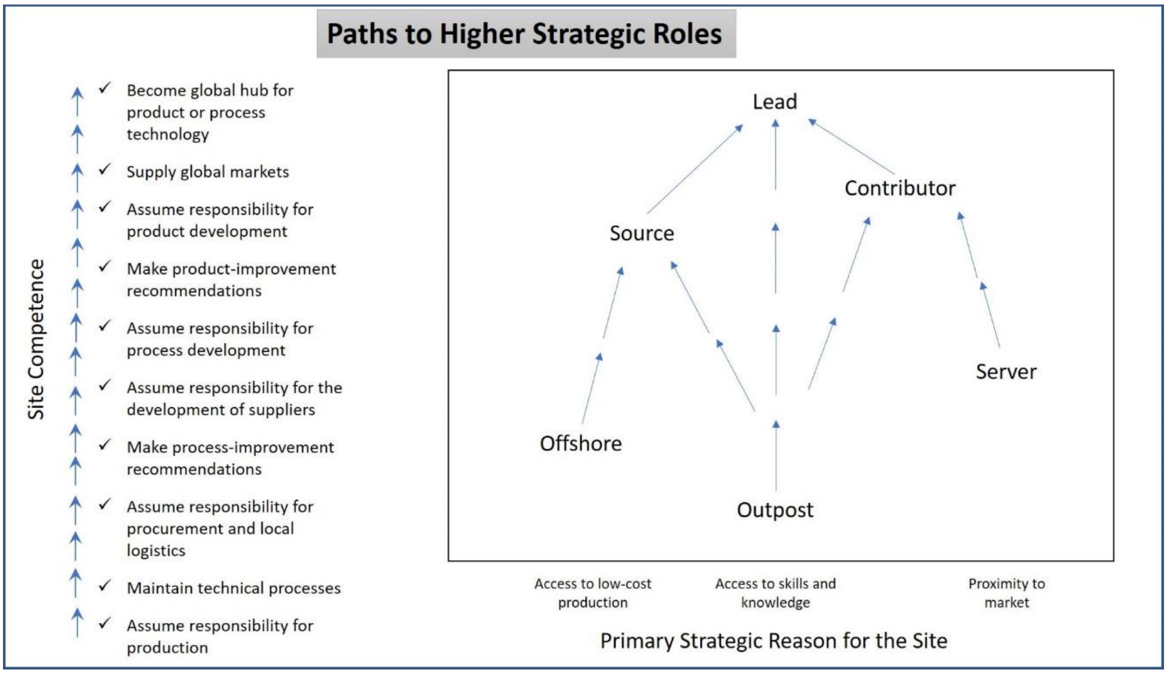

Figure. 1 Ferdows model for plant roles. Source: Ferdows (1997)

The types of plants that have a primary strategic reason to locate based on access to low-cost production are Offshore and Source Plants (Ferdows, 1997). Offshore Plants assume responsibility for production only. They consist of intensive labor and local production management activities. All other activities like procurement of materials, production planning, product and process development, are executed elsewhere in the IMN. The disadvantages of remote coordination, limited by the speed of communications, are compensated by the lower cost of production. Source Plants, on the other hand, progressively assume other responsibilities like process, procurement, logistics, and eventually simple process and product improvement recommendations. This arrangement overcomes the disadvantages of Offshore Plants but requires expensive resources at Source Plants (Ferdows, 1997).

Server and Contributor Plants locate next to markets. They differ from the low-cost operations in the sense that they are in touch with the markets they serve, therefore more sensitive to local adjustments to products (Ferdows, 1997). Server Plants typically focus on local production but generally have some freedom to adapt products to local markets. Contributor Plants locate in strategic markets, have proximity with the leader of the IMN, usually contributing to product, process and system upgrades.

Outpost Plants seek access to skills and knowledge. They locate in knowledge-intensive areas in order to capture those to the firm. In general, these are innovative ecosystems close to universities, suppliers and technical centers. Outposts, according to Ferdows (1997), would also have a secondary reason to locate, so that production is justified in that location. Also located where access to skills and knowledge is intense are the lead Plants. They lead the IMN and are global hubs for process and product knowledge.

Developed during the third industrial revolution in the late 1990s, Ferdows' model has remained untouched since then. Next, we look at the changes brought by the fourth industrial revolution or I4.0 that change the flow of data and therefore the way firms operate.

2.2 Digital Transformation, Industry 4.0, and digital technologies

Digital Transformation, Industry 4.0, fourth industrial revolution are widely used terms to denote recent developments that are changing the face of the world as we know it in the same way previous industrial revolutions did in the past. The first industrial revolution took place by the end of the 18th century with the invention of the steam machine that moved the industry from the home to the factory environment. The second one introduced the electrification, the use of the production line and marked the birth of operations management through Frederick Winslow Taylor and his "Principles of Scientific Management in 1911 (Taylor, 1998), later improved by Taiichi Ohno with the Toyota Production System (Yin, Stecke & Li, 2018). The third industrial revolution, also known as industry 3.0, introduced automation and digitalization that greatly improved productivity. Robots, computer systems, and early internet tools characterize this revolution (Liao, Loures, Deschamps, Brezinski & Venâncio, 2018; Rodrigues, de Jesus & Schützer, 2016; Schwab, 2017).

The fourth industrial revolution integrates the physical, digital and biological worlds (Schwab, 2017). It is also known as Industry 4.0, although the latter does not encompass the biological integration of worlds (Drath & Horch, 2014; Lichtblau et al., 2015; Barbosa, Baiso & Almeida, 2018). One of its distinctive features is the level of systems integration. While in industry 3.0 system integration was slow with manual data handling and a hierarchical structure, in Industry 4.0 systems are integrated real-time using automated data handling, cloud repositories and a network structure described in the Reference Architecture Model Industry 4.0 – RAMI4.0 (Adolphs et al., 2015).

Several technologies combine to enable I 4.0, like cheap sensors to collect data, the Internet of Things and Services to transmit it, cloud computing to store a large amount of data, big data analysis and artificial intelligence that enable automated simulation, forecast and decision making. Together, they allow firms to build digital shadows or twins that represent the physical systems. Digital and physical counterparts instantly update each other, forming a Cyber-Physical System (CPS) (Kagermann et al., 2013; Scwhab, 2017; Strange & Zuchella, 2017).

The building block of a CPS is an Industry 4.0 component, or CI4.0 (Adolphs et al., 2015). A CI4.0 may be any object, be it a product part, a machine, a production line or even a full plant in the manufacturing network. Each CI4.0 at each level is separated into two pieces, physical and digital. While the physical part of a CI4.0 represents the execution in the real world, the digital piece represents an administration shell that allows managing the component from any part of the world, like shown in Figure 2. The advantage is that while traditional digital systems present a delay in communicating between adjacent levels due to manual interactions, lack of standardization and the hierarchical structure to communicate, in Industry 4.0 a change at the shop floor level is instantly updated globally at all levels, including corporate systems, because all data is stored in a common repository in a standard format and all systems are able to access it (Adolphs et al., 2015).

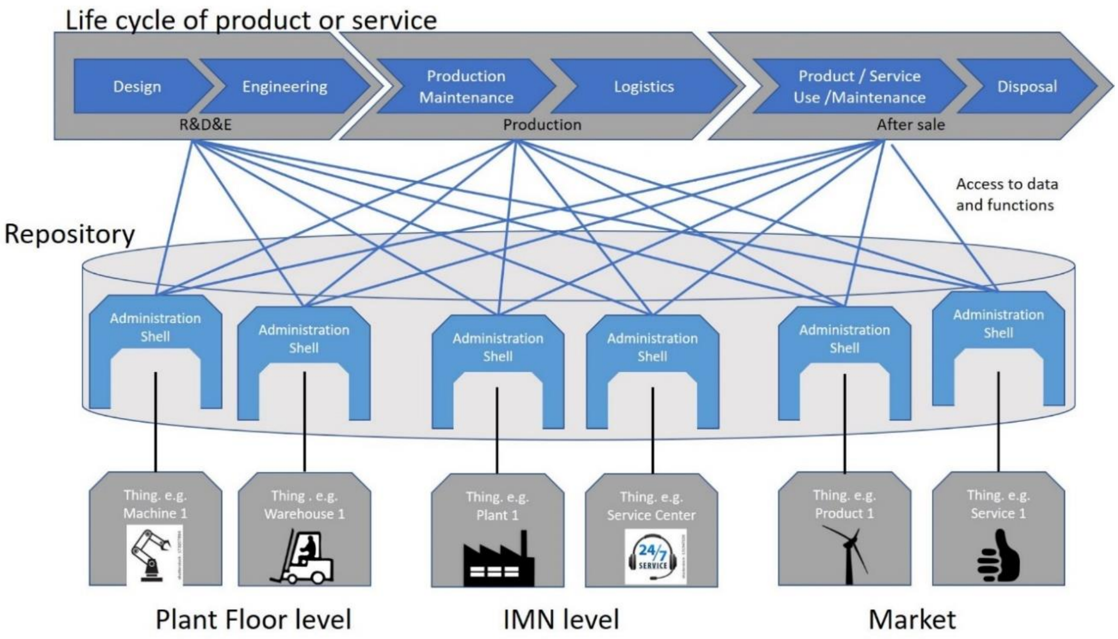

Figure 2. Industry 4.0 components in CPS of an IMN. Source: Adapted from Adolphs et al. (2015)

The integration of systems that enable CPS to work is made possible thanks to digital platforms. Gawer (2014) proposes three types of digital platforms depending on their use, as presented in Figure 3: a) Internal platforms are used within the firm to meet the needs from systems at different levels, plants, and functions inside the IMN of the firm, has closed interfaces, capabilities are kept inside the firm and its governance is obtained by managerial authority; b) economic or supply chain platforms that support the business ecosystem formed by suppliers, customers, clients and end-users, has interfaces and capabilities maintained within the supply chain, with governance determined by contractual relationships; and c) industrial platforms, used to build innovation ecosystems, intended for research and development of products, services, systems and applications, open to any contributor like research institutes, universities, complementors, users and supply chain partners, with its governance defined by the ecosystem itself (Gawer, 2014). Internal platforms support the IMN to expedite the network coordination of "intra-firm plants located in different places" (Cheng et al., 2015: 393). Economic platforms enable plants to engage with their supply chain partners and improve capture value in their business ecosystem, while the industry platform provides the innovation ecosystem with a faster and broader environment for value creation (Gawer, 2014; De Vasconcelos Gomes, Facin, Salerno & Ikenami, 2018).

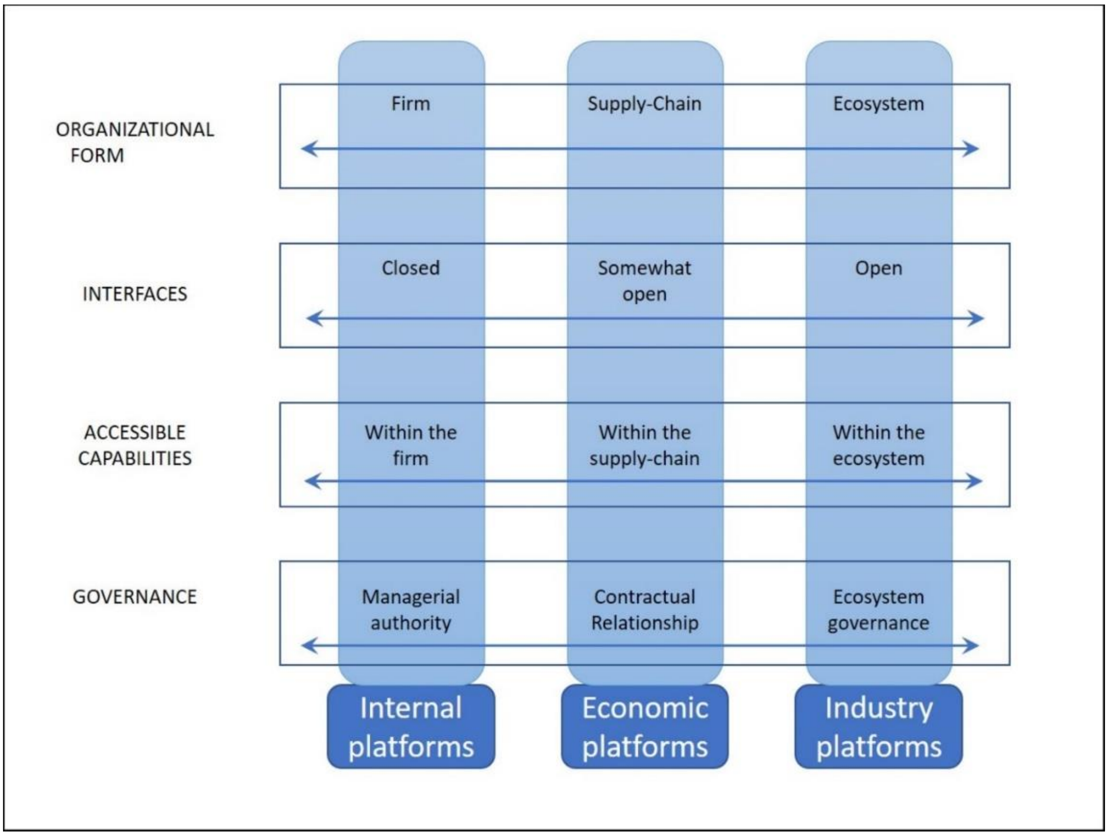

Figure 3. Digital Platforms. Source: Adapted from Gawer (2014)

3 PROPOSITIONS, ANALYTIC MODEL AND A NEW TAXONOMY FOR SUBSIDIARIES FROM THE IMN IN THE DIGITAL AGE

3.1 Implications of I4.0 to Global Operations Management

I4.0 has several implications for disciplines like IB and OM, particularly to global operations and IMNs. The following short cases and examples extracted from both the academic and business literature illustrate how firms manage to change their configuration and coordination using I4.0 technologies.

3.1.1 Function Centralization – Control, Service, Planning and R&D Centers.

Digital technologies enable firms to centralize management activities since these can be carried in the virtual environment of a CPS while the execution takes place on the floor of each plant. The networked nature of systems integration eliminates delays that did not allow effective real-time integration in the past (Adolphs et al., 2015). Telukdarie, Buhulaiga, Bag, Gupta & Luo (2018) simulate a machine breakout and repair process to demonstrate the higher effectiveness of a central functional system.

The aeronautical industry uses function centralization to optimize equipment operation and maintenance activities (Boeing, n.d.; Govindarajan & Immelt, 2019; Marketing Derby, 2017; Visintin, 2014). Govindarajan & Immelt (2019), describe the advantage of concentrating digital knowledge in centers of excellence with internal capabilities when they describe the digitalization path of GE, as well as using control centers to monitor CPS related to their products like aircraft engines or wind energy generators (Govindarajan & Immelt, 2019). Rolls Royce has inaugurated a data center to support its Derby operations in the UK that monitor their thousands of aircraft engines around the world in real-time (Marketing Derby, 2017). In the same way, Boeing keeps around-the-clock monitoring center in Everett, Washington, US, to track the global 787 Dreamliner fleet (Boeing, n.d.). During I3.0, airplanes had to be on the ground and connected to a terminal for diagnosis and maintenance routines to be executed. With IoT and other I4.0 technologies engines can be monitored, diagnosed and proper maintenance planned even before the airplane lands, saving important time on the ground. Digital I4.0 technologies enable traditional manufacturers like Procter & Gamble, Bayer, Roche, and Hewlett Packard to concentrate system management activities in Regional or Global coordination centers in countries like Costa Rica, Poland, and Singapore (Alvarado, 2018; CINDE, 2018; CINDE, n.d.; Cosmetics Technology, 2014; P&G, 2010; P&G Poland, n.d.; Sentence, 2018).

Digital technology leaders are also opening R&D centers out of their home country to gain access to regional or specific knowledge. For example, IBM announced a new IA R&D center in Brazil that will join one already existing in India and its other centers located in the US (Brigatto, 2019). GE has specialized R&D centers in the US, India, China, Germany and Brazil that aim to foster local innovation while making the results available for its global network (GE, 2014). GE's Brazil R&D center, for example, locates in the city of Rio de Janeiro, works closely with the Brazilian oil producer Petrobrás, with a common "focus on developing advanced subsea oil and gas technology" (GE, 2014). Procter & Gamble recently opened Global and Regional Innovation Centers in the US for North America, in Brazil for Latin America, in Warshaw for Europe, and in Singapore for Asia (Carnevalli, 2019; Chan, 2017; Coolidge, 2019; P&G Poland, n.d.). Digital technologies push these moves, particularly the Singapore digital innovation center in Singapore from P&G, specifically designed to research and develop new digital solutions for the company (Chan, 2017). These regional centers manage their R&D network through I4.0 technologies like CPS and platforms

Proposition 1. I4.0 technologies enable firms to concentrate functions in centralized operations that manage specific activities for the entire IMN.

Proposition 2. R&D management activities are dispersed to Regional R&D Centers out of the traditional R&D triad (North America, Western Europe, and Northeast Asia) and provide both access to technical capabilities related to physical and digital solutions, and knowledge acquired due to proximity to the market. These centers coordinate their innovation ecosystems with the support of digital technologies.

3.1.2 Servitization in the equipment industry – the cases of Xerox, Rolls Royce, and GE

The term "Servitization" was first coined by Vandermerwe & Rada (1988) and is studied by different communities like Services Marketing, Services Management, Operations Management (OM), Product-Service Systems and Service Science, the latter having evolved from Information Systems (Lightfoot, Baines & Smart, 2013). Brennan et al. (2015) describe servitization as an end-to-end approach that starts with R&D and affects all steps through after use of product or service. Lightfoot et al. (2013: 1412) define servitization as "the innovation of a manufacturing organization's product and service offering that delivers value in use". Moving from a product-centric business model to a service-centric one started being noticeable in the middle 1990s, when traditional equipment manufacturers such as ABB, Alstom, IBM, GE, Rolls Royce, Xerox, and Cannon transformed their businesses through selling services related to equipment instead of selling the equipment themselves (Martinez, Bastl, Kingston, & Evans, 2010; Lightfoot et al., 2013). For the customer, this means paying for the service instead of costly capital expenditures that later require further costs with maintenance or upgrades; for the service provider, it means offering customer-oriented solutions and building stronger relationship with clients instead of just selling physical products (Martinez et al., 2010; Frank, Mendes, Ayala & Ghezzi, 2019). Xerox sells copy services instead of copying machines; GE and Rolls Royce, KWh or flight-hours instead of wind generators and airplane engines; IBM office services instead of mainframe and computers (Govindarajan & Immelt, 2019; Martinez et al., 2010). The literature on servitization and digital technologies is still incipient, though (Frank et al., 2019). In the next paragraphs, we describe how digital technologies are supporting the servitization journey from two industries: photocopy and aerospace.

The photocopy industry is an early adapter that illustrates how servitization can evolve over time and how digital technologies play their part in this process. It started back in the 1950s with a "razor and blades" business model by keeping the equipment price relatively low and selling replacement parts and maintenance services with high-profit margins (Visintin, 2014). In the early 1960s, Haloid introduced a new service model by leasing their equipment named Xerox 914 with a free initial copy limit, while charging less for extra copies than their competitors, a business model that was so successful that the company changed their name to Xerox Corporation (Visintin, 2014). In the 1990s, the possibility to digitalize documents gave rise to a technological change in the photocopy industry. Processes moved from analogical to digital copying that enabled equipment not just to print hard copies, but also to store and transmit digital files, giving rise to multifunctional printers able to scan, copy and print. Connectivity to other devices through local networks allowed Xerox to offer services to manage printer networks connected to computer networks, a service soon offered by other companies like HP, Samsung, and Lexmark (Visintin, 2014). Digital technologies today allow remote access to these networks, be it from other offices or from home, increasing the complexity of managing companies' networks. Centralized helpdesk offices can forecast service demand more precisely, select the best equipment for each client location, deploy new equipment, remove old ones, qualify users, fine-tune the system, provide support to equipment and users, thanks to digital technologies like sensors installed at printers, IoT, BDA and Cloud Computing (Visintin, 2014). On the other hand, users can request services and interact directly with the service provider platform from their computers or using apps on their smartphones (Visintin, 2014). Lightweight service providers, Xerox's or third parties, execute the installation, maintenance and replacement of equipment on the floor (Baines et al., 2009; Visintin, 2014; Yin et al., 2018). These digital technologies also transformed Xerox into a company that offers business process services like human resources, reimbursement, accounting, and customer care services (Visintin, 2014; Yin et al., 2018).

The aircraft industry is another servitization case. It started in the late 1990s when Rolls Royce offered a "Total Care" package to American Airlines that would pay by the hour flown by the engine, a risky and potentially disadvantageous model for Rolls Royce by then (Baines & Lightfoot, 2014). Reliability and profitability of this service model were only achieved through the development of data collection, transmission and analysis systems that enable the construction of real-time CPS, connecting the in-flight engine, a centralized control center and dispersed service centers (Baines & Lightfoot, 2014; Govindarajan & Immelt, 2019). In the case of Rolls Royce, that makes over 50% of their revenue out of services, the central control center is located at Derby, UK while the service centers are dispersed at their customers' operational hubs like Texas, Singapore and Hong Kong (Baines & Lightfoot, 2014). The central service center monitors the engines in real-time so that they can forecast where and when to service them, trigger the service orders, ensure availability of all resources and respond to eventualities in real-time, while the dispersed service centers receive data from the control center and make themselves ready even before the plane to be serviced has landed. (Baines & Lightfoot, 2014; Govindarajan & Immelt, 2019).

In both cases, the configuration of the IMN is formed by a centralized control site and dispersed lightweight service centers close to consuming markets, in line with findings from about FDI investment in the digital era (Casella & Fomenti, 2019). Coordination of the IMN is defined by the role of its units, where the central service center is responsible for the entire system tracking and management, while the lightweight service centers carry on the execution activities on the ground. This IMN configuration/coordination design is enabled by business platforms that allow real-time monitoring of devices through CPS, shortens inspection and repair times, lower service costs and improves the reliability and productivity of the entire system.

Proposition 3. Servitization in the digital age allows the dispersion of execution activities of an IMN in Lightweight Service Centers located close to clients and markets, while the management of such services is concentrated in a Coordination Center.

3.1.3 Reshoring - the case of the apparel industry

A typical phenomenon from the third industrial revolution, offshoring production to low wage countries gained drive in the 1990s and early 2000s but suffered a reduction since the 2008 crisis (Kinkel, 2012). Reshoring, on the other hand, is associated with the correction of a failure offshore but may also be associated with a strategical decision in the evolution of an MNE (Barbieri, Ciabuschi, Fratocchi & Vignoli, 2018; Brennan et al., 2015; Kinkel, 2012). The need for higher customization, flexibility, and agility to respond to customers' requirements is appointed as one of the strategic reasons for reshoring production (Brennan et al., 2015). Digital technologies as 3-D printing and collaborative robots play an important role in counterbalance low-cost labor and enable production reshoring through innovative business models illustrated by the cases of German and Italian apparel firms (Barbieri et al., 2018; Brennan et al., 2015). Allied to digital platforms that allow product customization by the end-user, these technologies can be brought closer to markets, reducing cost and delivery time (Brennan et al., 2015; Strange & Zuchella, 2017). Nike took this step in 2013 and Adidas followed in 2017 by opening a new plant in Ansbach, Germany, and later a second one in the US. Adidas coined the concept of a "speed factory" to describe their new plants using technologies such as 3-D printing, collaborative robots, and automated systems to manufacture their customized products (Eurofound, n.d.; Green, 2016; Lund et al., 2019; Wiener, 2017). The "store factory", on the other hand, is Adidas small customization centers located in shopping malls, where consumers can go in, design their own apparel and have their measures taken with support of a store employee, have the piece made in a few hours on the spot and then take it right away, represent a new business model that may become predominant in the future apparel industry (Bertola & Teunissen, 2018; Wiener, 2017). Finally, the apparel sector could benefit from digital platforms in several ways: the creation of fashion "smart networks" to develop new products (Bertola & Teunisssen, 2018) and consumers interacting with suppliers via e-commerce digital platforms to design and order their products (Gawer, 2014).

Proposition 4. Low-cost labor subsidiaries become isolated Production Centers, with fewer opportunities to upgrade their plant roles since they are excluded from or have only user rights in digital systems from the IMN.

Proposition 5. Proximity to markets gains importance as a strategic reason to locate manufacturing plants. Being close to markets and key users of the IMN's systems, these plants, the Contributors, capture the tacit market and operational knowledge for the IMN and contribute with function centers to improve products, services, processes, and digital systems.

3.2 Analytical Model

The cases and propositions from the previous section call our attention to the changes in IMN configuration and coordination driven by technologies from I4.0 in ways that are not foreseen by Ferdows' model. As we discussed in the literature review, operations are now able to concentrate their management efforts in control centers while dispersing execution activities. By introducing a third factor to Ferdows' model, we expect to adjust it to the Digital Transformation era. We call it "digital maturity" after an indicator developed by several authors to describe advancements with the introduction of digital technologies in operations. (Frank et al., 2019; Lichtblau et al., 2015; Schuh, Anderl, Gausemeier, Hompel & Wahlster, 2017; Schumacher, Erol & Sihn, 2016). Schuh et al. (2017) use four dimensions to evaluate the digital maturity of an organization, two of them related to technologies – resources and information systems - and two related to the organization – organization design and culture. The Industrie 4.0 Maturity Index (Schuh et al., 2017) recognizes that it is not enough to implement digital technologies, but rather the organization itself needs to be redesigned, something that is also found in other academic and consulting sources (Capgemini, 2018; Frank et al., 2019; Lichtblau et al., 2015; Schuh et al., 2017; Schumacher et al., 2016).
Our proposition is that high digital maturity will lead firms to change their IMN coordination, closing operations that don't fit the new model, opening new ones with specific activities

enabled by digital technologies represented by CPS and digital platforms, leading to a new IMN configuration and novel Site roles.

The analytical model is depicted in Figure 4. An IMN with low digital maturity will organize according to the traditional model from Ferdows. As it increases its digital maturity, the activities from each of its Sites are modified and consequently the IMN coordination. Sites located in places that lose strategic importance will downgrade or even disappear, while other Sites will gain importance or be created thanks to the emerging strategic importance of their location, consequently evolving both the Site roles and the IMN configuration.

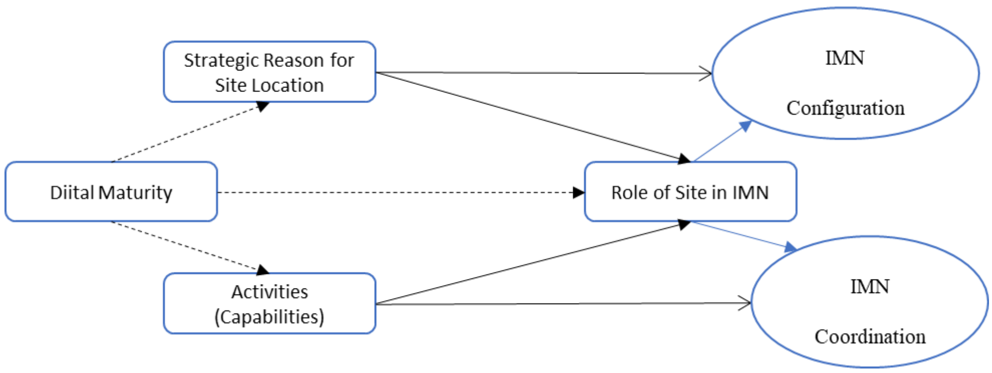

Figure 4. Analytical Model. Source: Authors

4 PROPOSING A NEW TAXONOMY FOR SUBSIDIARIES' ROLES IN THE DIGITAL ERA IMN

Before the Digital Transformation known as the fourth industrial revolution or Industry 4.0, the activities to manage and execute an operation had to be carried at a single physical location. Digital technologies like CPS and digital platforms enable these activities to take place at different locations. Industry 4.0 components allow the digital administration shells to be managed centrally, while the physical execution of operations tends to disperse and locate closer to their specific ecosystems, providing faster response and higher flexibility. This new arrangement results in scale effects and better network coordination.

There is a need to review the hierarchy of capabilities that describe site activities. Traditional classifications from Feldmann & Olhager (2013), Ferdows (1997), Meijboom & Vos (2004) and Vereecke & van Dierdonck (2002) don't consider that some activities for a single operation may take place in the digital world at one site while others happen in the physical world at other sites. Taking this into account, we suggest the following range of capabilities for a site: a) production or service execution; b) management of production or service, including procurement, production planning and scheduling, logistics, and administrative functions; c) suppliers development; d) simple process, product or service development; e) complex product, process, service or systems recommendation; f) product, service, process, and system R&D; g) global center of excellence for product, service, process, system and corporate strategy. The capabilities increase in complexity from a) to g), but a site may focus on a higher-order competency without necessarily performing all lower ones.

The propositions and analytical model presented in section 3 provide a basis for us to review the roles of sites considering the two independent factors, a strategic reason to locate and activities, modified by a third factor, the increased digital maturity. In this context, the roles of plants according to the discussions above are illustrated in Figure 5. They are discussed in the following paragraphs.

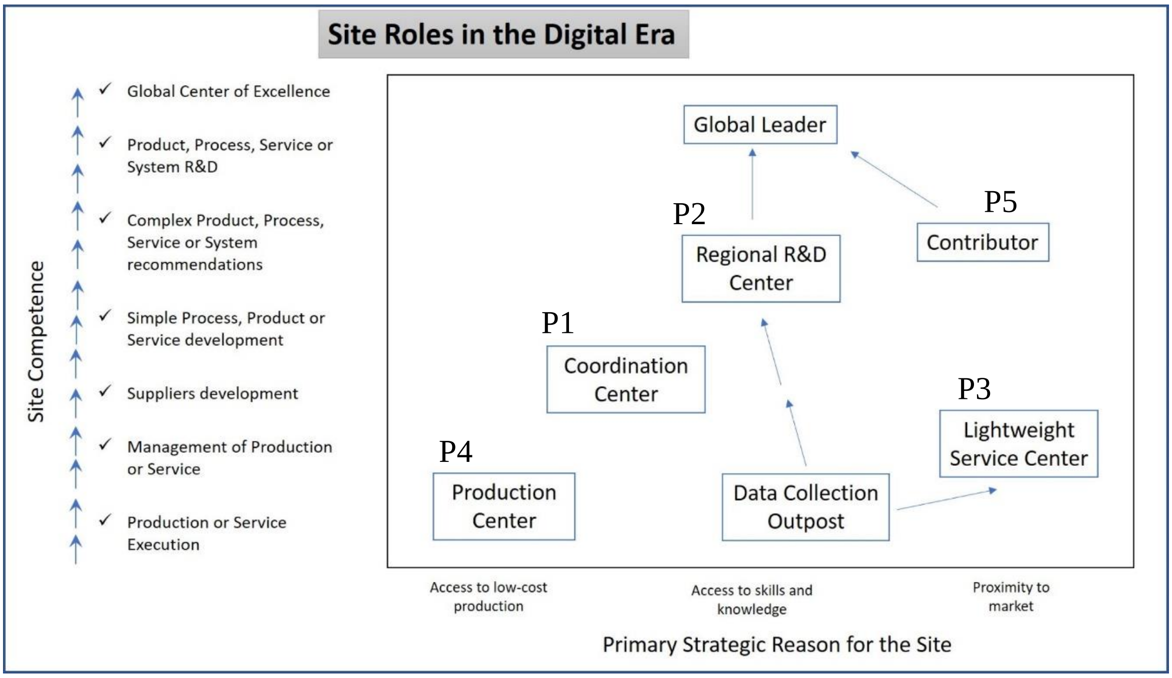

Figure 5. Plant roles in the digital age (Source: authors)

Proposition 1 describes a Site that has a strategic reason for its location-based on access to local skills and knowledge and takes responsibility for specific management activities for an entire IMN using CPS and digital platforms that provide real-time synchronization of both the digital and physical parts of the I4.0 components. We call this type of Site a “Coordination Center”. In manufacturing, instant access to all materials, work in process and finished product inventories, as well as materials purchase orders, inventory in transit, customers’ orders, manufacturing equipment status and other relevant data provided by the IMN’s CPS and internal digital platform enables the Coordination Center to assume responsibilities for managing production and maintenance planning, procurement, logistics and administrative support activities like Human Resources, Finance and ICT for the entire IMN, like described in the examples from P&G, Bayer, Roche and Hewlett Packard under section 3.1.1. In this context, the Coordination Center is a single location that can optimize the resource utilization of all the production sites. Likewise, in the case of service CPSs and digital platforms allow

Coordination Centers to monitor the equipment that is in use, anticipate service needs and coordinate the network of lightweight service execution sites from the IMN using the digital internal platform of the firm, as illustrated by the case of the aeronautics industry. Although there is little or no production or customer service execution at these sites, they are an important part of IMNs in the digital era. Ferdows model does not consider the existence of this type of site since before I4.0 since the necessary technologies were not yet commercially available.

Proposition 2 suggests that MNEs strategically locate what we call Regional R&D Centers looking for the availability of specific technology and market knowledge. Using digital industrial platforms and CPS, these Regional R&D Centers can generate innovation ecosystems or join existing ones in order to research and develop new products, services, processes and systems for the entire IMN. The examples from GE and IBM, described under section 3.1.1, illustrate this approach. There is also a tendency to co-locate “Regional R&D Centers” with manufacturing plants as proximity fosters broader inter-function collaboration (Brennan et al., 2015). An example of this strategy is P&G’s innovation centers in Brazil and Singapore, also described in section 3.1.1. The use of digital industry platforms managed by the Regional R&D Centers enables firms to broaden their innovation ecosystems by allowing a higher number of collaborators, both internal and external to the firms, to join them.

Proposition 3 tackles the phenomenon of servitization. The Coordination Centers still need services to be executed locally. Therefore, “Lightweight Service Centers” are required close to the locations where services will take place. The MNE’s strategic reason to locate these operations is, therefore, proximity to market, while their activities concentrate on executing the services planned by the service Coordination Centers. Proximity to customers allows these units to contribute with the IMN to improve systems and the quality of services provided. The evolution of the aircraft and photocopies industries, described in section 3.1.2, provide evidence of how digital technologies fostered servitization and generated new business models based on product-service solutions.

Proposition 4 addresses the reshoring phenomenon and the consequences for Sites located based on low-cost production. Since management activities are transferred to the Control Centers, sites that are justified by low-cost labor lose responsibilities and capabilities in the digital era. If corporate digital systems are too expensive for local implementation, these sites become isolated and cannot create conditions to upgrade. Their existence is only justified by their low cost, so they become at risk of closure or might face severe difficulties to upgrade in the IMN. The responsibilities of such subsidiaries are narrowed to manufacturing execution, a role that resembles the offshore plant described by Ferdows (1997), but with fewer opportunities to upgrade. We call them "Production Centers". Source plants, that in Ferdows' model would aggregate activities to production, lose activities that move to the Coordination Centers. Consequently, offshore and source plants become Production Centers in the digital era, with scarce upgrade possibilities and which survival depends solely on their production cost being more competitive than other subsidiaries. The move of factories from China to Cambodja or Vietnam due to the US-China trade war illustrates the fragility of such subsidiaries (Hufford & Tita, 2019).

On the other hand, Proposition 5 suggests that plants located close to markets gain importance with the Digital Transformation. Although they also lose some of their activities like the Production Centers, they still require specific skills to operate digital systems and benefit from market proximity and relevance. This way, such plants can actively participate in the IMN through internal digital platforms, helping Global Leader and Coordination Centers to develop and improve them. They can also collaborate with R&D sites, collecting tacit knowledge about products, services, processes, and systems, providing recommendations for upgrades in some or all these areas. These sites have the same role as the “Contributors” from Ferdows (1997). The other type of Site located due to proximity to the market in Ferdows' model (Ferdows, 1997), the server site, is unlikely to exist in the digital era since it is unlikely that a site with so much skill, data and knowledge would simply fill a production function.

Ferdows (1997) proposes two plant roles not covered by the propositions. The first one is the outpost plant, a role that Ferdows (1997) suggests should only exist in conjunction with another manufacturing plant. In our broader IMN definition, a site may exist without manufacturing activities. In this case, we call “Data Collection outpost” sites that might exist in locations with no manufacturing or service activity but with relevant tacit knowledge for the IMN.

The last role proposed by Ferdows (1997) is the lead site, a global hub of knowledge that determines the IMN objectives, strategy, products, services, and processes (Ferdows, 1997). In the digital era, Regional R&D centers and Contributors could upgrade to a lead site if they aggregate enough capabilities to take additional responsibilities inside their IMN. We call this type of site the “Global Leader”.

5 CONCLUSIONS

5.1 Contributions

The first contribution of this paper was to shed light on the impacts of I4.0 on the operations of MNEs through a set of propositions derived from literature and an analytical model that added digital maturity as a third factor on top of the two traditional ones that define plant roles and therefore the configuration and coordination of the IMN. Although rooted in the

OM field of research, the model and propositions from this paper could also be extended to IB, since both fields use the same traditional factors to determine configuration and coordination of the subsidiaries network of an MNE. The second contribution was the development of an updated taxonomy for plant roles by discussing the propositions built using selected cases found in the academic and business literature. We introduced cyber-physical systems and digital platforms as system integration and management tools for sites and IMNs to better create and capture value from the ecosystems in which they are inserted.

5.2 Managerial implications

The analytical model and the set of propositions resulted in a new taxonomy for site roles within an IMN that can be explored by MNEs. As the model takes manufacturing in its broadest sense, from product/service design to after-sales, the taxonomy includes operations like development, production, service, and management centers that form the international manufacturing network of the digital era. The fragmentation of management and execution activities in two different environments gives rise to separate sites that may assume partial functions related to the complete operation. A specific aspect of an operation, say production planning or services coordination, may be managed at the network level by one single site, while its execution takes place at the several other sites that form the network.

Dividing the physical and digital parts of a so-called cyber-physical component, where physical represents the actual execution at a site and digital is data and the component management allows a firm to configure its international operations in novel ways that cannot be foreseen with the traditional models available in current literature, since they are based on the third industrial revolution, when the level of fragmentation enabled by I4.0 did not yet exist. Firms could use the model to redesign their operations configuration and coordination.

sites could use I4.0 technologies to improve their capabilities and upgrade their role within the manufacturing network.

5.3 Research limitations and further research

There are limitations to this text. The first one is that this is a theory-building paper that requires future systematic empirical validation. It is also a first attempt to theorize the complex relationships between Digital Transformation and global operations. We intend to overcome this limitation through a series of case studies mentioned in the introduction of this paper. There are questions that require further investigation. For example, we did not cover implications for the marketing and sales functions in this paper. Being in close contact with customers and clients, these functions should provide significant market insights to the IMN, both in terms of opportunities to capture value from the business ecosystem and in terms of value creation as data sources for market preferences, requirements, and needs.

Another question that deserves further investigation is how governments can prepare their countries and take advantage of the Digital Transformation. Platform Industrie 4.0 in Germany, Manufacturing USA and Made in China 2025 (MIC2025) are national programs that intend to create the necessary conditions to fulfill their strategic goals, typically with joint efforts from governments, firms, and academy (Arbix, Salerno, Zancul, Amaral & Lins, 2017). Each of them illustrates one of three different approaches to tackling the digital revolution (Freitas, 2018). Germany, Japan, and South Korea represent the first approach, typical of technology and manufacturing leaders that intend to secure their competitivity in face of growing emerging countries and focus their programs to reinforce leadership in areas they excel (Freitas, 2018). Countries like the USA, UK, and France want to recover their manufacturing capability lost due to heavy offshoring in the second half of the twentieth century and at the beginning of the twenty-first century by establishing research centers and testbeds to provide innovative technical solutions to reshore production (Freitas, 2018). The third approach is represented by China with “MIC2025”, and India with “Make in India”, countries of late industrialization that want to catch up and consolidate themselves as new manufacturing and technology leaders (Freitas, 2018). There is a fourth group of emerging countries that have gained relevance with the Digital Transformation by specializing in specific areas like Costa Rica in regional or global services (Alvarado, 2018; CINDE, 2018; CINDE, n.d.; Cosmetics Technology, 2014), and Israel in ICT technology development (Breznitz, 2007). This brief discussion sheds light on a topic that deserves further research. The framework proposed in this article could be used in empirical studies in different sectors and geographies that organize their IMNs according to the needs and characteristics of their businesses. This is an excellent opportunity to validate the analytical model and propositions besides verify their generalization potential. Given the broad definition of manufacturing used here, the framework might also be used in conjunction with theories that describe functions like services and R&D. Another possibility would be to use the framework to study fields related to OM, like IB, Organizational Design, Strategic Management or other areas where digital technologies have had an impact that is still not yet fully understood. We hope that the analytical model, propositions and plant taxonomy presented in this paper may offer a lens for future studies about Digital Transformation, global operations management, and other research fields.

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