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Orchestrating industrial ecosystem in circular economy: A two-stage transformation model for large manufacturing companies

Vinit Parida[a,b,*], Thommie Burström[c], Ivanka Visnjic[d], Joakim Wincent[a,c,e]

[a] Luleå University of Technology, Sweden
[b] University of Vaasa, Finland
[c] Hanken School of Economics, Finland
[d] ESADE Business School, Ramon Llull University, Spain
[e] University of St. Gallen, Switzerland

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ABSTRACT

Making the transition to a circular economy is an important goal for society and individual companies, particularly in resource-intensive manufacturing industries. Yet the complexity and interdependencies of such an undertaking mean that no single company can achieve it alone and ecosystem-wide orchestration is necessary. Based on a qualitative study of six large manufacturing companies (ecosystem orchestrators) and their ecosystem partners, we develop a process model that describes the scarcely understood process of ecosystem transformation toward a circular economy paradigm. We provide evidence that ecosystem orchestrators achieve the transition toward a circular economy in two stages: 1) ecosystem readiness assessment and 2) ecosystem transformation. In each stage, specific and complementary mechanisms are deployed. The article elaborates on ecosystem transformation mechanisms and their purpose, use, and interdependencies in moving toward a circular economy paradigm.

1. Introduction

The goal of the circular economy paradigm is to minimize waste through cycles of reduction, reuse, and recycling with limited leakage and minor environmental impact (Ellen MacArthur Foundation, 2016; Pearce & Turner, 1990). While the circular economy debate is concerned mainly with societal actions and benefits, more attention is needed to establish how the circular economy paradigm can yield benefits and how it can be implemented at the company and ecosystem levels (Frishammar & Parida, 2018; Su, Heshmati, Geng, & Yu, 2013). Manufacturing companies would benefit from a circular economy paradigm that economizes both production and consumption (Yuan, Jun, & Moriguichi, 2006). Moreover, even minor improvements by large manufacturing firms could contribute significantly to the achievement of circular economy benefits.

Although the benefits of the circular economy are fairly well understood, in reality there are few industrial examples of companies (e.g., in business-to-business settings) that have implemented a circular economy paradigm (Bocken, de Pauw, Bakker, & van der Grinten, 2016; Lahti, Wincent, & Parida, 2018). We identify two research gaps that need addition from researchers. The first is the need for manufacturing companies to change their own business models while also enticing old or new ecosystem partners to change theirs to achieve transformation (Lockett, Johnson, Evans, & Bastl, 2011; Mont, 2002). For instance, when companies shift from the product sale to the pay-per-use model, customers pay according to their use of the product. This resources efficient business model requires manufacture to collaborate with service partners, third-party suppliers, customers and even other providers to profitably deliver the new business model (Parida, Sjödin, Wincent, & Kohtamäki, 2014; Parida, Sjödin, Lenka, & Wincent, 2015). This ecosystem-level change in the business model leaves many questions unanswered, such as how to incentive ecosystem partners, how to share risk and revenues, and how to change the roles and responsibilities between partners (Iansiti & Levien, 2004; Mont, Dalhammar, & Jacobsson, 2006). Thus, we lack understanding of how a company orchestrate business model change at the firm and ecosystem levels to achieve transformation toward circular economy paradigm.

The second research gap in the circular economy literature lies in understanding the transition to greater focus on offering advanced service-based business models or functional results (Parida, Sjödin, &

* Corresponding author.
E-mail addresses: vinit.parida@ltu.se (V. Parida), thommie.burstrom@hanken.fi (T. Burström), ivanka.visnjic@esade.edu (I. Visnjic), joakim.wincent@ltu.se (J. Wincent).

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Reim, Forthcoming; Tukker, 2004). In this context, the manufacturer retains full ownership of the product and guarantees the customer a certain outcome, such as a given production volume at a customer's factory (Reim, Parida, & Örtqvist, 2015; Tukker, 2004). Another example, can be a train manufacturer that charges customers per daily use of the train has a direct incentive to collaborate with ecosystem partners and reduce the life-cycle costs of design, development, manufacturing, and servicing that train (Visnjic, Jovanovic, Neely, & Engwall, 2017; Visnjic, Neely, & Jovanovic, 2018). The fact that customer pays for access to or use of the product and not per unit of product or service, leaves the manufacturing company free to economize on its products and services. More importantly, this advanced service-based business model enables the manufacturer to extend the lifespan of products and parts, thereby capturing environmental, social, and economic benefits (Bocken et al., 2016; Stål & Corvellec, 2018). However, we still lack insight into how advanced services drive resources efficiency and transformation toward circular economy.

To reduce design, development, manufacturing, servicing, use, and recycling costs, the manufacturer needs to work closely with other ecosystem partners that engage in each of these activities. These stakeholders (including the customer) need to assume new roles and responsibilities, which entails changing their own business models (Nußholz, 2017; Visnjic, Neely, Cennamo, & Visnjic, 2016). Thus, the transition to circular business models not only influences the business model of a single company by including increased service focus but also affects the organization of entire ecosystems. Although recent studies have started to recognize the need to understand how an industrial ecosystem based on a circular economy might be described and orchestrated (Lahti et al., 2018; Nußholz, 2017), the literature provides offers insight into the ways in which manufacturing companies perform ecosystem transformations toward the circular economy.

In this study, we investigate how manufacturing firms orchestrate ecosystem-wide transformation to the circular economy paradigm. Based on a qualitative study of six large manufacturing companies (ecosystem orchestrators) and their ecosystem stakeholders, we develop a process model that describes ecosystem transformation toward a circular economy. In addition, we demonstrate that ecosystem orchestrators approach this objective in two stages: ecosystem readiness assessment and ecosystem transformation. In each stage, specific and complementary mechanisms are iterated to meet its objectives.

Our study makes two theoretical contributions to the literature on the circular economy (Bocken et al., 2016; Tukker, 2015). The first is that we bring a novel empirical insight to the internal workings of the circular economy transformation of large companies in traditional industry settings such as manufacturing (Lieder & Rashid, 2016; Stål & Corvellec, 2018). Many studies in the circular economy literature are conceptual and either lack empirical insights or rely on cases that are idiosyncratic and difficult to replicate or generalize. Our second contribution is that we shed light on the broader process of transformation toward the circular economy that also encompasses the company's ecosystem. Ecosystem partners can include networks of customers, suppliers, specialized component providers, regional distributors, and service partners, all of which jointly need transform their business models. We provide evidence that successful circular economy initiatives requires orchestration of ecosystem partners.

2. Theoretical background

2.1. Circular economy and manufacturing firms

The circular economy entails the creation of a restorative, regenerative industrial system (see Ghisellini, Cialani, & Ulgiati, 2016). The circular economy logic of make-remake-use-return challenges the linear economy logic of take-make-use-dispose. This circular economy logic supports an economic model based on removing resource inputs and wastage through a holistic perception of the system (Ellen MacArthur Foundation, 2016). According to other associated views, the circular economy offers a way to close material flow loops throughout the entire economic by encouraging the application of the 3Rs: reduce, reuse, and recycle. The circular economy has emerged as a leading concept and industrial practice to address resource scarcity and environmental problems (Frishammar & Parida, 2018).

The concept of the circular economy has its roots in the study by Pearce and Turner (1990), who highlighted the need to view the relationships between resource use and waste as circular. This narrow focus on waste management has since broadened to include other issues such as efficiency-oriented control, energy efficiency, land management (Su et al., 2013), the service-life of products (Tukker, 2015), and more general business aspects (Jacobsen, 2006). Mathews, Tang, and Tan (2011, p. 480) describe this shift as follows: "from being an exclusively ecological concept it is becoming a business and competitive concept, where benefits are experienced not by firms acting on their own so much as in concert with each other, reducing their collective costs and making systemic gains that reduce the ecological toll of industrial activities." Unsurprisingly, therefore, recent review studies by Lieder and Rashid's (2016), Lahti et al. (2018) and Nußholz (2017) suggest that current circular economy literature lacks on two key shortcomings: that research on the circular economy is fragmented and that we lack insights into how companies implement circular economy principles. Thus, this study takes a practical approach to advance our understanding of how manufacturing companies can apply and benefit from the circular economy.

Manufacturing industries are special and have their own dynamics and efficiency problems (Callejón & Segarra, 1999; Wallin, Parida, & Isaksson, 2015). Undoubtedly, the manufacturing industry has a huge impact on ecology (Franco, 2017). New manufacturing techniques have enabled mass production. This positive development for the manufacturing industry has resulted in industrial growth, a high availability of products, and low costs. However, the combination of a growing world population and increasing product demand has also led to higher emissions. In addition, natural resources are limited, so the demands of an exponentially growing population and the situation of global resource scarcity cannot be reconciled. It follows that manufacturing industries, in their daily business operations, need to learn how to manage, for example, risk in resource supply, price volatility, and new environmental regulations (Lieder & Rashid, 2016).

Several researchers have advocated applying circular economy principles to the manufacturing industry to tackle resource and material scarcity. A specific step in this direction would involve a transformation toward a circular business model, which involves creating value by exploiting the value that is retained in used products to generate new offerings (Linder & Williander, 2017). According to Tukker (2004, 2015), some industrial examples of such innovative business models relate to offering customer-oriented or result-oriented product-service systems. For example, GE and Rolls-Royce offer airplane-engine performance-based service agreements dubbed 'Power-by-the-Hour' where the firm guarantees the performance (i.e. availability and reliability) of engines in order to enable airline customers to focus on their core activities and maximize flying potential. Circular transformation are purported to help the triple bottom line by providing economic, sustainable, and social benefits (Reim et al., 2015; Stål & Corvellec, 2018; Stubbs & Cocklin, 2008). Yet many manufacturing companies continue to pursue linear business models because of significant risks associated with circular business models. A widely agreed implementation challenge relates to radical change in the ecosystem or value network (Mont et al., 2006; Tukker, 2015). The benefits of linking circular economy development with business ecosystem transformation are discussed below.

2.2. Circular economy business models and ecosystem transformation

The circular economy and associated business models present a unique value creation opportunity, but they also entail challenges associated with increased risk and responsibility. According to Reim et al. (2015), the way that companies are expected to create, deliver, and capture value should be overhauled. For example, companies need to extend interactions and manage relationships with various stakeholders throughout the product life cycle (Veleva & Bodkin, 2018). Moreover, circular business models require reconsideration and analysis of the broader company ecosystem to understand how services can be integrated to ensure sustainable benefits and optimal customer value (Lockett et al., 2011; Mont, 2002; Rönnberg Sjödin, Parida, & Kohtamäki, 2016). According to Grönroos and Voima (2013), such a change may seem challenging. This is because the inability to develop business models that motivate companies to offer or acquire result-oriented product and service combinations requires companies to operate in a joint sphere (Rönnberg Sjödin, Parida, & Lindström, 2017).

In such joint sphere, business model issues transcend value chain relationships (cf. Peppard & Rylander, 2006) and thus highlight the need for the alignment of interests and incentives across ecosystem stakeholders (Parida et al., 2015). According to Su et al. (2013), the circular economy in an industry context is in practice realized through parallel ongoing activities at the micro (single object), *meso* (symbiosis association), and macro (city, province, or state) levels. However, most studies focus on the providers' perceptions and fail to provide insights into how the customer and other ecosystem partners can co-create value (Sjödin, 2018). Additionally Manninen et al. (2018) explain that individual firms' environmental value propositions have difficulties in reaching system level changes. This significantly influences the ability of manufacturing companies to implement circular economy.

Therefore, echoing prior research, we recognize the concept of business ecosystems coined by Moore (1993), who proposed that ecosystems are orchestrated by ecosystem leaders to create value in collaboration with a community of stakeholders. We draw on Moore's (1993) work and view a business ecosystem as a loosely related business community. Accordingly, due to the inherent system approach taken in business ecosystem studies, we propose that adopting the ecosystem perspective may help explain the implementation of the circular economy on a system level.

In this respect, the literature acknowledges that ecosystem leaders orchestrate business activities to create a shared vision of the values that should be nurtured (Nambisan & Sawhney, 2011). Nonetheless, not any firm can act as a business ecosystem orchestrator. These leaders needs to be resourceful, being able to create a healthy ecosystem by providing a stable set of common assets, simplifying the connection between various stakeholders, and encouraging innovation and niche creation (Iansiti & Levien, 2004).

Orchestration is defined as “a set of deliberate, purposeful actions” by a core firm (Dhanaraj & Parkhe, 2006, p. 659). Through orchestration, focal firms can provide business ecosystems with institutional stability (Thomas, Autio, & Gann, 2014). Orchestration therefore also includes enforcing the rules of the game and ensuring that other partners adhere to the rules. Such activities include promoting transparency between partners to control the risks of moral hazard and imposing sanctions or even excluding stakeholders who disregard the rules (Williamson & De Meyer, 2012). Indeed, a key role of ecosystem orchestrators has to do with coordinating and managing diverse interests and ensuring alignment among ecosystem partners.

Although studies have offered accounts of how an ecosystem might be described, it is unclear how ecosystems orchestrated. The focus of these prior studies is more descriptive in that it maps how individual relationships emerge and with how these relationships form. Thus, although research broadly explains and validated the importance of logic of ecosystems transformation, the way companies facilities change to fit new business models based ecosystem-level logics such as the circular economy is poorly articulated. Clarity is needed to understand how such changes occur and which mechanisms are applied by ecosystem orchestrator to promote circular economy paradigm.

3. Research method and data analysis

3.1. Research approach and data collection

The focus of this study was to advance our understanding of how large manufacturing companies implement the circular economy paradigm by changing their business models and influencing their ecosystem partners. We therefore investigated ecosystem transformation as a dynamic set of activities to enable the development of a process model (Langley, 1999). This approach is consistent with the interpretive approach to qualitative research. During the study, we observed the relevance of linking our data to theoretical insights originating from the circular economy and ecosystem literature.

We focused on the actions of ecosystem leaders or orchestrators. These orchestrators are large, resource-rich companies that initiate and change the circular economy by coordinate relationships with diverse ecosystem partners such as suppliers, customers, service partners, and other industrial stakeholders. To generate rich empirical insights, we conducted a multiple case study of large manufacturing companies (i.e., ecosystem orchestrators) and their ecosystem partners. More specifically, we chose six case studies, for three reasons. The manufacturing companies had explicit strategies that moved them toward the circular business model paradigm. These strategies were communicated on their website or through press releases. Based on our initial interactions with these companies, we identified specific circular business models, indicating the opportunity to gather real-life data on how large manufacturing companies manage the challenges associated with transformation to the circular economy. For example, Company A offers its global customers availability-based contracts that guarantee certain performance outputs.

In addition, because the study focused on ecosystem-level transformation, we needed to ensure that we could collect data from ecosystem partner. The cases presented in this study made such data collection possible by ensuring that we could gather data from two or more ecosystem partners such as customers, suppliers, and service delivery actor. Finally, these case companies represent a range of industries. Multi-industry sampling provided an opportunity to capture variations in the data and investigate the circular economy and ecosystem transformation in diverse contexts. Table 1 provides the descriptive background of the firms in this case study.

Data were collected from open-ended interviews, for which we had developed themes related to the research purpose (Yin, 2017). This interview offered respondents with a high degree of freedom to express their opinions and steer the interviews in the most interesting direction (Eisenhardt, 1989; Siggelkow, 2007). We conducted 53 interviews with respondents at different organizational levels and units within the case companies. The respondents belonged to R&D, sales and distribution, and regional units. They were chosen based on their participation in organizational transformation toward the circular economy or in the implementation of circular business models.

The data were collected in two steps. The first step consisted of interviews within the manufacturing company (ecosystem orchestrator), and the second step consisted of interviews within the associated ecosystem partner's organization. Because of the sensitivity of the questions, not all interviews were recorded. To capture interview data, notes were made during the interviews. More notes were added within 24 h of the interviews. To ensure reliability, several researchers conducted the interviews. To create overlap between data collection and data analysis, the authors held frequent discussions and continually took field notes. Secondary data were also collected in the form of archive materials and websites for validation of results and enhancing data triangulation (Neuman, 2003).

3.2. Data analysis

We used constant comparison analysis (Strauss & Corbin, 1990),

Table 1
Information about case study companies and circular economy business model description.

Case company	Company size	Circular economy business model	Circular economy business model description	Interviews with ecosystem leader and system partners
Company A (manufacturer of heavy construction equipment)	6254 MEUR/14,000 employees	Performance-based customer support agreements	Represents the highest value-adding package and includes benefits, such as a strong partnership between provider and customer, a focus on the customer's core business, maximum uptime potential, and effective cost control. The benefits of the circular economy include enhanced life of the equipment through improved maintenance and service contracts.	Provider (5), service partner (1), customers (2) and distributors (3)
Company B (manufacturer of telecom equipment and software)	19,4 Billion EUR/ 100,700 employees	Capacity-based contracts	A cost-per-data contract where customers pay for ability of provider to manage user traffic and optimizing the network operation. Provider guarantees delivery of uptime, system optimization, and revenue sharing based on cost saving. The circular economy benefits receded sale of products, increased focus on maximizing product utilization, and effective resources utilization.	Provider (6), supplier (1), service partners (2) and customers (2)
Company C (manufacturer of machine tools)	8202 Billion EUR/ 41,000 employees	Outcome-based contracts	A multi-level service contract for a press hardening tool in factories. The highest-level contact would guarantee a certain "number of strokes" that their tools will perform for a specified duration. This would offer include maintenance training, simulations, and process optimization. The circular economy benefits includes prolonged product-life, increased availability, reduced material wastage, and increased productivity.	Provider (5), Customers (3) and supplier (1)
Company D (manufacturer of automotive vehicles)	13,226 MEUR/38,000 employees	Luxury car sharing services	Includes access to an array of premium cars to residents of high-end apartments. The core idea is to promote access to cars without car ownership and thereby reduce the need for second car and provide incentives for the use of public transformation. The circular economy benefits include improved utilization of products, more effective maintenance, and reduction in the total number of cars needed.	Provider (4), service partner (1), and customer (2)
Company E (manufacture of aircrafts)	29,529 MEUR/16427 employees	Performance-based aircraft solutions	Provide access to military aircraft on performance-based terms. For an annual fee, customers gain access to services like flight training, logistics, upgrading, storage, and life-cycle management. The circular economy benefits include reduced maintenance costs, prolonged product life cycles, and increased availability.	Provider (3), Supplier (1), customer (1) and service partners (1)
Company F (manufacturer of cables)	6370 MEUR/26,000 employees	Sustainable paper cable packaging	A new capable packaging solution, which reduces the need for PVC and other types of plastic. The cable is surrounded by recycled biodegradable materials and customized design to ensure better fit to the customer's operational needs. The circular economy benefits include the stability of cable packaging during transport and that it is easy to stack, conserving space and minimizing transport costs.	Provider (5), suppliers (2) and customer (1)

which provides a systematic way to identify patterns in a large, complex dataset. This technique builds on the idea of conducting a series of iterations to discover analytical themes leading to the development of theoretically and empirically grounded frameworks. Thus, our analysis progressed through a series of iterations that built on differences and commonalities between first-order categories, second-order themes, and third-order aggregate dimensions (Nag, Corley, & Gioia, 2007; Van Maanen, 1979). Despite its iterative nature, our analytical procedure was divided into separate steps.

First, we systematically coded the verbatim transcripts. Similar terms, labels, and phrases were transformed into common codes across informants. These codes were then collapsed into first-order categories (Van Maanen, 1979). We then began to analyze and identify relationships and patterns among these first-order codes, and we aggregated them into theoretically distinct second-order themes. As an additional step in the coding, we developed more abstract, overarching third-order dimensions that arose from the second-order themes. To ensure rigor and increase confidence in our analysis and the assigned codes, multiple members of our group developed the coding scheme independently. In the event of a disagreement or difference, we discussed and modified the coding scheme to reach a consensus. Finally, we compared the text passages and ensured the data were correctly represented.

Fig. 1 displays the way in which the data were ordered and structured into codes and categories. Fig. 1 outlines the three higher-order themes that subsequently formed the basis for our data-driven process framework for circular economy transformation. Development of first-order, second-order, and third-order categories was based on grounded theory data analysis. Fig. 1 illustrates the particular importance of understanding two overarching dimensions in relation to the shift toward a circular economy paradigm. These dimensions are ecosystem awareness and the orchestration mechanism (i.e., standardization, nurturing, or negotiation).

4. Findings

In the following section, we provide evidence from the case study of how a company (an ecosystem orchestrator) assessed readiness level for transformation, used different ecosystem orchestration mechanisms, and ultimately achieved diverse benefits through circular business model implementation.

4.1. Ecosystem readiness assessment

Ecosystem readiness assessment provides an important starting point for understanding the orchestration and transformation processes that manufacturing companies and their ecosystem partner must undertake to move toward a circular economy paradigm. The purpose of this readiness assessment is to ensure that ecosystem companies can identify and gain a deeper understanding of gaps related to circular economy paradigm transformation. Readiness assessment was a fundamental step that helped managers of the companies we studied to be sensitive to external information, identify new business opportunities related to the circular economy, and understand their own capacity to embrace these opportunities (Hmieleski, Corbett, & Baron, 2013; Ray & Cardozo, 1996). Interestingly, assessment of the internal and external environment has been acknowledged as an important topic in studies of circular economy implementation at the societal level. For example, Xue et al. (2010) showed that officials are highly aware of the circular economy concept and principles. Liu, Li, Zuo, Zhang, and Wang (2009) explained that a lack of business awareness prevents the development

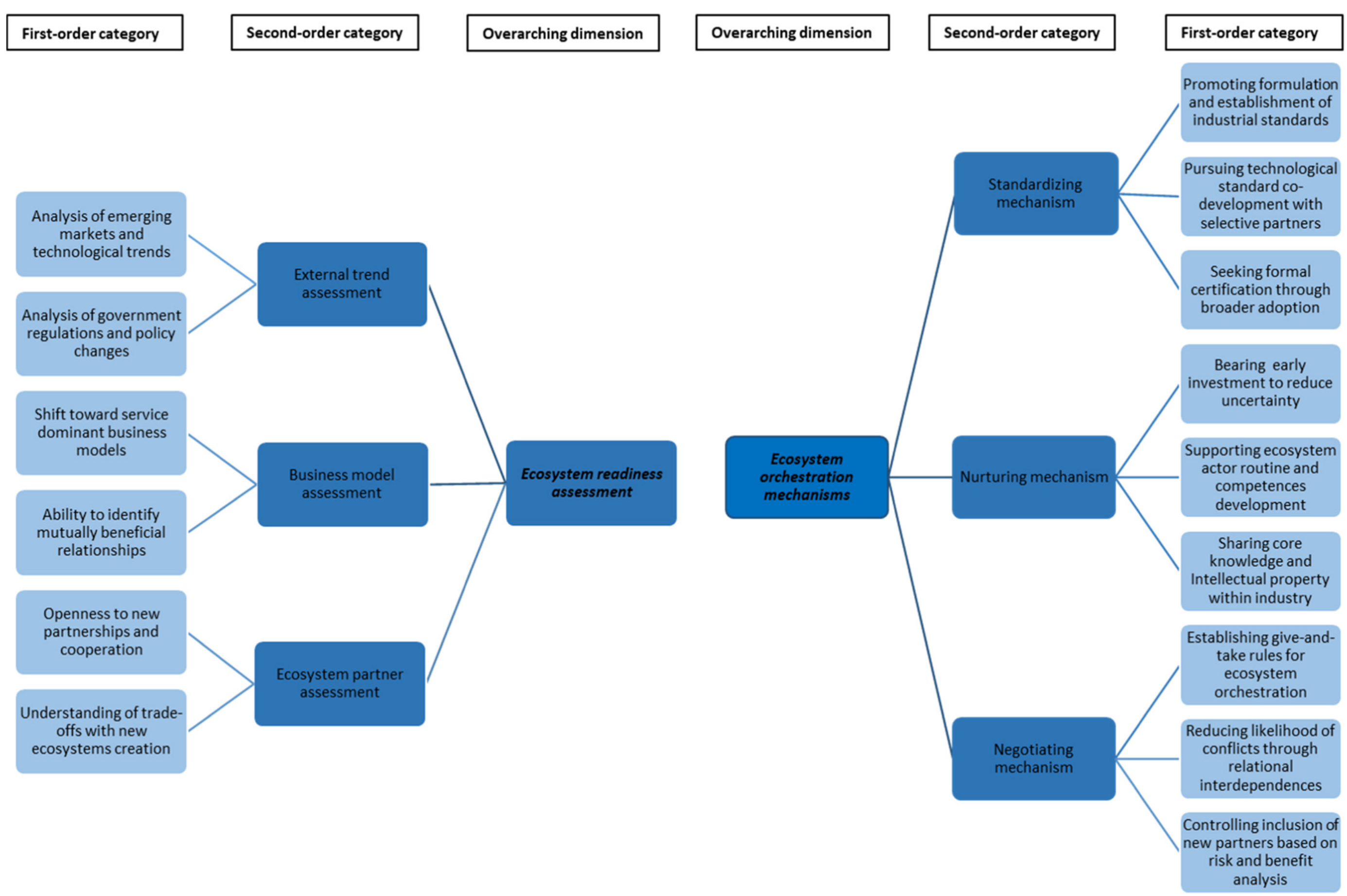

Fig. 1. Data coding.

of the circular economy in China and that this lack of critical assessment may be an important first step for the implementation of circular economy business models.

The manufacturing companies we studied assessed their readiness for the circular economy through three key readiness assessment activities. *External trend assessment* consisted of analyzing trends that may directly or indirectly affect the business potential of the ecosystem. More specifically, companies stayed abreast of upcoming technological (e.g., autonomous vehicles) and market (e.g., changing demographics) trends and used this knowledge to promote new thinking inside the company and motivate circular business model transformation efforts. In the words of a Portfolio Manager from company A, which manufactures heavy construction equipment, "*we are continuously having high-level strategic meetings about upcoming trends that can affect our business. Circular economy is a concept that we know about and have given full consideration in terms of future business development. A concrete example of how we approach circular economy is through engaging in a more service-oriented offering which enhances productivity for our customers and increases the life-time of the equipment*."

Another aspect of external environmental assessment is the assessment of the impact that policy and regulation changes have on the business. For example, a respondent from company D, which manufactures automotive vehicles, noted that regulation changes related to electrification meant that, by 2030, most major automotive markets would be mainly selling fully electric or hybrid cars. Or, as a senior manager from Company C explained, "*we are currently a highly profitable organization but the future is constantly changing. We know that circular economy or higher focus on sustainability will not be an option but rather a requirement in the near future. We don't want to wait until governmental policy changes are proposed; we want to be forward looking and test new technologies coupled with new business models. Of course this means failure, but it is a better way forward than being taken by surprise*."

The second dimension of the ecosystem readiness assessment stage was *business model assessment*. This business model assessment involved taking stock of the current business model in terms of the dimensions of value creation, value capture, and value delivery and taking a stance on the actions that need to be undertaken to move toward a "game-changing" circular economy business model. A common thread across the case companies was the move away from resource-intensive product-centric business models toward service-centric business models such as pay-per use models or outcome-based contracts.

Concerning the assessment of future business models, one notable aspect involved understanding the implications of the business model shift for ecosystem partners because of the myriad interdependencies in their ecosystems. According to a New Business Development Manager from Company B, "*in new business development meetings we always evaluate the influence of any decision on existing ecosystem actor relationships. We are a leading organization which needs to make key decisions in light of how it would influence our associated actors. We are well informed to make such critical decisions*."

The final dimension of readiness assessment was *ecosystem partner assessment*. Managers from the case companies emphasized the importance of having a deep knowledge of their ecosystem partners' roles and responsibilities. All managers could effortlessly describe relationships with ecosystem partner such as suppliers, customers, service partners, and other potential partners. For example, one manager had compiled a book on the subject of business ecosystem actor. The book described the relational negotiations between the ecosystem orchestrator and its partners over the years, including negotiations related to profit sharing and purchasing arrangements. The book provided a well-documented basis for evaluating roles, responsibilities, and activities for circular economy paradigm transformation. A second manager had created a map outlining the hierarchy of the company's ecosystem. The map contained different layers of ecosystem partners with clearly identified roles and responsibilities. At times, this involved taking stock of the challenges that partners were facing to follow the ecosystem leader toward the circular economy. As a manager from Company F explained, "*we had long ago understood the need for changing our business model towards performance based aircraft solutions, but for a long time, our service partners were unprepared for such a major transformation*."

In addition to the assessment of the existing ecosystem partners, companies were also assessing the need and potential for new ecosystem partners. One manager from Company F, a cable manufacturer, described how companies assessed opportunities for new partnerships. For example, Company F lacked in-house competencies to introduce new packaging material. They therefore invited new suppliers to engage in innovative projects and explore new technological and business opportunities for circular business model innovation. The result of such meetings was a new arrangement between company F and a small supplier that developed a durable yet eco-friendly packaging solution for the cables. The packaging solution was reusable and included design improvements for greater customer satisfaction.

4.2. Ecosystem orchestration mechanisms

Although ecosystem readiness assessment provided a good first step, to ensure real change, manufacturing companies reported the need for diverse orchestration mechanisms, which we present below.

4.2.1. Standardization mechanism

Standardization activities are frequently described as important mechanisms for implementing the circular economy in emerging ecosystems (Wen & Meng, 2015). The large manufacturing companies in this study reported their involvement in many activities (e.g., lobbying) and investments (e.g., publishing early technology test reports) devoted to *formulating and establishing industrial requirements* associated with circular business models. Usually, changes in standards and regulations originate from national or international lawmakers and industrial networks, but ecosystem orchestrators or leaders have always taken an active role in the debate on establishing industry standards. Thus, across cases, senior manages cited numerous activities to influence setting standards for the circular economy rather than merely adopting standards to comply with government regulations. For example, respondents from Company E reported numerous lobbying efforts such as sponsoring third-party testing of new technologies, which are preferred by the orchestrating firms, to influence policy and industrial standard changes. In this case, they lobbied the government and military to increase requirements for ISO level certifications and thereby became an eligible supplier of aircraft spare parts and service contracts.

Besides participating in the debate to set industry standards, ecosystem leaders use informal standards to shape and guide the creation of the ecosystem with their closest ecosystem partners (Williamson & De Meyer, 2012). One example is the creation of de facto *informal standardization*, where manufacturing companies create dominant standards that are largely accepted by the industry, despite not being legally binding. According to respondents from Company C and Company A, succeeding in such a strategy requires commitment from ecosystem stakeholders. For example, *pursuing technological standard co-development with selected partners* was found to be a way to ensure acceptance of environmentally friendly materials for Company E's development of aircraft spare parts.

Although informal standardization was used to shape the ecosystem together with the core ecosystem partners, the ecosystem leader also tended to use *formal certification* for the new circular economy concepts or technologies that required large-scale acceptance from all ecosystem partners, including non-core industrial partners. According to respondents from Company E, extensive lobbying across the ecosystem took place to introduce ISO certifications that would soon become industry norms and that made environmental and financial sense. According to a Tool Development Manager, "*to achieve higher profits in the future, tests of new technologies with futuristic tools will be critical. For these technologies to become value adding and cheaper, we need a large-*

scale acceptance by other industrial actors. So we are demanding our suppliers to accept our preferred technology standards." Indeed, promoting novel offers (e.g., advanced product-service combinations) and standardizing novel technologies (e.g., technological algorithms) have proved essential for the advancement of the circular economy at the societal level (Sarkis & Zhu, 2008).

4.2.2. Nurturing mechanism

Nurturing activities and their potential influence on the ecosystem's shift toward a circular economy have scarcely been discussed by the research community, although nurturing has been described as essential in the orchestration of new business opportunity exploitation for ecosystems. Williamson and De Meyer (2012) describe how orchestrators should nurture the ecosystem to ensure a high speed of innovation that in turn contributes to a successful business ecosystem.

Our data suggest that nurturing is a core theme across case companies. Leading manufacturing companies actively nurture ecosystem transformation using several mechanisms. The first is *baring early investment costs* associated with the circular economy. The ecosystem orchestrators that we studied reported that a key challenge for most of their ecosystem partners was that they had no means (e.g., financial resources) of investing in transformation toward the circular economy because of the high uncertainty surrounding this paradigm. As a respondent from Company B explains, "*many suppliers in our network are small and medium-sized firms, so we need to support them. Some of these suppliers are progressive, but most are unable to look beyond current business needs and pursue circular business model opportunities*." Thus, ecosystem orchestrators must actively invest and show the path for ecosystem partner companies to achieve circular business models. Investment in IT infrastructure and systems enables ecosystem orchestrators to incentivize ecosystem partners to engage in transformation, which would otherwise be expensive and complex.

In addition to early investments, the ecosystem orchestrators we studied supported the *development of new routines and processes* with selected partners. Examples include improving the use of digitalization for service delivery, developing competencies, providing revenue and cost calculation support, managing portfolios, and increasing the ability to configure product and service components. Such activities promote the alignment of incentives and the rapid adaptation of circular business models. A respondent from Company A, which manufactures heavy construction equipment, described how the company actively works to protect and cultivate business model development by service delivery partners. The company fully understands that service partners maintain close contact with customers and ensure successful delivery of performance-based services, which extend the life of the equipment. Thus, the business growth of service partners and other ecosystem partners is critical for successful circular business model implementation.

Finally, nurturing also included *openness toward sharing core knowledge and IP materials* for the development and acceptance of circular business models. The sharing of knowledge and IP is a way to promote complementary innovation (Jacobides, Knudsen, & Augier, 2006). Moreover, sharing IP represents a basis for developing new ecosystem partnerships and is the core component for changing the ecosystem to offer a business solution that is consistent with the circular economy. For example, Company B opened its telecom platform for local distributors to design, build, and offer advanced services to end customers. In practice, the company understands the importance of openness by sharing IP to develop mutually beneficial relationships with ecosystem partner.

4.2.3. Negotiation mechanism

Our data suggest that negotiating activities represent an indispensable mechanism for ecosystem orchestration. Orchestrating a circular economy ecosystem requires aligned actions across multiple ecosystem partners that, at times, may have inconsistent incentives (Pan et al., 2015). Our data analysis indicates that the complex pattern of mutual interdependencies among partner in a business ecosystem makes negotiating a central part of the orchestration concept. For example, without explicitly mentioning negotiation, scholars have described how ecosystem leaders may use selective collaboration programs (Ceccagnoli, Forman, Huang, & Wu, 2011) to steer partners toward a sustainability agenda and have suggested that future value should be co-created (Clarysse, Wright, Bruneel, & Mahajan, 2014).

We found that ecosystem orchestrators use negotiation activities to safeguard interests of core ecosystem partners by *setting rules of game based on give-and-take relationships*. In practice, this means that ecosystem partners need to place emphasis on incentivizing each other rather than just maximizing individual benefits. According to a New Technology Testing and Development Manager from Company D, "*our value chain actors such as service partners are closely involved in designing and developing future mobility-based solutions for city residents. To offer luxury car sharing services, requires a new type of collaboration with strategic partners, where they take risks but also can foresee clear benefits from joining forces with us*." Managers in manufacturing firms explained that most rules could not be standardized across the ecosystem. Instead, the rules must be negotiated with individual firms.

The negotiation would often be a give-and-take process where rules were gradually revised as the relationship became more trust based. For example, Company B described the problems faced by one of their partner company which was a marketing-based SME that wanted to access information on the customers of the customer in the ecosystem. Such information is crucial for taking greater responsibility from a circular economy perspective because it increases the company's understanding about end customers' needs. However, the ecosystem leader was reluctant to share information. At first, the SME only had access to strictly necessary customer information. After some time, the SME gained access to certain general information about customer segments. Later, the SME partner was in a position to individually access and analyze customer information for predicting customers' decision-making behavior for the ecosystem leader. This new position enabled the SME to work closely with the ecosystem leader to develop a holistic view of customer relationships and fine-tune the supply chain so that greater attention could be paid to circular economy targets. In this case, the SME gained negotiating power and could put more pressure on other suppliers to offer environmentally friendly products.

Moreover, the large manufacturing companies recognized that ecosystem relationships are prone to conflict. *Reducing conflicts through relational interdependence between selected ecosystem partners* is a highly valuable way of preventing conflicts in this context. Two examples show how interdependencies develop and are used to meet the goals of the circular economy. In the telecom industry, Company B wanted to offer capacity-based business models, which meant that they needed to negotiate the new business model with their customer. The offer presented considerable economic and environmental benefits because customers needed to buy 20% less equipment, and the lifespan of the equipment increased by 30% thanks to better installation and maintenance. However, this new business model was highly risky and unclear for both parties. They therefore negotiated a 50%–50% risk and revenue arrangement, which created incentives for relational interdependence.

In another case, smaller firms in business ecosystems hesitated to invest in circular economy solutions because of high costs and high uncertainty of a return on investment. To encourage circular economy investment, ecosystem leaders granted exclusivity to one or several firms. In one case, the ecosystem leader engaged in an agreement granting market space to the complementary partner. Such exclusivity agreements created relational interdependence where all participating firms enjoyed collaborative benefits, clear role distribution, and a collective desire to meet circular economy targets.

Finally, the negotiation mechanism implies that ecosystem orchestrators are reserved when it came to new partners entering the ecosystem. However, the scaling of circular business models requires involvement from new partners. This involvement includes addressing a lack of in-house competencies, expanding into new markets, and delivering on promised outcomes. The controlled *inclusion of new partners based on risk and benefit analysis* can be used to achieve these goals through ecosystem transformation. For example, Company A realized that it could not create high customer satisfaction without partners' complementary offerings. The company therefore adopted a two-sided platform approach. They offered their own core services while allowing complementary firms to make additional offers, thereby improving the customer experience. Customers could benefit from solutions tailored to their individual needs. All partners reaped the benefits of this solution. The platform owner (i.e., the ecosystem orchestrator) could offer better customer service for the same risk (responsibilities were clearly divided), complementary ecosystem partners had more business opportunities, and customers received better service. More importantly, a network of environmentally friendly services was connected, thereby saving resources and enabling several firms to strive for shared environmental targets. A manager from Company F offered another example: "*initially we thought about controlling the logistic needs for the new cable system, but such arrangement would means taking on role which is not fitting to our organization. So after long negotiations with numerous partners, we decided to agree terms with an international logistic company that made heavy upfront investments to our new business logic and provides long term commitment to us and our partners*." Thus, if used properly, negotiation can be a powerful mechanism of ecosystem orchestration for circular business models.

5. Toward a two-stage process for circular economy ecosystem transformation

Fig. 2 illustrates the ecosystem transformation generalized from the activities reported by the companies that we studied. Before starting the ecosystem transformation, ecosystem orchestrators conducted an ecosystem readiness assessment. In other words, ecosystem readiness assessment was a precursor to the actual transformation. We noted three readiness assessments: external environmental, business model, and ecosystem partner. The external environmental assessment consists of the gathering of information on circular trends in the industry (e.g., customer interests and technological opportunities) and regulatory changes (e.g., introducing mandatory standards). This assessment helps companies to gauge the opportunities of the transition to the circular economy and identify potential threats that would emerge if the ecosystem failed to complete the transition on time.

The business model and ecosystem partner assessments complement the external ecosystem assessment because they provide information on the readiness of the ecosystem orchestrator and ecosystem partners for the transition. Taken together, all three assessments establish the gap between circular economy aspirations (defined by the external assessment analysis) and the capabilities of the ecosystem to achieve these aspirations. The gap reflects the capabilities and resources that are missing in the ecosystem and the processes of ecosystem governance that would be necessary to transition the ecosystem to the circular economy paradigm. Notably, ecosystem readiness assessment is rarely a linear process; ecosystem orchestrators usually engage in multiple iterations of (re)assessment of the three factors of readiness before they meet the objective of the assessment, namely identification of the transformation gap.

Once the gaps are clarified, manufacturing companies engage in ecosystem transformation. At this stage, we isolated three mechanisms that jointly move the ecosystem toward establishing its circular economy goals. Standardization mechanisms are used to define and legitimize circular economy goals for ecosystem partners. Ecosystem orchestrators set the overarching standards that the ecosystem will be evaluated against (e.g., life-cycle costs for equipment and its use), develop the specific standards with the selected ecosystem partners (e.g., standards for engine design), and impose certain standards on the broader set of ecosystem partners, including potential new partners (e.g., material quality).

Once the goals are set using standardization mechanisms, ecosystem orchestrators turn their attention to ensuring that all ecosystem partners have access to the necessary resources and capabilities to implement the goals. Nurturing mechanisms are central to this process. Aside from making internal investments, ecosystem orchestrators bear the early infrastructure investment costs and facilitate investment by core ecosystem partners by helping them offset uncertainty or improve the business case for investments that are specific to the circular economy (e.g., Company D, an orchestrator of the mobility solution ecosystem, helped their service partner by directly investing in their business). Besides direct investment and investment facilitation, nurturing mechanisms encompass activities related to supporting competence development of key ecosystem partners (e.g., Company A provided

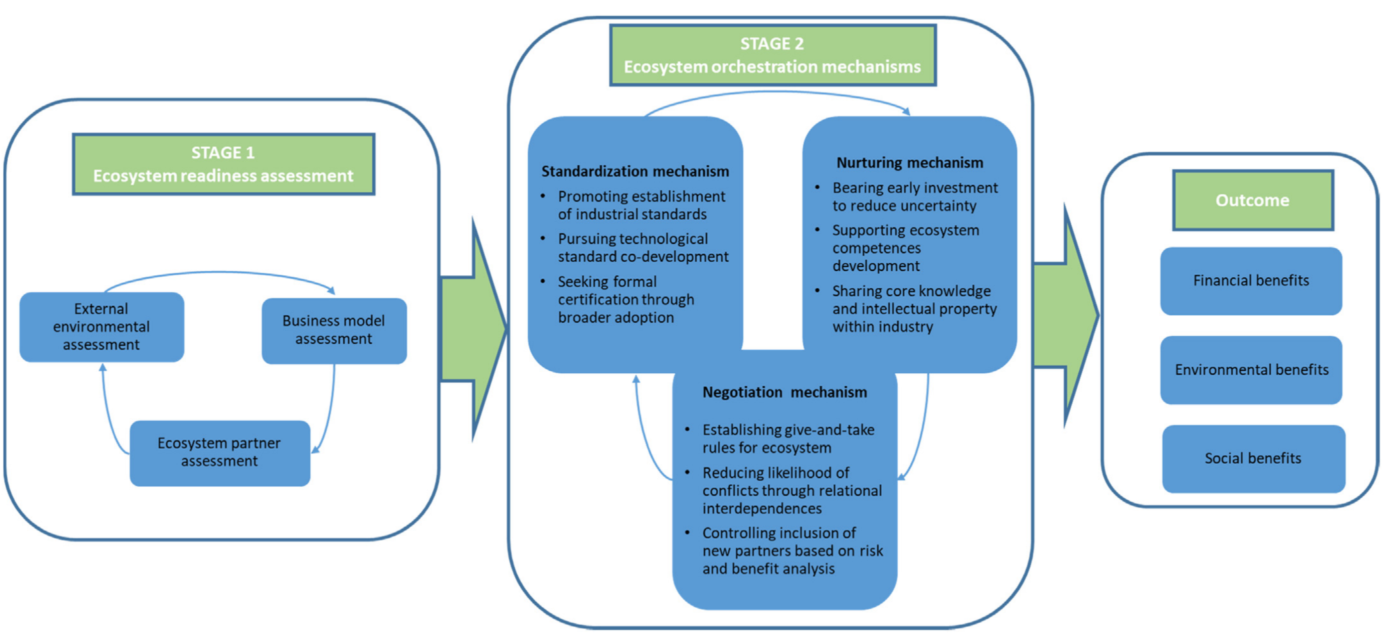

Fig. 2. Two-stage process model of ecosystem transformation to a circular economy.

training and material support for competence development of their global distributors) as well as open sharing of knowledge and IP that enables the broader ecosystem to achieve the circular goals.

Once the capabilities have been ensured, the incentives and activities of multiple ecosystem participants must be coordinated as they incorporate circular economy standards in their individual offerings. The ecosystem orchestrators we studied accomplish this coordination using negotiation mechanisms such as give-and-take rules, relational interdependence setting, and risk-benefit analysis for new partner inclusion. Standardization, nurturing, and negotiation mechanisms, in this order, guide the transformation from the point where each partner has circular economy objectives that contribute to the alignment of ecosystem aspirations. As they did in the readiness assessment stage, ecosystem orchestrators use transformation stage mechanisms iteratively. Although standardization mechanisms appear first, followed by nurturing and then negotiation mechanisms, there is a strong feedback loop with multiple iterations until the ecosystem is transformed and the desired financial, environmental and societal outcomes are reached.

In conclusion, the outcome of ecosystem awareness and orchestration mechanisms can lead to diverse benefits and competitive advantages. Strategic advantages such as differentiation and cost leadership are the most common. However, we argue that the core advantage of ecosystem transformation is to increase the ability of ecosystems to achieve good triple-bottom-line performance by providing social, financial, and environmental benefits to customers. For example, companies achieve higher productivity, better resource use, a reduction of dangerous jobs, greater transparency in the ecosystem, market growth, and financial gains. Thus, ecosystem transformation toward the circular economy paradigm creates opportunities for sustainable industry.

6. Discussion and conclusions

Theoretical contributions.

The circular economy paradigm has the potential to bring about positive economic, environmental, and social benefits. For the circular economy to fulfill its promise, large manufacturing companies must both transform their own strategies and business models, and entice their ecosystem partners to follow them in this transition (Ellen MacArthur Foundation, 2013). This transformation to a circular economy ecosystem poses a major challenge for manufacturing companies because it requires them to coordinate and manage the incentives and investments of multiple companies (Ghisellini et al., 2016; Lahti et al., 2018). Still, the current knowledge about how such transformation should come about is limited.

This study makes three contributions to the circular economy literature by explaining how manufacturing firms orchestrate ecosystem-wide transformation to the circular economy paradigm. The first is that we argue that the role of ecosystem orchestrator or leader is critical for implementation of circular economy principles. Kortmann and Piller (2016) indicate that the move to the circular economy is accompanied by the emergence of an ecosystem orchestrator role, what they term a platform owner. Similarly, Iansiti and Levien (2004), propose diverse roles, such as keystone, dominant and niche players, within an ecosystem and recognize the importance of having the ecosystem orchestrator that apply and designate a clear strategy for ecosystem transformation. Although research has recognized the need for ecosystem orchestration, the literature currently lacks insights into the activities undertaken by the ecosystem orchestrator. We therefore identify and explain how the large manufacturing companies use diverse activities related to ecosystem readiness assessment and ecosystem transformation to promote changes in the ecosystem (Manninen et al., 2018). The proposed set of complementary activities and mechanisms are iterated to accomplish the objectives of that stage and to orchestrate an ecosystem-wide circular economy transformation.

Second, current the research on the circular economy has ignored the need for a comprehensive ecosystem readiness assessment (Bocken et al., 2016; Frishammar & Parida, 2018). We therefore warn manufacturing companies not to overlook internal and external readiness assessments. A transformation to a circular economy entails significant change in the individual company and its ecosystem partner business models, creating fertile ground for conflict and opportunistic behavior (Lahti et al., 2018; Reim, Parida, & Sjödin, 2016). It is therefore necessary to assess ecosystem readiness by scanning the external environment for emerging technologies, evaluating government regulations and policies, gaining a deeper understanding of their own business models, investigating win-win scenarios, and creating new partnerships. Scanning the external environment and government regulations helps define the aspirations for the circular ecosystem paradigm, whereas by identifying the activities related to readiness assessment, manufacturing companies can arrive at a deeper understanding of the scope of the ecosystem transformation toward a circular business model paradigm.

Our third contribution is the recognition that the transformation to the circular economy conducted by ecosystem orchestrators is oriented toward different types of ecosystem partners (Parida et al., Forthcoming; Visnjic et al., 2016). Some of the mechanisms that ecosystem orchestrators use are aimed at the core ecosystem partners, and others at peripheral ecosystem partners and potential new partners. Managing the diverse portfolio of partners that is part of the ecosystem needs different approaches. In addition to providing new insights into the application of three mechanisms: standardization, nurturing, and negotiation, this study builds on and extends prior studies (e.g., Mathews et al., 2011; Sarkis & Zhu, 2008; Wen & Meng, 2015; Williamson & De Meyer, 2012) by detailing how these mechanisms are implemented by ecosystem orchestrators to influence the transformation of core ecosystem partners and peripheral ecosystem partners. For example, nurturing mechanisms for circular economy transformation needs ecosystem orchestrator to bear heavy early investment to reduce uncertainty about transformation (i.e. internal transformation), support ecosystem competence development of selected partners (i.e. core partners transformation), and share core knowledge and IP within industry for large-scale adaptation of products, services, and/or technology (i.e. peripheral partners transformation). Thus, this study contributes to the literature by providing multi-actor level insights to the circular economy transformation.

To conclude, manufacturing companies are facing the challenge of making the transition to the circular economy paradigm. The literature on the circular economy literature remains conceptual and mainly provides discussion on broad steps to make our world more sustainable. Our study directly addresses lack of empirical findings by presenting a two-stage framework to describe how large manufacturing companies entice and help their ecosystem partners to follow them in adopting the circular economy paradigm. Identifying and exemplifying how large manufacturing companies work to implement the circular economy paradigm can support the large-scale adoption of these principles in the shift toward sustainable industry.

7. Limitations and suggestions for future research

This study has three limitations that merit consideration when interpreting the results. The first limitation is that this study provides insights from cross-sectional qualitative analysis of manufacturing companies, at the time of ecosystem transformation to circular economy paradigm. However, such transformations tend to be emergent and prolonged. Thus, we encourage longitudinal studies to showcase how the ecosystem undergoes a transformation throughout its evolution. The second limitation is that this study builds on a rich but limited interviews of ecosystem orchestrators and selected ecosystem partners. A more comprehensive analysis of the ecosystem stakeholders (i.e. core and peripheral partners) can provide novel insights into the activities conducted by ecosystem orchestrators for circular economy transformation and the effects of those activities. We suggest future studies go beyond partners to include a wider array of competing stakeholders and supporting actors (such as government or research institutions) and explore their engagement in the transformation of their business model into a circular economy. Finally, qualitative data limits the possibility to generalize the findings, such as relationships between circular economy paradigm effect on the economic, environment and social benefits. Future studies are encouraged to use more comprehensive panel data and look at both firm- and industry-level effects of circular economy transformation. Specifically, by looking into anteceded (e.g., regulative change or financial incentives), moderators (e.g., role in the ecosystem, networking capability) and mediators (e.g., ability to innovate and orchestrate ecosystem) would benefit the development of the emerging literature on the circular economy.

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