

**Challenges of Creating and Capturing Value in Open Eco-Innovation:
Evidence from the Maritime Industry in Denmark**

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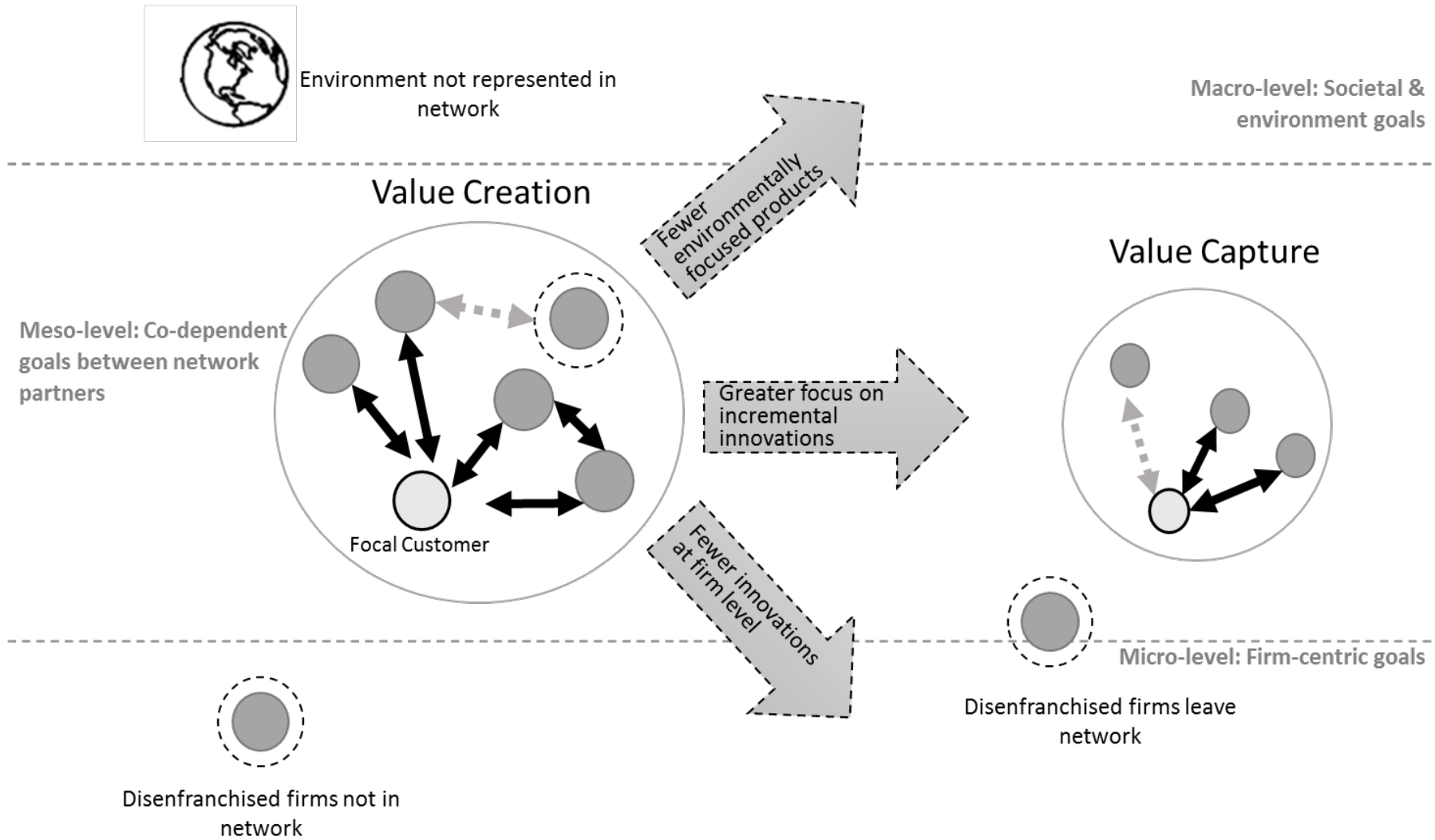
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Highlights

- We examine value creation and capture across the micro-, meso-, and macro-levels of an open eco-innovation network.
- Value is *created* at the level of the individual firm and *co-created* with partners, yet *captured* by the firms and the environment.
- Challenges emerge because of the incongruent goals that exist at multiple levels.
- We observe fewer innovative solutions because of conservative decision-making in the network.
- Overcoming these challenges requires both a central orchestrating organization and an environmental champion.

Graphical Abstract

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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.

Keywords: open innovation; value creation; value capture; eco-innovation; competing goals

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3
4 **1 Introduction**

5 In a climate of growing concern about the environmental impact of products and their
6 resource-intensive production, more firms are considering introducing eco-innovations to
7 create both economic and environmental value simultaneously (Carrillo-Hermosilla et al.,
8 2010; Jakobsen and Clausen, 2016; Christensen, 2011). Examples of such efforts have been
9 linked to the increased efficiency of energy and resource use and waste reduction (Sardianou,
10 2008; Kostka et al., 2013). As individual firms often do not possess all the core competencies
11 required to produce products that minimize their impact on the natural environment, they turn
12 to open innovation (Jakobsen and Clausen, 2016). In particular, the complexity of knowledge
13 that is integral to many eco-innovations drives the need to work with partners through open
14 innovation (Cainelli et al., 2012). Indeed, several scholars have proposed using open innovation
15 to solve the “grand challenges” of environmental conservation (Miles et al., 2010; Chesbrough,
16 2017a, 2017b).

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

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

31 The present research-is an embedded case study of a maritime network that operated
32 over a six-year period in Denmark. The study was conducted to identify the set of challenges
33 that emerge at the micro level (firm, organization), macro level (society, environment) and the
34 meso level (networks, intermediate structures, co-partnering institutions) when diverse
35 organizations unite to bring eco-innovations to market. The contributions of this study are
36 threefold. First, open innovation theory has primarily focused on interfirm cooperation in a
37 distributed innovation process as knowledge flows across organizational boundaries
38 (Vanhaverbeke et al., 2014). Few studies have examined the ecosystem environment where
39 value creation and value capture occur across three interconnected levels (micro, meso, and
40 macro) when either the society, the environment, or both are essential stakeholders (Carrillo-
41 Hermosilla et al., 2010). We contribute to the open innovation knowledge base by
42 demonstrating how extracting value from the multilevel open eco-innovation process is not
43 straightforward. Value is *created* at the level of the individual firm (micro level) and *co-created*
44 between stakeholders (meso level); however, the major goals of value *capture* are meant to be
45 achieved at the level of the society/natural environment (macro level). Secondly, we identify
46 challenges that emerge because of the incongruent goals that exist at multiple levels of the
47 multi-stakeholder network. These challenges subsequently lead to diminished value capture as
48 firms become more conservative in their decision making, resulting in fewer innovations and
49 less innovative solutions when developing eco-innovations. This situation is paradoxical in the
50 context of our current understanding of open innovation (West and Gallagher, 2006; van de

51 Vrande et al., 2009; Cohen et al., 2016). Thirdly, in advancing our knowledge of eco-
52 innovations, we find that although regulatory constraints are meant to motivate more
53 development of eco-innovations (Rennings, 2000), their impact is marginalized in the open
54 innovation network without a central champion for the environment.

55 **2 Open Innovation for Eco-innovations**

56 *2.1 Open innovation*

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

66 Insights from network theory and knowledge-based theory of the firm (Shan et al., 1994)
67 were introduced in studies on open innovation to provide an understanding of how firms
68 exchange knowledge in a network of actors external to the firm. This development led to a
69 refinement of Chesbrough's definition: "Open Innovation is the use of purposive inflows and
70 outflows of knowledge to accelerate internal innovation, and expand the markets for external
71 use of innovation, respectively" (Chesbrough, 2006b, p. 1). This later research focused on the
72 analytical lenses of technological exploration (customer involvement, external networking) and
73 technological exploitation (venturing, outward licensing of intellectual property) (van de
74 Vrande et al., 2009). Knowledge exchange is explained in light of strategies that are pecuniary
75 (e.g., purchase or licensing of inventions) and non-pecuniary (i.e., sourcing of external ideas to

76 suppliers) (Dahlander and Gann, 2010). A fundamental concept in open innovation is that value
77 exchange occurs to benefit the partners in the exchange.

78 Open innovation research has primarily focused on the firm and interfirm levels. Several
79 studies have empirically shown that open innovation leads to increased profitability (Chiang
80 and Hung, 2010; Lichtenthaler, 2009), R&D performance (Chiesa et al., 2009), product
81 innovativeness (Laursen and Salter, 2006), access to knowledge (Rohrbeck et al., 2009), and
82 new product success (Rohrbeck et al., 2009). Other studies have indicated possible negative
83 open innovation effects in terms of high search costs for external knowledge (Laursen and
84 Salter, 2006; Rothaermel and Deeds, 2006), power struggles to control knowledge assets
85 (Torkkeli et al., 2009), and unfavorable attitudes toward open innovation (Lichtenthaler et al.,
86 2010). Understanding of the open innovation–performance relationship remains fragmented
87 and merits further exploration.

88 2.2 *Open eco-innovation*

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

98 In this study, based on Chesbrough’s definition (2006b), we view open eco-innovation
99 as the development of innovations utilizing inflows and outflows of knowledge to accelerate
100 internal innovation and expand the market for innovations created with partners outside the

101 firm, with one of the goals of achieving a positive impact on the society, the environment, or
102 both. This approach requires a multi-level perspective of micro, meso and macro levels to
103 observe partners creating value for the environment and society.

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

114

115 2.3 *Value Creation and Capture within the Open Eco-Innovation Network*

116 The value creation/capture logic in business systems extends to the collaborative
117 agreement emerging from open-innovation activities (Chesbrough, 2017a; Chesbrough, 2006a;
118 Radziwon et al., 2017; Enkel, 2010). In open innovation, firms must undertake a “series of
119 activities that yield a new product or service in such a way that there is net value created
120 throughout the various activities... [The firm] captures value from a portion of those activities”
121 (Chesbrough, 2006a, p. 108). Organizations need to consider not only how they create and
122 capture value internally but also how the network serves as a platform of value creation and
123 capture across and between partners (Adner and Kapoor, 2010; Chesbrough and Bogers, 2014;
124 Rong et al., 2013; Vanhaverbeke, and Cloudt 2006). Bocken et al. (2014) identified open

125 innovation as a collaborative model that can bring like-minded individuals, firms, and partners
126 together to create and capture value to facilitate an industrial sustainability agenda.

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

137 Traditionally, value capture has been examined at only the company level and the
138 intercompany network level. However, with eco-innovation, value capture must occur at all
139 levels of the system—micro, meso, and macro levels. An extended, overall understanding of
140 value capture is one of appropriation or retention. In the setting of open eco-innovation, network
141 actors capture value by securing new knowledge and exploiting it to achieve a mutual goal
142 focused on the ecosystem (Balka et al., 2014). Specifically, at the level of the *individual* (micro
143 level), value capture is characterized by: power position, unique experiences, and absorptive
144 capacity or similar benefits to the firm. It may or may not benefit the ecosystem as a whole, but
145 it provides the individual firm with increased value. At the level of the *network* (meso level),
146 sharing of knowledge and acting in a “partnership-building way” instead of a “transactional
147 way” facilitates value capture (Rowland and Perry, 2009) that is shared between partners. Thus,
148 value capture at the meso level is concerned with how members in the network collaborate to
149 achieve a desirable level of reward/monetization to advance a common goal. At the *eco-*

150 *systemic* level (macro level), the concept of environmental value capture is more diffuse as it
151 involves not only the producers' and consumers' perspectives but also eco-systemic
152 performance and impact on society (Lacoste, 2016). Consequently, at the macro level, the
153 interconnected nature of societal value must be addressed (Faber and Frenken, 2009). Value
154 must include benefits to the environment that may not be measured economically but instead in
155 terms of societal/ecological value (e.g., lower unemployment, air and water quality
156 improvements, resource conservation).

157 Value spaces define where value is captured at each of the levels. At the meso level
158 (network partnerships), factors related to unique organizational cultures, evolving network
159 structures, and power struggles in partner relationships can influence the decisions made at the
160 micro level (individual firms); where decisions impact the macro level (Rowland and Parry,
161 2009) environmental and social issue . In Figure 1, we map the different levels where value
162 creation and capture can occur. Although the levels are dependent upon each other, the focus
163 in this study is on separate levels in order to identify the different challenges that may arise at
164 each level.

165

166

Insert Figure 1 about here

167

168

169 **3 A case study on multi-partner, multi-year eco-innovation project**

170 *3.1 Longitudinal embedded case study*

171 The relative lack of understanding of open eco-innovation and its inherent challenges
172 regarding value creation and value capture favor a longitudinal embedded case-study approach
173 (van de Ven and Poole, 1990; Huizingh, 2011). Building on the argument that value creation
174 and capture in open eco-innovation happens at all levels of the eco-system, an embedded case-
175 study design facilitates the discovery of the challenges at multiple levels between multiple

176 stakeholders (Järvensivu and Törnroos, 2010; Whitmarsh, 2012). Additionally, the
177 development of an eco-innovation is often characterized as complex and can be divided into
178 different stages that are more easily documented (Rennings, 2000; van de Ven, et al., 1999).

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

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

197

198 *3.2 Case description*

199 A network of maritime and consultancy firms located in a coastal town in Denmark
200 developed the Clean Ship¹² network from 2009 to 2016. Harbor Town² has a long maritime
201 history, and the region's economic activities depend heavily on the local maritime industry.
202 Due to a series of financial setbacks and restructuring, two key actors, the shipyard and an
203 engine factory, closed their operations in Harbor Town in 2007 (Interview 2, Consultant). The
204 suppliers of those two key actors needed to search for new opportunities to survive (Interviews
205 2 and 5, Consultants). At the same time, the awareness of environmental degradation and
206 pollution caused by the maritime industry continued to increase. Consequently, regulators had
207 recently established new environmental rules, and the industry expected other regulations in
208 the near future. These changes, combined with increased environmental awareness, gave birth
209 to different but related innovations such as energy-saving technologies, the use of exhaust gas
210 cleaning systems, and emission-monitoring systems.

211 The Clean Ship eco-innovation aimed to co-develop cleaner products to retrofit
212 maritime vessels with greener and more energy-efficient technologies. The network's goal was
213 to combine both the suppliers' competencies and high-end technology to promote a more
214 environmentally friendly maritime industry. The initial group of partners from 17 different
215 organizations included the customer (Shipping Company), suppliers, universities, and
216 governmental institutions (see Table 1 for the partner list and timeline of participation). Each
217 entity agreed to the open innovation concept of working together to share knowledge and
218 resources to achieve a common goal - successfully retrofitting the customer's ship to transform
219 it into a more environmentally-friendly "Clean Ship." The partnership recognized that no single

¹ See Table A.1 in the online appendix for additional information about the informants.

² All informants' names are fictitious to ensure confidentiality.

220 organization had the resources or capabilities necessary to complete the project on its own.
221 Motivation and collaboration were initially strong as each partner recognized the innovation's
222 potential to have a lasting impact on the shipping industry.

223

224 -----
Insert Table 1 about here

225

226 *3.3 Data sources and collection*

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

233 We conducted 17 in-depth interviews of the network's individuals in the timeframe
234 between 2011 and 2016 to ensure the longitudinal character of the case. The interview
235 transcripts comprised more than 300 pages and 916 minutes of transcribed materials. All
236 interviewees actively participated in the Clean Ship initiative in Harbor Town. We first became
237 acquainted with the network activities during fieldwork in 2011 in Harbor Town through a
238 round of interviews with maritime business consultants in the Harbor Town Municipality.
239 Following a snowball sampling strategy (Marshall and Rossman, 2014), the first informant
240 suggested additional informants and facilitated access to the network's internal documents. This
241 assistance allowed us to prepare a list of potential interviewees and ensure a balance among
242 different suppliers and the customers involved over the six-year period. We also conducted
243 contextual interviews with Danish ship owners to gather information about the environmental
244 regulations forcing the maritime industry to develop certain types of environmental

245 technologies and about their perceptions of the network and innovation process. The interviews
246 were audio-recorded and transcribed verbatim. Additional details are available from the authors
247 and are in the online appendix.

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

258 *3.4 Data coding and analysis*

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

264 As a first step, we used an open coding approach (Bazeley and Jackson, 2013), and a
265 coauthor did the first round of open coding the data materials. This coauthor was not involved
266 in the data collection, had no affiliation with the Clean Ship innovation, and consequently had
267 no preconceived understanding of the Clean Ship innovation and the challenges the actors
268 faced. Through the open coding process, the raw textual data was initially analyzed and
269 categorized (Miles and Huberman, 1994). During this stage, the codes were broad, and new

270 codes were added to the NVivo coding scheme as the interviewees mentioned new challenges.
271 We identified 36 first-order concepts in the raw data that represent the different groups of
272 challenges; these analyses are available in the online appendix (Table A.3).

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

279

280 3.5 *Ensuring trustworthiness*

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

291 Through several rounds of discussions based on the first-order concepts, theoretical
292 insights, and the coding scheme developed with NVivo, we addressed confirmability issues
293 related to non-matching patterns and researcher bias (Beverland and Lindgreen, 2010; Gibbert
294 et al., 2008). Through this process, the observed challenges were compared to challenges

295 identified in extant studies. We applied the well-established theoretical lens of stakeholder and
296 network theory for an analysis of the data material. The challenges were studied based on the
297 Clean Ship case, an eco-innovation developed in a network of multiple actors as shown in Table
298 1. Hence, we studied 15 of the 19 actors (identified in Table 1) nested in the case study with
299 multiple interviews with some respondents, obtaining varied insights into the process. The
300 challenges mentioned by the informants were accumulated which established confirmability
301 (Beverland and Lindgreen, 2010).

302 **4 Challenges of Value Creation and Capture in Open Eco-Innovation**

303 *4.1 Conceptual framework of micro-meso-level analysis*

304 The interview data were analyzed using the theoretical framework on value creation and
305 capture in multi-stakeholder innovation (Reypens et al., 2016; Vanhaverbeke and Cloodt,
306 2006), focusing in this study on challenges emerging from an economic-environmental process
307 of open innovation in the maritime industry. We categorized the challenges into three levels:
308 firm level (micro level), network level (meso level), and the external environment including
309 society and the natural environment (macro level).

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

318 -----
Insert Table 2 about here

320 4.2 *Challenges linked to the firm level (micro level)*

321 Micro-level challenges identified in our case study included conflicting goals, resource
322 constraints, and evolving commitment. Confusion reigned early in the project concerning the
323 actual goal of the partnership. *“That we did something to become an environmentally friendly*
324 *ship, that is true. But what it is ... all those things have never been described concretely. What*
325 *actually is the goal?”* (Interview 10, Customer, translated from Danish). It quickly became
326 evident that each firm had a specific goal that did not align with those of its partners. For the
327 Municipality³, the goal was economic revival for the area and distinction as a carbon-neutral
328 town. The mission of the Shipping Company (the customer) was to prolong the vessel’s life
329 expectancy of to reduce costs. For the Equipment Suppliers, the outcome was purely economic
330 with an eco-friendly product as a bonus. Other external goals related to local job generation,
331 visibility of the ship’s innovativeness to passengers, and the need to be seen as “green” in order
332 to receive public funding for innovation projects. As stakeholder theory suggests (e.g., Mele,
333 2011; Rowley, 1997), each firm in the network had its individual goals or expectations for the
334 Clean Ship eco-innovation project.

335 With this lack of cohesive direction, the Municipality noticed that the initial euphoria
336 of working toward a common goal of an eco-friendly innovation dissipated as soon as the
337 discussion turned to costs. *“I think from the beginning, this wasn’t clarified correctly; they*
338 *thought they [the customer] could have this for free. That doesn’t happen in real life; there*
339 *should be a signed contract....”* (Interview 9, Municipality). For suppliers, greenness was

³ All informants’ names are fictitious to ensure confidentiality.

340 regarded as attractive and important but only if it was economically beneficial. “*It is*
341 *unfortunately not possible to do something only because it is good for the environment; it has*
342 *to be economically viable [for us].” (Interview 13, Supplier).* Given that each firm and
343 organization had a set of individual goals that sometimes conflicted with those of its partners,
344 each firm/organization focused on maximizing its own value creation in the eco-innovation
345 process. Subsequently, value capture was compromised as fewer green redesigns were
346 undertaken by the firms. Thus, we propose:

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

350

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

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

363

364 Without an agreed-upon common goal (micro-level challenge 1) that was exacerbated
365 by the withholding of resources (micro-challenge 2), the path forward was continually evolving.
366 Four suppliers completely withdrew from the partnership. Two suppliers and the Shipyard did
367 not contribute at Phase 2 (the prototype-testing stage), but they rejoined at Phase 3 (the
368 commercialization stage). A new supplier and a Danish regulatory entity contributed only at
369 Phase 2. The total turnover across participants was more than fifty percent from the
370 ideation/initiation phase to the commercialization phase. *“The status, you can see it has been
371 running for two to three years. I think the issue with this project has been that too many people
372 have been involved. First, one started the project, new people ran it, then stopped, and then,
373 now I take it, now I stop” (Interview 4, Consultant).*

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

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

384

385 4.3 *Challenges linked to the network level (meso level)*

386 Evaluation at the meso level allows us to understand the dynamics that occur between
387 partners where actions at the micro level indirectly impact the outcomes at the macro level
388 through the meso level (House, 1991). For example, when a partner decided to focus on

389 economic goals instead of environmental value creation, this firm-level decision could
390 reverberate throughout the network and subsequently influence other partners' product designs.
391 Challenges linked to the meso level included power struggles, network evolution, and mistrust
392 of partners due to competing value spaces.

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

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

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

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

409

410 Also at the meso level, the process of coming to an agreement on a complex combination
411 of value propositions was lengthy, and concrete actions occurred slowly. *"There has been very*
412 *little progress. I have asked several times, contacting [the Business Consultant]: 'Where are*

413 *we now?’ ‘Is it canceled?’*” (Interview 14, Supplier). Frustration with the process was evident:
414 *“That is what I’m missing. We still don’t have a clear idea what projects are of interest*
415 *moneywise, the process of [writing] applications, the when and the what, or who’s in charge.*
416 *I’m still asking for that. I get a little dizzy when I talk to the [Customer]”* (Interview 14,
417 *Supplier*). At the network level, both the diffusion of knowledge and innovation across the
418 network slowed. Thus, we propose:

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

422

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

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

433

434 4.4 *Challenges linked to the external environment (macro level)*

435 Because eco-innovations address issues at the level of the society and the natural
436 environment, our study required examination at the macro level. Challenges linked to the micro

437 level included the double externalities problem, lack of environmental stewardship, and the eco-
438 innovation paradox.

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

454 *Macro-Level Challenge 1:* The problem of double externalities in eco-
455 innovations (the conflict of creating value for the environment at the firm's
456 expense) leads to more conservative innovation policies at the macro level of
457 an open eco-innovation network.

458

459 Theory regarding double externalities in eco-innovations suggests that regulatory
460 policies are required to capture value for society, the natural environment, or both (Rennings,
461 2000), and the environment, as a stakeholder, needs a voice in the process (Olson, 2009). The

462 Clean Ship initiative did not have a dedicated environmental agent such as a governmental
463 agency or NGO to solely advocate for the natural environment. The local municipality initially
464 assumed the role of this agent to address the challenges faced by the restructuring of the local
465 industry that included many large companies closing in the town. However, the municipality-
466 as-advocate did not materialize once the Clean Ship network commenced activities. As one
467 facilitator puts it: *“I won’t say that it is not that we don’t care about the environment, but it’s*
468 *not our primary concern; it is not. I mean, the reason that we are going into a project like this*
469 *is purely about the business opportunities. We are not an organization paid to look after the*
470 *environment” (Interview 2, Consultant).*

471 Existing safety regulations also impacted value creation. In the Clean Ship project, value
472 creation was limited by safety regulations. *“You have two different things here: safety and*
473 *energy. From the safety side: I have two auxiliary engines running at 40%. If one of them fails,*
474 *then I still have the other to produce energy. The energy savings part will say: ‘only one*
475 *auxiliary engine to be running at 85% because it is then where it is more efficient’” (Interview*
476 *1, Consultant).* Two engines were required in the ship for regulatory requirements; however, a
477 single engine was more environmentally friendly. Absent an agent dedicated to the goals of
478 society and the natural environment, value creation and capture at the macro level were limited.
479 Thus, we propose:

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

484

485 We also observed a phenomenon similar to the common goal paradox (Lauritzen, 2017)
486 which we identify as the *eco-innovation paradox of open innovation*. Luhmann (1995) defines

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

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

506

507 **5 Discussion**

508 *5.1 Contributions*

509 Extant studies on open innovation assume either a firm (micro level) perspective or a
510 network (meso level) perspective in evaluating value creation and value capture (West et al.,

511 2014). However, the existing literature on eco-innovations has primarily taken either a firm
512 (micro level) perspective (Klewitz and Hansen, 2014; Xavier et al., 2017) or a
513 societal/environment (macro level) perspective (Oltra and Saint Jean, 2009; Cuerva et al.,
514 2014). The present study provides empirical support for the theory that an open innovation
515 approach to eco-innovation should be evaluated at the micro, meso, and macro levels as
516 multiple stakeholders collaborate to achieve a collective societal goal. The study contributes to
517 the open-innovation knowledge base by demonstrating how extracting value from a multilevel
518 open eco-innovation process is complicated as firms create the value that is captured by the
519 society and/or the environment but with no immediate paybacks to the firms.

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

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

532 At the macro level, the problem of double externalities in eco-innovation led to 1) more
533 conservative innovation policies; 2) fewer environmentally-friendly innovations; and 3) the
534 eco-innovation paradox of open innovation. Initially, the network's members were optimistic
535 and enthusiastic about being involved in a project that could potentially have a lasting impact

536 on the local environment. However, the constraints of operating in the challenge-limiting
537 network did not result in the disruptive innovations they sought to achieve. Due to this *eco-*
538 *innovation paradox of open innovation*, there was less focus by the firms on value creation as
539 the program progressed. Such resulted in fewer value capture opportunities for the environment.
540 This situation led to a “closing” of the open network as firms realized that adding new partners
541 could require sharing the value capture with those who had not contributed to value creation.
542 This closing of the open innovation network ultimately resulted in fewer innovations that could
543 benefit the environment.

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

549 5.2 *Theoretical implications*

550 The present study theoretically advances the knowledge of open innovation by
551 evaluating it within an eco-innovation network. After examining an open innovation approach
552 to eco-innovation, we proposed the need to evaluate the micro, meso, and macro levels of the
553 network. Open innovation research has primarily focused on the micro and meso levels,
554 whereas eco-innovation research has primarily focused on the micro and macro levels. Table 3
555 presents a framework on how each of the levels should be represented in open eco-innovation.

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

561

562

Insert Table 3 about here

563

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

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

580 Furthermore, theoretical solutions to the "two market failures" of double externalities
581 suggest the need for policy makers to incentivize companies to innovate to create socially
582 desirable products (Jaffe et al., 2005). However, in our case study, although a regulatory
583 organization was present, it did not mitigate the challenges that limited environmental
584 innovations. Vanhaverbeke and Cloudt (2006) suggest that in open innovation, value creation
585 and value capture can only be realized if a central organization acts as an orchestrator and

586 manages what they call the *value constellation* which we identify as the *open innovation*
587 *network*. The central organization's role is to explore the relevant technological space to create
588 value for customers in radically new ways and to shape the external environment accordingly
589 (Normann, 2001; Iansiti and Levien, 2004; Vanhaverbeke and Cloudt, 2006). We propose that
590 in the open eco-innovation value network, a central firm is necessary but not sufficient to
591 overcome the unique challenges that may arise. Because the benefits of cleaner production are
592 not immediate and it is difficult for firms to justify expenses that may not materialize for many
593 years, an environmental advocate is needed. Similar to our results, Behera et al. (2012)
594 demonstrated that in industrial symbiosis networks, 'self-organized' networks were insufficient
595 for cultivating relationships in a Korean eco-industrial parks, and 'designed' networks were
596 required to ensure their success. The results of this study emphasize the need to 'design-in'
597 environmental champions into the network.

598 Extant studies in open innovation have noted the need for the network to be managed
599 proactively and with strategic intent (Rohrbeck, et al., 2009; Cheng and Huizingh 2014).
600 Likewise Mirata and Emtairah's (2005 p 1001) found that industrial system networks benefit
601 from inter-organizational collaboration if "*collective problem formation and definition, search*
602 *at the inter-sectoral interfaces and inter-organizational collaboration and learning*" are
603 present. However, in our open eco-innovation maritime network, the strategic intention was
604 clear – produce a cleaner passenger ship – however, this did not ensure the network's success.
605 The combination of a central firm *and* an environmental champion is required to orchestrate
606 and manage the network to ensure that the environment benefits from value creation.

607 Overall, our study has expanded the domains of open innovation and eco-innovation by
608 demonstrating the need to take a multilevel (micro, meso, and macro level) approach in studying
609 open eco-innovations. Open innovation theory argues for the sharing of resources and expert
610 knowledge bases among partners to speed the innovation process and to create more innovative

611 products/services. Instead, we demonstrate how eco-innovations developed in an open
612 innovation network inherently entail incongruent goals at the different levels that slow the
613 innovation process and lead to less-innovative products and services. These insights provide a
614 lens to better understand the (dis)incentives for partnering through open innovation. Thus, our
615 knowledge of how environmentally-focused innovations are developed in open innovation
616 networks must be re-evaluated. We present a model in Figure 2 that depicts the relationships at
617 the different levels of the network that can be used in future research to further test our
618 theoretical propositions.

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

625

626 5.3 *Managerial implications*

627 Research suggests that SO_x control regulations from the International Maritime
628 Organization (IMO) in the North and the Baltic Seas increasingly become a driver for
629 environmental upgrading of shipping fleets (Doudnikoff and Lacoste, 2014; Kontovas et al.,
630 2015; Notteboom, 2011). Possible compliance measures include the use of liquefied natural gas
631 (LNG) as fuel or the use of sulphur abatement technologies as scrubbers (Brynolf et al., 2014).
632 There is a growing market for the suppliers of this technology and for the service providers who
633 are able to retrofit older vessels to comply with the regulations (Doudnikoff and Lacoste, 2013;
634 Mosgaard and Kerndrup, 2016). Besides these regulations, research points to “green” retrofit
635 packages with the potential to improve the overall environmental performance of ship fleets

636 while reducing costs (Krikke, 2015). In any case, “green” retrofitting of older ships with
637 regulatory or operational intentions require collaboration among shipyards, multiple suppliers
638 of the technologies that are part of the “package,” and shipping firms (Krikke, 2015; Mosgaard
639 and Kerndrup, 2016). Retrofitting these fleets also has the promise to unfold emerging
640 innovations in this context (Comas and Blanco-Davis, 2012; Hermann and Wigger, 2017).

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

655 Our case study of maritime technology suppliers identifies the challenges they face at
656 the three different levels during the process of innovating green retrofit solutions that provide
657 compliance with forthcoming IMO regulations. Managing these tensions across levels is an
658 exceptionally important task to better collaborate and design the appropriate green retrofit
659 combination and attract customers (ship owners willing to invest in these packages). This three-

660 level perspective suggests that it is not only the issue of handling tensions with
661 suppliers/purchasers directly involved in the retrofit projects, but also the importance of
662 considering the potential contingencies on a larger scale (the meso and macro levels).

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

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

681 Additionally, our study suggests the importance of an environmental steward,
682 innovation champion, or similar bridging organization that works in conjunction with a central
683 organization to help break down barriers in eco-innovation networks. These roles should be
684 assigned early-on to maximize value creation and capture. Clear roles foster dialogue that is

685 essential to resolve conflicts and to minimize disagreements about goals, tasks, and resources
686 (Mele, 2011).

687 5.4 *Limitations and further research*

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

695

696 **6 Conclusion**

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

707 maritime industry, the results can be generalized to any industry where multiple partners have
708 divergent goals on how to address sustainable product design or regulations.

709

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995 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
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

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997

998 Table 2. Challenges of Value Creation and Capture in Open Eco-innovations

		Challenges	
Antecedents of 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 interactions)	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

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?	<i>“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)</i>
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?	<i>“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)</i>
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?	<i>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)</i>

Appendix

Table A1. Interviews

Stakeholder	Interview	Purpose
Consultant	1	Network facilitator in 2013
Consultant	2 & 3	Network facilitator in 2009 and 2010
Consultant	4	Network facilitator 2012-2013
Consultant	5	Network facilitator 2014-2015
Consultant	6 & 7	Network facilitator in 2011
Consultant	8	Maritime business consultant/ Scandinavian cooperation project
Municipal business support unit	9	Person who supported the launching of the green ship initiative
Shipping firm	10	Participant in the network, technical manager of the shipping firm
Shipping firm	11	Participant in the network, director of the shipping firm 2014-2015
Maritime supplier	12	Supplier involved in the test-projects
Maritime supplier	13	Supplier involved in the test projects
Maritime supplier	14	Supplier involved in all phases of the network
Maritime supplier	15	Supplier who initiated the network
Ship-owner	16	Drivers and barriers for the implementation of cleaner technologies; senior adviser in environmental regulations, Ship-owners Association Copenhagen
Ship-owner	17	Scandinavian large shipping firm, legal department executive, Oslo

Table A2: Data structure

First order 'value creation' concepts Second order themes First order 'value capture' concepts



Table A3 – Interview guide

Interview sub-theme	Examples of interview questions
Stage of the innovation process in which the partner is involved	<ul style="list-style-type: none"> • Tell us about your organization activities and main products • Could you tell us how has your company been involved in this project?
Innovation at firm level	<p>Project --- explain how the project became a project within the organization— role of management in relation to the project</p> <ul style="list-style-type: none"> • Resources/ budget • Who initiated the contacts with the other partners and why?
Innovation at network level	<ul style="list-style-type: none"> • Which other companies took/ take part in this project or the preparation of the project? • What they do? (funding by each part) • How do you handle priorities between partners • Which kind of agreements have you made? Are they formal (through contracts)? • Which partner has an active role?
Complexities associated with innovation processes	<ul style="list-style-type: none"> • Difficulties with the new green technology, • Prototyping, • Timing coordination between actors, • How to address timing issues? • How companies appreciate time?
Approaches to complexities	<ul style="list-style-type: none"> • Role of management/ company in dealing with complexity/ collaboration with external parties? How?
Steering of the network	<ul style="list-style-type: none"> • Did other organizations (out of the involved companies) took part in the project? • Let's talk about [partner X] and its role in this project? • Why this “external” organization got involved? • Who contacted this “external” organization at the first place? –Did they approached or did your company contacted • When this “external” organization started to collaborate?
Challenges during the collaboration	<ul style="list-style-type: none"> • How were meetings? Who organized and invited other companies? • Did they provided with the possibility to meet other partners? • Besides meetings, did you contacted with this external party for support? Which kind of support? • Which challenges did you faced during the collaboration with this extern party • Have regulations/ or market demand delayed or make the project a top priority within your company?