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Challenges of creating and capturing value in open eco-innovation: Evidence from the maritime industry in Denmark

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ABSTRACT

Developing eco-innovations using open innovation comes with a distinct set of challenges as the dual goals of economic and environmental value creation produce tension that is not easily overcome in a multi-stakeholder network. These incongruent goals are inherent in an open eco-innovation network and potentially involve governmental agencies, regulators, and non-governmental organizations along with suppliers and other partners. Consequently, they add a layer of complexity to the creation and capture of value throughout the innovation network. Thus, in this study, we ask: *What are the challenges in creating and capturing value in open eco-innovation networks?*

Based on an embedded case study of a network developing eco-innovation over a six-year period in the maritime industry in Denmark, this paper identifies challenges and links them to their impact on value creation and value capture. Our findings indicate that firms and partners are less innovative and more conservative in their approaches to innovation than has previously been observed in open-innovation partnerships. This research contributes to the eco-innovation knowledge base by demonstrating how extracting value from open eco-innovation is complicated as value is created at the micro and meso levels of the network, yet, a major goal of value capture is at the environment and social macro level. Thus, our results indicate that firms are less willing to commit resources and knowledge to co-creation, thereby negatively impacting value capture for the entire network, the society and/or the environment. Using open innovation to address "grand" societal challenges requires understanding value creation and value capture within this micro-meso-macro systemic framework of competing goals.

1. Introduction

In a climate of growing concern about the environmental impact of products and their resource-intensive production, more firms are considering introducing eco-innovations to create both economic and environmental value simultaneously (Carrillo-Hermosilla et al., 2010; Jakobsen and Clausen, 2016; Christensen, 2011). Examples of such efforts have been linked to the increased efficiency of energy and resource use and waste reduction (Sardianou, 2008; Kostka et al., 2013). As individual firms often do not possess all the core competencies required to produce products that minimize their impact on the natural environment, they turn to open innovation (Jakobsen and Clausen, 2016). In particular, the complexity of knowledge that is integral to many eco-innovations drives the need to work with partners through open innovation (Cainelli et al., 2012). Indeed, several scholars have proposed using open innovation to solve the "grand challenges" of environmental conservation (Miles et al., 2010; Chesbrough, 2017a, 2017b).

However, developing eco-innovations using open innovation comes with a distinct set of challenges regarding the creation and capture of value that has not been well studied (Garud et al., 2013). Such is especially the case in situations where open eco-innovation is developed in an extensive, multi-stakeholder network that can involve governmental agencies, regulators, non-governmental organizations (NGOs), suppliers, and other partners. The stakeholders involved have individual goals and interests that can contradict or complement the goals of the network (Hall and Martin, 2005; Hörisch et al., 2014), and the resulting benefits from the invested resources can be unbalanced between firms (Das and Teng, 2000). Therefore, the involvement of a multi-stakeholder open innovation network adds a layer of complexity to value creation and capture in

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eco-innovation development (e.g., Lee et al., 2012; Ping-Chuan and Shiu-Wan, 2014). Thus, in this study, we ask: *What are the challenges in creating and capturing value in open eco-innovation networks?* If open innovation is to be used to solve the environmental concerns of the 21st century, it is essential to identify and understand the factors that may hinder its implementation in developing eco-innovations.

The present research is an embedded case study of a maritime network that operated over a six-year period in Denmark. The study was conducted to identify the set of challenges that emerge at the micro level (firm, organization), macro level (society, environment) and the meso level (networks, intermediate structures, co-partnering institutions) when diverse organizations unite to bring eco-innovations to market. The contributions of this study are threefold. First, open innovation theory has primarily focused on interfirm cooperation in a distributed innovation process as knowledge flows across organizational boundaries (Vanhaverbeke et al., 2014). Few studies have examined the ecosystem environment where value creation and value capture occur across three interconnected levels (micro, meso, and macro) when either the society, the environment, or both are essential stakeholders (Carrillo-Hermosilla et al., 2010). We contribute to the open innovation knowledge base by demonstrating how extracting value from the multilevel open eco-innovation process is not straightforward. Value is *created* at the level of the individual firm (micro level) and *co-created* between stakeholders (meso level); however, the major goals of value *capture* are meant to be achieved at the level of the society/natural environment (macro level). Secondly, we identify challenges that emerge because of the incongruent goals that exist at multiple levels of the multi-stakeholder network. These challenges subsequently lead to diminished value capture as firms become more conservative in their decision making, resulting in fewer innovations and less innovative solutions when developing eco-innovations. This situation is paradoxical in the context of our current understanding of open innovation (West and Gallagher, 2006; Van de Vrande et al., 2009; Cohen et al., 2016). Thirdly, in advancing our knowledge of eco-innovations, we find that although regulatory constraints are meant to motivate more development of eco-innovations (Rennings, 2000), their impact is marginalized in the open innovation network without a central champion for the environment.

2. Open innovation for eco-innovations

2.1. Open innovation

The academic discourse on open innovation has been predominantly driven by Chesbrough's (2003) work that opposed the conventional view of innovation as an activity within the boundaries of the firm. Chesbrough's (2003, p. 43) original definition, “Open Innovation means that valuable ideas can come from inside or outside the company and can go to market from inside or outside the company as well” inspired new research on how companies in asset-driven industries could benefit from ideas, research, and patents created by other organizations (Dahlander and Gann, 2010; Huizingh, 2011; Van de Vrande et al., 2009). Additionally, Dahlander and Gann (2010) proposed a better conceptualization of the “openness” construct by highlighting the complementary assets aspect.

Insights from network theory and knowledge-based theory of the firm (Shan et al., 1994) were introduced in studies on open innovation to provide an understanding of how firms exchange knowledge in a network of actors external to the firm. This development led to a refinement of Chesbrough's definition: “Open Innovation is the use of purposive inflows and outflows of knowledge to accelerate internal innovation, and expand the markets for external use of innovation, respectively” (Chesbrough, 2006b, p. 1). This later research focused on the analytical lenses of technological exploration (customer involvement, external networking) and technological exploitation (venturing, outward licensing of intellectual property) (Van de Vrande et al., 2009). Knowledge exchange is explained in light of strategies that are pecuniary (e.g., purchase or licensing of inventions) and non-pecuniary (i.e., sourcing of external ideas to suppliers) (Dahlander and Gann, 2010). A fundamental concept in open innovation is that value exchange occurs to benefit the partners in the exchange.

Open innovation research has primarily focused on the firm and interfirm levels. Several studies have empirically shown that open innovation leads to increased profitability (Chiang and Hung, 2010; Lichtenthaler, 2009), R&D performance (Chiesa et al., 2009), product innovativeness (Laursen and Salter, 2006), access to knowledge (Rohrbeck et al., 2009), and new product success (Rohrbeck et al., 2009). Other studies have indicated possible negative open innovation effects in terms of high search costs for external knowledge (Laursen and Salter, 2006; Rothaermel and Deeds, 2006), power struggles to control knowledge assets (Torkkeli et al., 2009), and unfavorable attitudes toward open innovation (Lichtenthaler et al., 2010). Understanding of the open innovation–performance relationship remains fragmented and merits further exploration.

2.2. Open eco-innovation

The growing awareness of environmental deterioration has led to a transition in innovation toward sustainable economic activities based on environmental technology and sustainable consumption patterns (Foxon, 2011; Jakobsen and Clausen, 2016) resulting in eco-innovations. We define an eco-innovation as an innovation that results, “throughout its life cycle, in a reduction of environmental risk, pollution, and other negative impacts of resources use (including energy use) compared to relevant alternatives” (Kemp and Pontoglio, 2007, p. 10). Eco-innovation has primarily assumed a micro (firm) and macro-level (ecosystem) perspective, whereas open innovation, as described in the previous section, has primarily utilized a micro and meso-level perspective.

In this study, based on Chesbrough's definition (2006b), we view open eco-innovation as the development of innovations utilizing inflows and outflows of knowledge to accelerate internal innovation and expand the market for innovations created with partners outside the firm, with one of the goals of achieving a positive impact on the society, the environment, or both. This approach requires a multi-level perspective of micro, meso and macro levels to observe partners creating value for the environment and society.

The systemic nature of eco-innovations requires a multi-faceted knowledge base that is unlikely to reside wholly within one firm (Horbach et al., 2012). For instance, environmental mandates reside with regulatory agencies; scientific knowledge of eco-friendly materials that meet regulatory standards may come from universities and research institutes. The knowledge of sustainable production may be housed with suppliers, and the market acceptance of new eco-innovations is dependent on consumer feedback. These broad knowledge requirements are difficult for a single firm—or even two—to satisfy. Consequently, eco-innovation requires a network of partners wherein the knowledge boundaries between the firm and the external environment become permeable (Ghisetti et al., 2015). Each partner brings a knowledge base that can be exploited to create and capture value for all partners in the network.

2.3. Value creation and capture within the open eco-innovation network

The value creation/capture logic in business systems extends to the collaborative agreement emerging from open-innovation activities (Chesbrough, 2006a, 2017a; Radziwon et al., 2017; Enkel, 2010). In open innovation, firms must undertake a "series of activities that yield a new product or service in such a way that there is net value created throughout the various activities … [The firm] captures value from a portion of those activities" (Chesbrough, 2006a, p. 108). Organizations need to consider not only how they create and capture value internally but also how the network serves as a platform of value creation and capture across and between partners (Adner and Kapoor, 2010; Chesbrough and Bogers, 2014; Rong et al., 2013; Vanhaverbeke, and Cloodt, 2006). Bocken et al. (2014) identified open innovation as a collaborative model that can bring like-minded individuals, firms, and partners together to create and capture value to facilitate an industrial sustainability agenda.

The process of value creation in an open innovation network should facilitate mutually beneficial collaboration between the various partners that leads to added value for direct (e.g., customers) and indirect (e.g., society) stakeholders (Radziwon et al., 2017). The extent of value creation differs depending on whether value is created by an individual, an organization, or society (Lepak et al., 2007). Value creation has been a central concept in the management and organization literature at both the micro level (firm, organization) and the meso level (networks, intermediate structures, co-partnering institutions) (Lepak et al., 2007). At the meso level, co-creation should generate knowledge sharing, expansion of networking contracts, licensing opportunities, and new business models. Similarly, at the micro level, co-creation should result in knowledge acquisition, new customers, new products, and financial benefits for the firm.

Traditionally, value capture has been examined at only the company level and the intercompany network level. However, with eco-innovation, value capture must occur at all levels of the system—micro, meso, and macro levels. An extended, overall understanding of value capture is one of appropriation or retention. In the setting of open eco-innovation, network actors capture value by securing new knowledge and exploiting it to achieve a mutual goal focused on the ecosystem (Balka et al., 2014). Specifically, at the level of the *individual* (micro level), value capture is characterized by: power position, unique experiences, and absorptive capacity or similar benefits to the firm. It may or may not benefit the ecosystem as a whole, but it provides the individual firm with increased value. At the level of the *network* (meso level), sharing of knowledge and acting in a "partnership-building way" instead of a "transactional way" facilitates value capture (Rowland and Parry, 2009) that is shared between partners. Thus, value capture at the meso level is concerned with how members in the network collaborate to achieve a desirable level of reward/monetization to advance a common goal. At the *eco-systemic* level (macro level), the concept of environmental value capture is more diffuse as it involves not only the producers' and consumers' perspectives but also eco-systemic performance and impact on society (Lacoste, 2016). Consequently, at the macro level, the interconnected nature of societal value must be addressed (Faber and Frenken, 2009). Value must include benefits to the environment that may not be measured economically but instead in terms of societal/ecological value (e.g., lower unemployment, air and water quality improvements, resource conservation).

Value spaces define where value is captured at each of the levels. At the meso level (network partnerships), factors related to unique organizational cultures, evolving network structures, and power struggles in partner relationships can influence the decisions made at the micro level (individual firms) where decisions impact the macro level (Rowland and Parry, 2009) environmental and social issue. In Fig. 1, we map the different levels where value creation and capture can occur. Although the levels are dependent upon each other, the focus in this study is on separate levels in order to identify the different challenges that may arise at each level.

3. A case study on multi-partner, multi-year eco-innovation project

3.1. Longitudinal embedded case study

The relative lack of understanding of open eco-innovation and its inherent challenges regarding value creation and value capture favor a longitudinal embedded case-study approach (Van de Ven and Poole, 1990; Huizingh, 2011). Building on the argument that value creation and capture in open eco-innovation happens at all levels of the eco-system, an embedded case-study design facilitates the discovery of the challenges at multiple levels between multiple stakeholders (Järvensivu and Törnroos, 2010; Whitmarsh, 2012). Additionally, the development of an eco-innovation is often characterized as complex and can be divided into different stages that are more easily documented (Rennings, 2000; van de Ven et al., 1999).

Our context of interest, the shipping industry, is highly regulated, and new environmental regulations have been or are about to be implemented (Fagerholt et al., 2015). Consequently, the shipping industry provides a rich empirical setting in which to examine our research question. Additionally, formal networks such as this maritime example, often have an administrator who can be queried for unique insider knowledge about the eco-innovation process and member firms who can provide insights not normally available.

We see this network of maritime industry partners who focused on a common goal of eco-innovation development as a representative case to study the challenges of open-innovation (Henry and Foss, 2015). Prior research has identified market and regulatory changes as key drivers of eco-innovation (Kesidou and Demirel, 2012). This duality of value (economic and environmental) provides a relevant context to study open innovations and facilitates the study of the difficulties of creating and capturing sustainable value. Thus, this maritime setting is demonstrative of an asset-intensive network that is typical of open innovation studies. The setting also provides the added factor that the goal is to design a more environmentally friendly passenger ship that differentiates this study from previous research on open innovation. This setting allows learning outcomes beyond the case context to be maximized (Stake, 1995). A longitudinal approach to our analysis enables us to examine how project goals morph during the process and how different challenges emerge across time and levels.

3.2. Case description

A network of maritime and consultancy firms located in a coastal town in Denmark developed the Clean Ship[1,2] network from 2009 to 2016. Harbor Town[2] has a long maritime history, and the region's economic activities depend heavily on the local maritime industry. Due to a series of financial setbacks and restructuring, two key actors, the shipyard and an engine factory, closed their operations in Harbor Town in 2007 (Interview 2, Consultant). The

[1] See Table A1 in the online appendix for additional information about the informants.

[2] All informants' names are fictitious to ensure confidentiality.

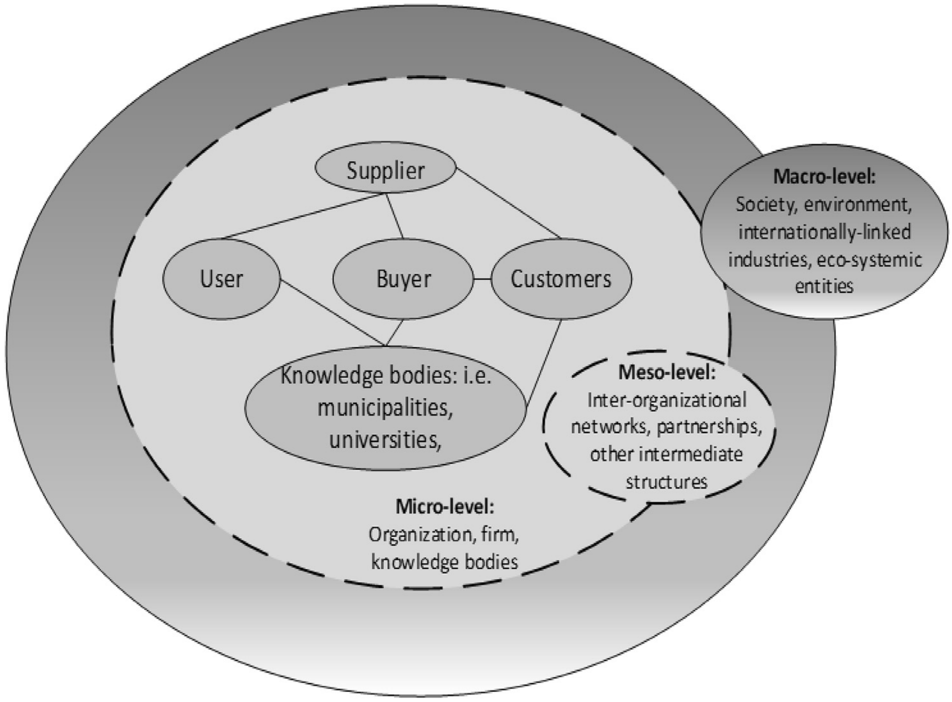

Fig. 1. Multi-level perspective of open-innovation.

suppliers of those two key actors needed to search for new opportunities to survive (Interviews 2 and 5, Consultants). At the same time, the awareness of environmental degradation and pollution caused by the maritime industry continued to increase. Consequently, regulators had recently established new environmental rules, and the industry expected other regulations in the near future. These changes, combined with increased environmental awareness, gave birth to different but related innovations such as energy-saving technologies, the use of exhaust gas cleaning systems, and emission-monitoring systems.

The Clean Ship eco-innovation aimed to co-develop cleaner products to retrofit maritime vessels with greener and more energy-efficient technologies. The network's goal was to combine both the suppliers' competencies and high-end technology to promote a more environmentally friendly maritime industry. The initial group of partners from 17 different organizations included the customer (Shipping Company), suppliers, universities, and governmental institutions (see Table 1 for the partner list and

Table 1
Actors and their Involvement in Clean Ship.

Actors	Initiation (2009–2012)	Evaluation, testing & selection (2012–2015)	Commercialization (2015–2016)	Contribution to Clean Ship
Shipping firm (Customer)	X	X	X	Testing the concepts, idea generation
Supplier engines	X	X	X	Improvements in the ship's propeller and speed pilot system
Supplier propeller	X			Improvements of propelling system
Supplier noise control equipment	X	X		Noise reduction
Supplier ventilation 1	X			Improvements of the heating/ ventilation system
Supplier ventilation 2	X	X		Cleaning of ventilation systems
Supplier exhaust control 1	X		X	Design/ installation of NOX and SOX emission control equipment
Supplier exhaust system 2	X			Improvements of exhaust system
Supplier electrical systems 1	X	X	X	Energy saving lighting systems
Supplier electrical systems 2	X			Remote monitoring of ship's energy performance
Supplier electronic systems 1	X		X	Monitoring of fuel energy use
Supplier electronic system 2		X		Energy use monitoring system- user friendly
Supplier electronic systems 3	X	X	X	Energy measurements
Shipyard	X		X	Dry docking for retrofit projects (i.e. engine, propellers)
Danish technology approval organization		X		Regulatory advice
Technological institute	X	X		Feedback for project applications
Universities	X	X	X	Shaping value-proposition Improving process
Business Council/Maritime Centre	X	X	X	Coordination and application for external funds
Maritime branch organization	X			Expert advice

timeline of participation). Each entity agreed to the open innovation concept of working together to share knowledge and resources to achieve a common goal - successfully retrofitting the customer's ship to transform it into a more environmentally-friendly "Clean Ship." The partnership recognized that no single organization had the resources or capabilities necessary to complete the project on its own. Motivation and collaboration were initially strong as each partner recognized the innovation's potential to have a lasting impact on the shipping industry.

3.3. Data sources and collection

The authors relied on in-depth interviews, document review, and observations to gain insights into the challenges of open eco-innovations. The authors had access to more than 500 pages of the network's internal documents including meeting minutes, PowerPoint presentations, formal contracts, and lists of attendees at various meetings. The information gathered through the document review was subsequently useful in locating key informants and preparing the interview guides.

We conducted 17 in-depth interviews of the network's individuals in the timeframe between 2011 and 2016 to ensure the longitudinal character of the case. The interview transcripts comprised more than 300 pages and 916 min of transcribed materials. All interviewees actively participated in the Clean Ship initiative in Harbor Town. We first became acquainted with the network activities during fieldwork in 2011 in Harbor Town through a round of interviews with maritime business consultants in the Harbor Town Municipality. Following a snowball sampling strategy (Marshall and Rossman, 2014), the first informant suggested additional informants and facilitated access to the network's internal documents. This assistance allowed us to prepare a list of potential interviewees and ensure a balance among different suppliers and the customers involved over the six-year period. We also conducted contextual interviews with Danish ship owners to gather information about the environmental regulations forcing the maritime industry to develop certain types of environmental technologies and about their perceptions of the network and innovation process. The interviews were audio-recorded and transcribed verbatim. Additional details are available from the authors and are in the online appendix.

Direct observation allowed us to understand the discourses surrounding the environmental regulations and environmental technologies regarding the shipping industry and the Clean Ship innovation. One of the authors is associated with the maritime foundation that coordinated the eco-innovation initiative, and so the researcher was able to attend as an observer some of the project's facilitation meetings. The foundation interacted closely with European shipping stakeholders on a regular basis. This interaction allowed the author to participate in meetings, seminars, conferences, and networking activities. After each event, the author created narrative memos, and some memos covered the most important issues at stake. The network formally dissolved in late 2015, but several members continued to participate in a maritime network of partners.

3.4. Data coding and analysis

The data was systematically coded and analyzed. We took inspiration from Gioia et al. (2013) whose data analysis strategy organizes the raw data into concepts and thereafter develops themes that facilitate the identification of groups of challenges. We used QSR NVivo 10 software that supported the coding approach and enabled us to keep track of the emergence of new concepts and relationships (Rohrbeck et al., 2009).

As a first step, we used an open coding approach (Bazeley and Jackson, 2013), and a coauthor did the first round of open coding the data materials. This coauthor was not involved in the data collection, had no affiliation with the Clean Ship innovation, and consequently had no preconceived understanding of the Clean Ship innovation and the challenges the actors faced. Through the open coding process, the raw textual data was initially analyzed and categorized (Miles and Huberman, 1994). During this stage, the codes were broad, and new codes were added to the NVivo coding scheme as the interviewees mentioned new challenges. We identified 36 first-order concepts in the raw data that represent the different groups of challenges; these analyses are available in the online appendix (Table A3).

The second round employed a structural coding approach and was theoretically driven but anchored in the first-order concepts. During several rounds of discussion, the 36 first-order concepts were grouped into nine second-order themes representing the antecedents of the challenges identified in the first step. In the third and final step, we further structured the data and we grouped them into the level(s) (micro, meso, macro) where the challenges occurred. We then evaluated the data in regards to two processes: value creation and value capture.

3.5. Ensuring trustworthiness

This study employed criteria for research validity, credibility, and confirmability to ensure the trustworthiness of the qualitative research (Guba and Lincoln, 1982; Järvensivu and Törnroos, 2010). The study's validity was tested in two ways. First, we presented preliminary and final results to a scientific audience through workshops, seminars, conferences, and discussions with research colleagues. We obtained two rounds of feedback and comments on the results from the network administration. To ensure credibility, we triangulated three sources of evidence: interviews, observations, and document analysis (Guba and Lincoln, 1982). Additionally, we interviewed different kinds of stakeholders, including suppliers, customers, and ship owners (Beverland and Lindgreen, 2010). In this way, we addressed issues related to response bias, inaccuracies due to poor recall of past events, and biased selectivity.

Through several rounds of discussions based on the first-order concepts, theoretical insights, and the coding scheme developed with NVivo, we addressed confirmability issues related to non-matching patterns and researcher bias (Beverland and Lindgreen, 2010; Gibbert et al., 2008). Through this process, the observed challenges were compared to challenges identified in extant studies. We applied the well-established theoretical lens of stakeholder and network theory for an analysis of the data material. The challenges were studied based on the Clean Ship case, an eco-innovation developed in a network of multiple actors as shown in Table 1. Hence, we studied 15 of the 19 actors (identified in Table 1) nested in the case study with multiple interviews with some respondents, obtaining varied insights into the process. The challenges mentioned by the informants were accumulated which established confirmability (Beverland and Lindgreen, 2010).

4. Challenges of value creation and capture in open eco-innovation

4.1. Conceptual framework of micro-meso-level analysis

The interview data were analyzed using the theoretical framework on value creation and capture in multi-stakeholder innovation (Reypens et al., 2016; Vanhaverbeke and Cloodt, 2006), focusing in this study on challenges emerging from an economic-environmental process of open innovation in the maritime

Table 2
Challenges of value creation and capture in open eco-innovations.

Antecedents of Challenges		Challenges	
		Value Creation	Value Capture
Micro-level (firm actions)	Conflicting firm/organizational goals	Firm focuses on its own individual goals	Fewer green redesigns are undertaken by the firm
	Withholding/ withdrawing resources	Firm chooses to minimize resource commitment and activity level to lower its own risks	Greater focus by a firm on safe, incremental innovation instead of disruptive innovation
	Evolving commitment to project by firm	Withdrawal of commitment, sometimes followed by recommitment	Returns on investment are not realized for many months/years (if ever) by the firm
Meso-level (network i nteractions)	Power struggles at the network level	Less influential members compete to be recognized as valuable players	Missed opportunities to co-innovate with partners
	Network evolution	Prolonged co-development cycles due to continually changing partners	Slowed diffusion of knowledge between partners decreases innovation output
	Mistrust of partners/competing value spaces	Partners withhold knowledge & resources from each other	Diminished resource and knowledge exchange marginalize output of network
Macro-level (social-environment)	Double externalities problem	Firm commits resources, yet the environment reaps benefits	Conservative innovation policies result in less value for the environment
	Lack of environmental steward/regulatory advocate	No voice for the environment stakeholder leads to fewer eco-innovations	Technological advancement and market evolution hindered
	Eco-innovation paradox	Firms are restricted in innovation because of organizational and regulatory constraints	Closing of network limits knowledge exchange benefiting environment

industry. We categorized the challenges into three levels: firm level (micro level), network level (meso level), and the external environment including society and the natural environment (macro level).

As previously described, the Clean Ship project involved a diverse group of stakeholders driven by different goals. Structuring the data with respect to the multiple levels of open eco-innovation is essential given the systemic approach required by eco-innovation. Specifically, we evaluated the actions of the firm, the interactions between firms, and the impact on the eco-system as a whole (Lin, 2002). Although the data structure is presented in a static way, the analysis revealed that the challenges are dynamic and intertwined. Table 2 summarizes the different challenges that impacted value creation and value capture at different levels of the network.

4.2. Challenges linked to the firm level (micro level)

Micro-level challenges identified in our case study included conflicting goals, resource constraints, and evolving commitment. Confusion reigned early in the project concerning the actual goal of the partnership. *"That we did something to become an environmentally friendly ship, that is true. But what it is … all those things have never been described concretely. What actually is the goal?" (Interview 10, Customer, translated from Danish).* It quickly became evident that each firm had a specific goal that did not align with those of its partners. For the Municipality,[3] the goal was economic revival for the area and distinction as a carbon-neutral town. The mission of the Shipping Company (the customer) was to prolong the vessel's life expectancy to reduce costs. For the Equipment Suppliers, the outcome was purely economic with an eco-friendly product as a bonus. Other external goals related to local job generation, visibility of the ship's innovativeness to passengers, and the need to be seen as "green" in order to receive public funding for innovation projects. As stakeholder theory suggests (e.g., Mele, 2011; Rowley, 1997), each firm in the network had its individual goals or expectations for the Clean Ship eco-innovation project.

With this lack of cohesive direction, the Municipality noticed that the initial euphoria of working toward a common goal of an eco-friendly innovation dissipated as soon as the discussion turned to costs. *"I think from the beginning, this wasn't clarified correctly; they thought they [the customer] could have this for free. That doesn't happen in real life; there should be a signed contract …. " (Interview 9, Municipality).* For suppliers, greenness was regarded as attractive and important but only if it was economically beneficial. *"It is unfortunately not possible to do something only because it is good for the environment; it has to be economically viable [for us]." (Interview 13, Supplier).* Given that each firm and organization had a set of individual goals that sometimes conflicted with those of its partners, each firm/organization focused on maximizing its own value creation in the eco-innovation process. Subsequently, value capture was compromised as fewer green redesigns were undertaken by the firms. Thus, we propose:

> *Micro-Level Challenge 1*: Myopic goal setting that suppresses innovation activities results in fewer environmentally-focused innovations at the firm level of an open eco-innovation network.

As the eco-innovation process progressed over the six years and with the participants' realization that there was no alignment on a common goal, firms began to withhold resources from the project. Although open innovation is expected to facilitate reliable and durable access to knowledge and resources of the network's member firms, it was not realized in this maritime network. This withdrawal of resources subsequently led to fewer new product improvements or innovations in ship redesign that minimized the value that could have been co-created. *"We had assessed diverse types of technologies, exhaust cleaning systems, noise reduction, new propellers, LED-lights all over the ferry, and we also discussed about the HVAC. Many of these ideas remained undeveloped …. " (Interview 10, Shipping Company).* Thus, we propose:

> *Micro-Level Challenge 2*: Resource constraints marginalize innovation activities, resulting in greater focus on incremental innovations at the firm level of an open eco-innovation network.

Without an agreed-upon common goal (micro-level challenge

[3] All informants' names are fictitious to ensure confidentiality.

1) that was exacerbated by the withholding of resources (micro-level challenge 2), the path forward was continually evolving. Four suppliers completely withdrew from the partnership. Two suppliers and the Shipyard did not contribute at Phase 2 (the prototype-testing stage), but they rejoined at Phase 3 (the commercialization stage). A new supplier and a Danish regulatory entity contributed only at Phase 2. The total turnover across participants was more than fifty percent from the ideation/initiation phase to the commercialization phase. *"The status, you can see it has been running for two to three years. I think the issue with this project has been that too many people have been involved. First, one started the project, new people ran it, then stopped, and then, now I take it, now I stop" (Interview 4, Consultant).*

Increasing speed to market is often a motivating factor for firms to participate in open innovation (Chesbrough and Crowther, 2006). However, without a clear direction for the project, firms committed and withdrew from the network at will thereby slowing the development process. "*Those who dragged [in resource commitment], they shouldn't wait … the [Clean Ship] could have been much further developed, if the three to four companies had done what had been promised" (Interview 15, Supplier, translated from Danish).* Thus, we propose:

> *Micro-Level Challenge 3*: Lack of full commitment to the project by a firm jeopardizes its own potential for value capture at the firm level of an open eco-innovation network.

4.3. Challenges linked to the network level (meso level)

Evaluation at the meso level allows us to understand the dynamics that occur between partners where actions at the micro level indirectly impact the outcomes at the macro level through the meso level (House, 1991). For example, when a partner decided to focus on economic goals instead of environmental value creation, this firm-level decision could reverberate throughout the network and subsequently influence other partners' product designs. Challenges linked to the meso level included power struggles, network evolution, and mistrust of partners due to competing value spaces.

At the meso level, power struggles emerged from the competing goals of the different partners as previously discussed. Extant research indicates that the success of a network's co-creation process and thus value capture, depends on the power of each of the stakeholders (Mele, 2011; Reypens et al., 2016). In this eco-innovation network, a power struggle ensued between competing suppliers. Competition led to the creation of value by the "winning" competitor and a missed chance for value creation by the "losing" competitor.

> Yes, between [supplier electrical systems 2] and [supplier electrical system 1], there was a conflict. Two companies doing the same things. Then I talked with the director of [name of supplier electrical systems 2]. I said to him … no, I cannot give you [the business]. You prepare your proposal and [supplier electrical system 1] makes his own, and then we find which is the best one. Then he left the meeting, I never heard from him again (Interview 7, Consultant).

Lack of meso-level cooperation between partners meant fewer jointly-designed innovations between partners. Thus, we propose:

> *Meso-Level Challenge 1*: Power struggles lead to missed opportunities for co-innovation with partners at the meso level of an open eco-innovation network.

Also at the meso level, the process of coming to an agreement on a complex combination of value propositions was lengthy, and concrete actions occurred slowly. "*There has been very little progress. I have asked several times, contacting [the Business Consultant]: 'Where are we now?' 'Is it canceled?'" (Interview 14, Supplier).* Frustration with the process was evident: *"That is what I'm missing. We still don't have a clear idea what projects are of interest moneywise, the process of [writing] applications, the when and the what, or who's in charge. I'm still asking for that. I get a little dizzy when I talk to the [Customer]" (Interview 14, Supplier).* At the network level, both the diffusion of knowledge and innovation across the network slowed. Thus, we propose:

> *Meso-Level Challenge 2*: Prolonged development cycles due to the evolving network slow diffusion of knowledge among partners and diminish output at the meso level of an open eco-innovation network.

Furthermore, what started out as disruptive innovation became more conservative in its approach as the process unfolded. Mistrust of competitors led to withholding of knowledge, leading to less-rewarding solutions in the final innovation. "*We agreed this is confidential. I won't accept that he is going [to use our technology], that I do all the designs and then he goes out with the design to someone else" (Interview 13, Supplier).* The competing value spaces in the project reduced the willingness of partners to share knowledge, resulting in less value extraction for the network. Thus, we propose:

> *Meso-Level Challenge 3*: The withholding of knowledge and resources resulting from mistrust between partners reduces output at the meso level of an open eco-innovation network.

4.4. Challenges linked to the external environment (macro level)

Because eco-innovations address issues at the level of the society and the natural environment, our study required examination at the macro level. Challenges linked to the macro level included the double externalities problem, lack of environmental stewardship, and the eco-innovation paradox.

As previously observed at the micro and meso levels, conflicts occurred when partners focused on economic value capture instead of environmental value capture. At the macro level, the firm directly benefits from R&D but so does the environment (double externalities) that disincentivizes firms' commitment to eco-innovation due to shared value capture but not shared costs. A firm must not only incorporate new technological knowledge bases into their innovations, it must also incorporate the needs of the society and the environment into its development activities although it may not derive any direct benefit by doing so. Malen and Marcus (2017) assert that firms will thus favor the development of incremental rather than groundbreaking technologies. The customer recalled: "*However, it was not easy to carry out these investments [on innovation]. We soon needed to invest in a new ferry; therefore, we could not easily ask the board of directors for five million krone for these green retrofits and then in two years sell the ferry. Simply it was not realistic" (Interview 10, Shipping Company).* The individual firms had to absorb the costs associated with adhering to the standards and norms set by the maritime authority, further exacerbating the double externality problem. Thus, we propose:

> *Macro-Level Challenge 1*: The problem of double externalities in eco-innovations (the conflict of creating value for the

environment at the firm's expense) leads to more conservative innovation policies at the macro level of an open eco-innovation network.

Theory regarding double externalities in eco-innovations suggests that regulatory policies are required to capture value for society, the natural environment, or both (Rennings, 2000), and the environment, as a stakeholder, needs a voice in the process (Olson, 2009). The Clean Ship initiative did not have a dedicated environmental agent such as a governmental agency or NGO to solely advocate for the natural environment. The local municipality initially assumed the role of this agent to address the challenges faced by the restructuring of the local industry that included many large companies closing in the town. However, the municipality-as-advocate did not materialize once the Clean Ship network commenced activities. As one facilitator puts it: *"I won't say that it is not that we don't care about the environment, but it's not our primary concern; it is not. I mean, the reason that we are going into a project like this is purely about the business opportunities. We are not an organization paid to look after the environment" (Interview 2, Consultant).*

Existing safety regulations also impacted value creation. In the Clean Ship project, value creation was limited by safety regulations. "*You have two different things here: safety and energy. From the safety side: I have two auxiliary engines running at 40%. If one of them fails, then I still have the other to produce energy. The energy savings part will say: 'only one auxiliary engine to be running at 85% because it is then where it is more efficient'" (Interview 1, Consultant).* Two engines were required in the ship for regulatory requirements; however, a single engine was more environmentally friendly. Absent an agent dedicated to the goals of society and the natural environment, value creation and capture at the macro level were limited. Thus, we propose:

Macro-Level Challenge 2: Fewer innovative solutions resulting from the lack of an environmental steward leads to the slowing of technological advancements and slower market evolution at the macro level of an open eco-innovation network.

We also observed a phenomenon similar to the common goal paradox (Lauritzen, 2017) which we identify as the *eco-innovation paradox of open innovation*. Luhmann (1995) defines a paradox as the "reentry of a distinction"—an act of observing that simultaneously indicates the presence of opposing elements. Such makes it impossible to determine which element contributed the most value. In this study, firms were encouraged to partner through open innovation to generate new, out-of-the-box eco-ideas. However, when immersed in the network, the firms had to operate within organizational and regulatory constraints that limited the innovativeness and risk-taking needed to develop socially and environmentally impactful eco-innovations which, paradoxically, was the reason for being in the partnership. "*What we do is, we do not develop. We implement, and we use existing equipment, and we try to think smart on how to use this. The reason is, if you use something unknown, untested to a vessel and it is sailing around in the middle of nowhere and something happens. The ship-owner says, 'I don't dare to take the chance'" (Interview 14, Maritime Supplier).* This conservative approach effectively led to a "closing" of the open network as current partners realized that adding new partners could require sharing the value capture with those who had not incurred the expense of value creation. The eco-innovation network paradox of open innovation minimized value creation and, subsequently, value capture. Thus, we propose:

Macro-Level Challenge 3: The *eco-innovation paradox of open innovation* leads to the "closing" of the network and thus the limiting of knowledge exchange that would benefit the environment at the macro level of an open eco-innovation network.

5. Discussion

5.1. Contributions

Extant studies on open innovation assume either a firm (micro level) perspective or a network (meso level) perspective in evaluating value creation and value capture (West et al., 2014). However, the existing literature on eco-innovations has primarily taken either a firm (micro level) perspective (Klewitz and Hansen, 2014; Xavier et al., 2017) or a societal/environment (macro level) perspective (Oltra and Saint Jean, 2009; Cuerva et al., 2014). The present study provides empirical support for the theory that an open innovation approach to eco-innovation should be evaluated at the micro, meso, and macro levels as multiple stakeholders collaborate to achieve a collective societal goal. The study contributes to the open-innovation knowledge base by demonstrating how extracting value from a multilevel open eco-innovation process is complicated as firms create the value that is captured by the society and/or the environment but with no immediate paybacks to the firms.

Goal incongruence in value creation at multiple levels led to several challenges that emerged throughout the eco-innovation network. For example, at the micro level, firms competed with each other concerning whether the primary outcome of the project should be economic or environmental maximization. This conflict produced: 1) fewer green redesigns, a primary goal of the network; 2) more conservative innovations as few partners wanted to assume the responsibility for risk without capturing the full rewards; and 3) delayed return on investments.

At the meso level, power struggles between suppliers and mistrust of partners produced product delays and network disruptions. These outcomes led to 1) missed opportunities for value creation as less-powerful firms left the network when they realized their own value capture would be minimized; 2) slowed diffusion of innovation as the exit and re-entry of partners impacted the transfer of knowledge; and 3) marginalized output from the network.

At the macro level, the problem of double externalities in eco-innovation led to 1) more conservative innovation policies; 2) fewer environmentally-friendly innovations; and 3) the eco-innovation paradox of open innovation. Initially, the network's members were optimistic and enthusiastic about being involved in a project that could potentially have a lasting impact on the local environment. However, the constraints of operating in the challenge-limiting network did not result in the disruptive innovations they sought to achieve. Due to this *eco-innovation paradox of open innovation*, there was less focus by the firms on value creation as the program progressed. Such resulted in fewer value capture opportunities for the environment. This situation led to a "closing" of the open network, which ultimately resulted in fewer innovations that could benefit the environment.

Overall within the open eco-innovation network, firms were less willing to co-create as the value capture occurs at the macro level; however, the costs of innovation occur at the micro level. When cooperation did occur, it was more conservative because the cost of disruptive innovations would not necessarily translate into higher returns on investment for the contributing firm.

5.2. Theoretical implications

The present study theoretically advances the knowledge of open innovation by evaluating it within an eco-innovation network.

After examining an open innovation approach to eco-innovation, we proposed the need to evaluate the micro, meso, and macro levels of the network. Open innovation research has primarily focused on the micro and meso levels, whereas eco-innovation research has primarily focused on the micro and macro levels. Table 3 presents a framework on how each of the levels should be represented in open eco-innovation.

The micro level focuses on the actions of individual organizations (Lin, 2002) whose goals are to maximize benefits and minimize costs or put differently, to minimize the cost of value creation but maximize value capture. The challenge at the organizational level is to develop strategies to accomplish these goals. In our study, firms struggled with how to create economically viable products that minimized the impact on the environment.

Within an open eco-innovation network, the organization's actions result in interactions at the meso level (Lin, 2002). The challenge at the inter-organizational level is to agree on mutually beneficial outcomes when organizations in the network may have incongruent goals. In our study, firms were unwilling to share knowledge with competitors, thereby limiting opportunities to innovate.

At the macro level, ecosystems theory describes idealistic goal setting to maximize social benefits while minimizing environmental impact (Rennings, 2000). However, eco-innovations differ from normal innovations as they generate external benefits for both the firm and for the environment but at the expense of the innovating firm. This situation creates a disincentive for the firm to innovate as the returns on R&D do not remain internal to the organization. To date, few studies have empirically demonstrated the impact of double externalities on ecosystems because of the complex nature of testing the phenomena at the macro level (del Río et al., 2016). We contribute to the knowledge base by providing empirical support for how this problem may affect value creation and capture in an open eco-innovation system. Because of the competing goals of simultaneously maximizing economic value and environmental benefits, firms in an open innovation network end up accomplishing neither.

Furthermore, theoretical solutions to the "two market failures" of double externalities suggest the need for policy makers to incentivize companies to innovate to create socially desirable products (Jaffe et al., 2005). However, in our case study, although a regulatory organization was present, it did not mitigate the challenges that limited environmental innovations. Vanhaverbeke and Cloodt (2006) suggest that in open innovation, value creation and value capture can only be realized if a central organization acts as an orchestrator and manages what they call the *value constellation* which we identify as the *open innovation network*. The central organization's role is to explore the relevant technological space to create value for customers in radically new ways and to shape the external environment accordingly (Normann, 2001; Iansiti and Levien, 2004; Vanhaverbeke and Cloodt, 2006). We propose that in the open eco-innovation value network, a central firm is necessary but not sufficient to overcome the unique challenges that may arise. Because the benefits of cleaner production are not immediate and it is difficult for firms to justify expenses that may not materialize for many years, an environmental advocate is needed. Similar to our results, Behera et al. (2012) demonstrated that in industrial symbiosis networks, 'self-organized' networks were insufficient for cultivating relationships in a Korean eco-industrial parks, and 'designed' networks were required to ensure their success. The results of this study emphasize the need to 'design-in' environmental champions into the network.

Extant studies in open innovation have noted the need for the network to be managed proactively and with strategic intent (Rohrbeck et al., 2009; Cheng and Huizingh, 2014). Likewise Mirata

Table 3
Multi-level framework to open eco-innovation.

Level	Structure	Theory	Primary Goal	Challenge	Case Study Support
Macro	Societal/ Environmental	Eco-systems theory (Rennings, 2000)	Maximize social benefits/ minimize environmental impact from innovation	How can the network of firms together address the needs of the environment and still meet its goals?	*"The main issue with the new IMO regulation is that it requires ships to reduce the sulfur emissions. New regulations might come with this and that other environment issue, you know. With all those possible regulatory scenarios in the future, what we want is that companies in the [clean ship network] are ahead of other competing [ship] yards. (Consultant)*
Meso	Inter-organizational	Network theory (Rowley, 1997)/ Interaction theory (Lin, 2002)	Maximize mutual benefits/ Minimize mutual costs of innovations co-created in a partnership	How do firms cooperate for the mutual benefit of each other when goals are incongruent?	*"So [supplier A] decided to leave the network, because they did not want to participate in a development project where they will sit with their competitors and release the ideas they had in relation to a green retrofit [of the ship]." (Supplier)*
Micro	Organizational	Action theory (Lin, 2002)/ Resource based-theory of the firm (Das and Teng, 2000)	Maximize benefits/ Minimize costs of innovations created	How can companies alter their strategies to optimize their goals?	*It is unfortunately not possible to do something only because it is good for the environment; it has to be economically viable for [us]." (Supplier)*

and Emtairah's (2005 p 1001) found that industrial system networks benefit from inter-organizational collaboration if "*collective problem formation and definition, search at the inter-sectoral interfaces* and *inter-organizational collaboration and learning*" are present. However, in our open eco-innovation maritime network, the strategic intention was clear – produce a cleaner passenger ship – however, this did not ensure the network's success. The combination of a central firm *and* an environmental champion is required to orchestrate and manage the network to ensure that the environment benefits from value creation.

Overall, our study has expanded the domains of open innovation and eco-innovation by demonstrating the need to take a multilevel (micro, meso, and macro level) approach in studying open eco-innovations. Open innovation theory argues for the sharing of resources and expert knowledge bases among partners to speed the innovation process and to create more innovative products/services. Instead, we demonstrate how eco-innovations developed in an open innovation network inherently entail incongruent goals at the different levels that slow the innovation process and lead to less-innovative products and services. These insights provide a lens to better understand the (dis)incentives for partnering through open innovation. Thus, our knowledge of how environmentally-focused innovations are developed in open innovation networks must be re-evaluated. We present a model in Fig. 2 that depicts the relationships at the different levels of the network that can be used in future research to further test our theoretical propositions.

Although this study focused on a specific project, we believe these results can be applied across any asset- or knowledge-intensive industry with multiple stakeholders looking to collaborate on cleaner production/innovation. Complex new technologies, such as biotechnology, medical technology, assistive robotic technologies, and many other knowledge-intensive industries with a social or environmental impact, can be developed through open innovation. Our findings are applicable in these types of innovation networks as well.

5.3. Managerial implications

Research suggests that SO_X control regulations from the International Maritime Organization (IMO) in the North and the Baltic Seas increasingly become a driver for environmental upgrading of shipping fleets (Doudnikoff and Lacoste, 2014; Kontovas et al., 2015; Notteboom, 2011). Possible compliance measures include the use of liquefied natural gas (LNG) as fuel or the use of sulphur abatement technologies as scrubbers (Brynolf et al., 2014). There is a growing market for the suppliers of this technology and for the service providers who are able to retrofit older vessels to comply with the regulations (Doudnikoff and Lacoste, 2013; Mosgaard and Kerndrup, 2016). Besides these regulations, research points to "green" retrofit packages with the potential to improve the overall environmental performance of ship fleets while reducing costs (Krikke, 2015). In any case, "green" retrofitting of older ships with regulatory or operational intentions require collaboration among shipyards, multiple suppliers of the technologies that are part of the "package," and shipping firms (Krikke, 2015; Mosgaard and Kerndrup, 2016). Retrofitting these fleets also has the promise to unfold emerging innovations in this context (Del Castillo de Comas and Blanco-Davis, 2012; Hermann and Wigger, 2017).

Scant attention is given to the agency behind the suppliers of cleaner shipping technology. In the maritime supply chain literature, most of the research appears to occur from the perspectives of the adopters, analyzing what drives the greening of shipping fleets and the implications of their competitive advantages (Chang and Danao, 2017; Lai et al., 2011) or from the end users of the shipping services such as cargo owners (Poulsen et al., 2016). Inspired by the need to advance the knowledge about how to develop better maritime supplier relationships in the context of cleaner technologies market opportunities, a new research stream has emerged. Its focus is the analysis of collaborative aspects in the context of green retrofitting projects with either the energy retrofit demonstration projects (Mosgaard and Kerndrup, 2016), intermediaries' roles (Hermann et al., 2016) or sectoral/technological innovation systems of maritime cleaner technologies (Makkonen and Inkinen, 2018). Our study adds to this research stream by identifying and examining the perspective of the actors directly in contact with ship owners during the process of upgrading polluting vessels with environmental friendly technology.

Our case study of maritime technology suppliers identifies the challenges they face at the three different levels during the process of innovating green retrofit solutions that provide compliance with forthcoming IMO regulations. Managing these tensions across

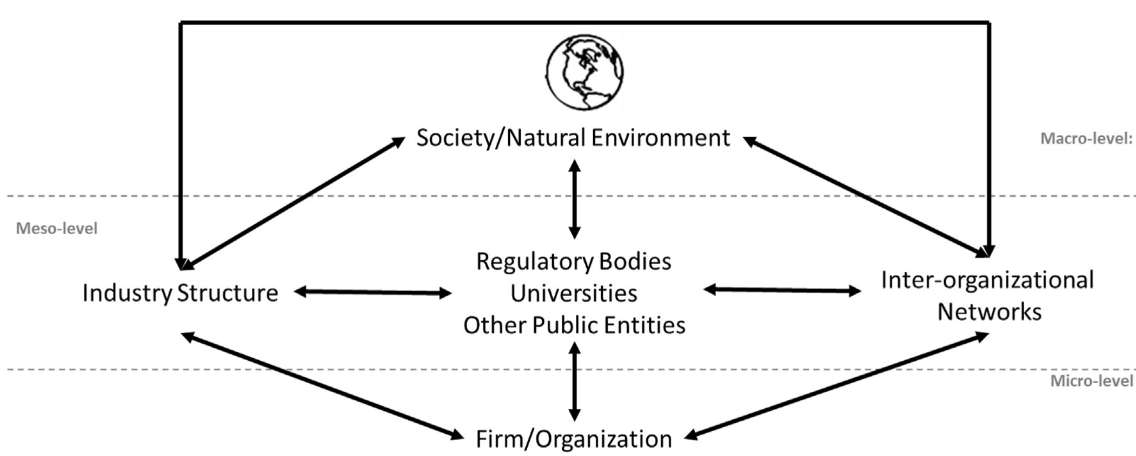

Fig. 2. A model of the meso theory of open eco-innovation (based on House, 1991).

levels is an exceptionally important task to better collaborate and design the appropriate green retrofit combination and attract customers (ship owners willing to invest in these packages). This three-level perspective suggests that it is not only the issue of handling tensions with suppliers/purchasers directly involved in the retrofit projects, but also the importance of considering the potential contingencies on a larger scale (the meso and macro levels).

Actors involved in green retrofit projects in the maritime industry can adapt our management recommendations especially in the early stages of the project's development. These recommendations outlined as follows. The co-creation of environmental and economic values developed in eco-innovation networks requires distinct management practices to address the challenges outlined above. Knowledge of the challenges identified through this case study facilitates managerial awareness of the pitfalls and possible solutions and how they interrelate at the micro, meso, and macro levels.

Environmental value is a subjective construct requiring a clear communication of goals. Managers should be very specific in communicating their environmental goals particularly regarding the ways the firm wants to be green, what costs it is willing to bear, and how a clear strategy is developed to prioritize conflicting values. These goals should be communicated early to direct partners and to the entire network. Seeking consensus about the product to be developed and establishing common economic and environmental goals should be key elements in any network's project plan. At the same time, the network should retain the flexibility to adjust to changes in the external environment especially concerning regulatory changes and competitive offerings. Procedures and routines for how to deal with evolving values should be designed and implemented at the initial stage of an eco-innovation to minimize later disagreements about how to handle those changes.

Additionally, our study suggests the importance of an environmental steward, innovation champion, or similar bridging organization that works in conjunction with a central organization to help break down barriers in eco-innovation networks. These roles should be assigned early-on to maximize value creation and capture. Clear roles foster dialogue that is essential to resolve conflicts and to minimize disagreements about goals, tasks, and resources (Mele, 2011).

5.4. Limitations and further research

The theoretical and managerial implications discussed in this paper are presented with a rich contextual description to facilitate the transferability of the results to other eco-innovation contexts (Tsang, 2014). However, qualitative case studies face the challenge of external validity (Yin, 2013); thus, our results are propositional in nature. Future research should develop hypotheses to be tested in other contexts. Future studies of multi-stakeholder co-creation networks in different industries and different geographical settings will help to develop stronger conceptualizations of the challenges associated with eco-innovation capture and co-creation.

6. Conclusion

Eco-innovation is becoming increasingly important for the maritime industry as regulations impose more sustainability requirements on large ship modifications. To respond to these requirements, ship owners are relying on open innovation to acquire the knowledge base needed to design and build these eco-innovations. With open innovation comes the challenge of coordinating a network of partners with potentially conflicting goals. By introducing a framework that identifies where conflicts in economic and environmental value creation and capture may occur, this study provides insights concerning how to minimize issues around goal incongruence, power struggles, and mistrust between the actors. Additionally, the problems of double externalities in eco-innovation can be minimized if managers are aware they may occur. Although this framework was developed based on the insights of a multi-year case study of the maritime industry, the results can be generalized to any industry where multiple partners have divergent goals on how to address sustainable product design or regulations.

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Appendix A. Supplementary data

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