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Embracing stakeholder engagement in sustainability-oriented innovation

Internal capabilities and dynamics of open innovation in the Norwegian minerals industry

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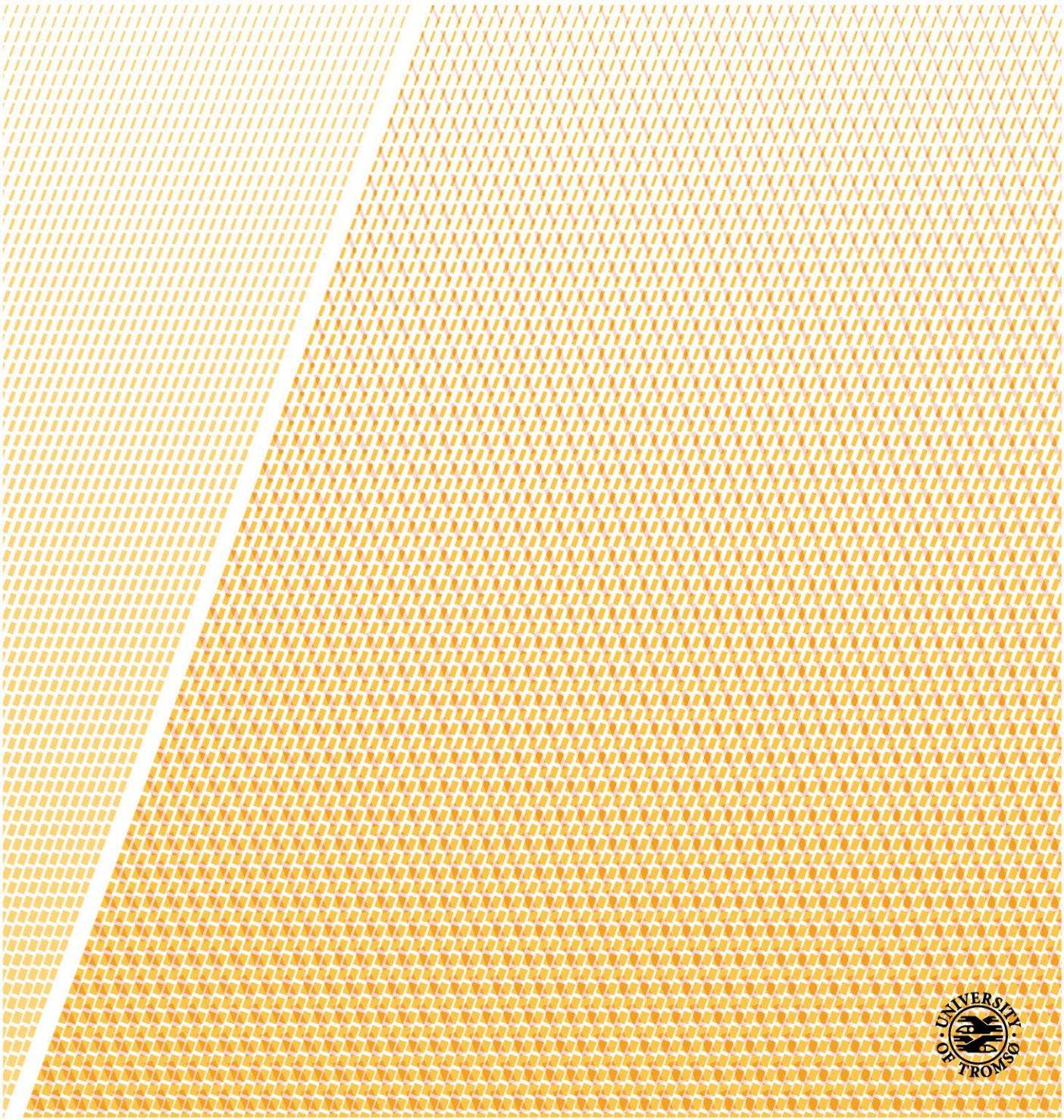

Abstract

This thesis is motivated by the need to ensure corporate sustainability in the minerals industry, which entails simultaneous improvements in economic, environmental and social performance. The transition towards a sustainable minerals industry will rely on pursuing sustainability-oriented innovation (SOI), requiring continuous innovations in extraction and production processes, product offerings and the way the industry deals with its social responsibilities. Considering the breadth of SOI, mineral firms have no choice but to engage with and seek knowledge from multiple key external stakeholders, including value chain partners, universities, not-for-profit organizations and local communities. However, this stakeholder multiplicity poses significant challenges to firms, bearing in mind the diverse knowledge backgrounds and interests of these stakeholders, as well as the internal capabilities required to integrate and apply the externally acquired knowledge.

Despite the growing scholarly interest in studying stakeholder engagement in SOI processes, a considerable amount of knowledge in this research field is restricted to specific types of SOI, for instance eco-innovations, which ignore the comprehensiveness of sustainability, considering its three pillars of economic, environmental and social issues. This, in turn, limits our understanding of the wider range of internal capabilities and inter-organizational factors that might affect firms' innovative outputs. Moreover, previous research has surprisingly overlooked the importance of providing evidence regarding a business rationale for sustainability. Therefore, the overall aim of this thesis is to answer the following question:

"Under which conditions and to what extent can engaging external stakeholders improve a firm's SOI outputs and financial performance?"

This research question is explored through four sub-research questions in three empirical papers that draw on different theoretical perspectives and methodological approaches. The first and second papers provide insights into the conditions in which stakeholder engagement can be beneficial for SOI, focusing on internal and inter-organizational factors respectively. The third paper then positions SOI itself as a mediating condition that can assist firms to reap the financial benefits from stakeholder engagement practices. As far as the extent of the effect of stakeholder engagement is concerned, the second and third papers establish an empirical link between stakeholder engagement and SOI outputs.

More specifically, paper 1 draws on the theory of absorptive capacity to explore the underlying skills and routines that form a firm's capabilities in the recognition, assimilation and exploitation of external stakeholders' knowledge. In terms of recognition, firms need to first keep abreast of technological and market changes that emanate from sustainability objectives, and second to increase their awareness of social issues. Accordingly, assimilation depends on the established routines for facilitating the dissemination of knowledge internally, whereas the exploitation capability rests on maintaining external relationships and piloting new solutions.

Paper 2 argues that besides stakeholder multiplicity, localization in peripheral regions adds to the complexity of SOI caused by the dearth of local knowledge spillovers and difficulty in

accessing highly uncodified knowledge from a distance. The paper then builds on the concept of non-geographical proximity dimensions and proposes that a firm's success in SOI can be explained by means of its organizational, cognitive and institutional proximity to external stakeholders. The analysis, based on survey data from 101 mineral companies in Norway, reveals that these dimensions of proximity are positively related to various types of SOI, i.e. process, product and social innovations, although in different ways. Organizational proximity and informal institutional proximity spur social innovation, while formal institutional proximity and cognitive proximity are conducive to process and product innovations.

Finally, paper 3 explains the extent to which stakeholder engagement affects SOI outputs, and whether these condition the impact of stakeholder engagement on financial performance. To this end, the paper draws on stakeholder theory and distinguishes between two main types of stakeholder engagement, namely transactional and relational interactions. By using the data from the same survey as in paper 2, it finds that both increasing the frequency of transactional engagement and the diversity of stakeholders in relational engagement are positively associated with augmented SOI outputs. Subsequently, in light of the natural resource-based view of the firm, the paper develops a mediation model, implying that SOI acts as a capability through which firms continuously respond to sustainability challenges (by means of engaging external stakeholders), thereby improving their competitiveness and profitability. The empirical analysis combines the previous survey data with firms' accounting data, and finds that SOI fully mediates the association between stakeholder engagement and financial performance.

Overall, the thesis contributes to the literature and practice by uncovering the "what", "how", "why" and "when"[1] of the phenomenon of stakeholder engagement in SOI. First, it identifies what internal, inter-organizational and external factors should be considered to explain SOI, and thereby portrays a more complete picture of SOI and its unique characteristics. Second, the study offers a pure measure of SOI to provide empirical evidence for the associations between the aforementioned factors and various types of SOI outputs. Hence, the thesis extends the literature on open innovation by introducing and testing the effect of a wider range of external stakeholders on innovative outputs. Third, the findings suggest that in order to address the fragmented and inconsistent findings in the literature, the insights from absorptive capacity, stakeholder theory and natural resource-based theory prove to be useful for theorizing the associations between engagement practices, SOI outputs and financial performance. Fourth, the thesis shows that although engaging external stakeholders can potentially lead to superior SOI outputs, internal capabilities and proximity to external stakeholders are among the key considerations that should come into play so that de facto effects appear. Finally, the work contributes to the growing debate on how corporate sustainability generates a win-win situation (for a firm and its external stakeholders) by showing that SOI lays the basis for pursuing profit-maximizing objectives, while fulfilling social and environmental responsibilities.

Keywords: sustainability, innovation, external stakeholders, minerals industry, Norway

[1] According to Whetten (1989), these are the four main pillars of a theoretical contribution.

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Tromsø, Norway
October 2018

Babak Ghassim

List of appended papers and contributions

Paper 1

Title: Understanding the micro-foundations of internal capabilities for open innovation in the minerals industry: a holistic sustainability perspective

Authors: Babak Ghassim, Lene Foss

Status: Published in *Resources Policy*, 2018. https://doi.org/10.1016/j.resourpol.2018.09.011

Paper 2

Title: Sustainability-oriented innovation in the minerals industry: an empirical study on the effect of non-geographical proximity dimensions

Author: Babak Ghassim

Status: Published in *Sustainability*, 2018, 10(1), 282. https://doi.org/10.3390/su10010282

Paper 3

Title: Linking stakeholder engagement to profitability through sustainability-oriented innovation: a quantitative study in the minerals industry

Authors: Babak Ghassim, Marcel Bogers

Status: Manuscript under review (submitted: August 1, 2018) in *Journal of Cleaner Production*

Contributions

	Paper 1	**Paper 2**	**Paper 3**
Concept and idea	BG	BG	BG
Study design and methods	BG	BG	BG
Data collection	BG	BG	BG
Analysis and interpretation	BG, LF	BG	BG, MB
Manuscript preparation	BG	BG	BG
Critical revision of the intellectual content	LF, MB	LF, MB	MB, LF

BG = Babak Ghassim

LF = Lene Foss

MB = Marcel Bogers

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1 Introduction

1.1 Practical relevance and background of the study

During recent years, environmental and social performance has become increasingly central to firms' success in various industries, particularly in the resource extractive ones such as minerals, whose business activities are closely intertwined with their impact on the social and natural environments (George et al., 2015). Emitting hazardous pollutants into the air, water and land endanger the health and wellbeing of local communities where such extractive operations are located. On some occasions, extracting natural resources from the earth's crust may result in the permanent displacement of an entire city, such as in the case of Kiruna underground iron mine in Sweden. These negative impacts have led to growing opposition from social and environmental activists, which in turn is triggering governments to cease mining operations or postpone the granting of exploration and production licenses. For example, Laurence (2011) inspected about 1000 Australian mine closures over a period of 30 years ending in 2009 and found that only 25% of them had been planned due to resource depletion or exhaustion. In fact, the lion's share of closures had happened because of the failure to adequately overcome environmental, social or economic issues, implying that any of these matters were significant in forcing firms to stop exploration or production.

Nonetheless, minerals are required as they provide essential elements in everyday life, including, but not limited to, nutrition (e.g. fertilizers), energy production (e.g. electricity generation), human communication (e.g. cell phones), buildings (e.g. glass) and transportation (e.g. airplanes). A recent analysis conducted by The Science Park in Bodø (2017) highlighted that in Norway the minerals value chain (considering the manufacturing of mineral-based products) accounted for 12% of national Gross Domestic Product in 2015. This is a relatively high figure, considering the dominance of the oil and gas industry in the country, and its upstream and downstream linkages to other sectors in the national economy.

More importantly, minerals are at the heart of the surge in the development of green infrastructures, by providing the raw materials required in the production of wind turbines, electric cars and solar cells, amongst others. As a result, "to mine or not to mine" is not an option, but instead we have to establish under what economic, social and environmental conditions the extraction of natural resources should occur. While acknowledging the significance of the minerals industry for the world economy and society, the final declaration of the RIO+20 conference provides a concise answer to this question: "(…) mining activities should maximize social and economic benefits, as well as effectively address negative environmental and social impacts." (UN, 2012, p. 43). Therefore, the further economic development of the minerals industry should ensure that resource extraction and minerals production occur in an environmentally and socially sustainable way.

While the 'reactive' approach towards environmental and social sustainability positions them solely as costly practices driven by stakeholder and institutional pressures (Porter & van der Linde, 1995; Zollo et al., 2013), increasing awareness of the opportunities at the crossroads of

these practices and shareholder value is giving rise to a more 'proactive' approach (Hall & Wagner, 2012; Hart & Milstein, 2003). Such an integrated pursuit of economic, environmental and social sustainability has brought into focus the concept of 'Corporate Sustainability', which requires firms to satisfy three criteria in order to ensure success in the long term: economic prosperity, environmental protection and social equity (Wilson, 2003). The underlying logic of an integrated corporate sustainability perspective is therefore its emphasis on undertaking practices that yield better socio-environmental performance and higher economic benefits.

By building on the corporate sustainability perspective, organization and management scholars have to date paid considerable attention to the topic of 'what' makes some firms successful in simultaneously improving economic, environmental and social performance. Research in this area can be grouped into three broad themes: that which focuses on the association between environmental and economic performance (Aragón-Correa et al., 2008; Sharma & Vredenburg, 1998); social and economic performance (Cai et al., 2012; Waddock & Graves, 1997); and all three aspects of sustainability (Bansal, 2005; Eccles et al., 2014). Due to the mixed findings regarding the patterns of associations (positive, negative or neutral), the recent literature argues that there is a conditional effect of social and/or environmental practices on economic performance (Dixon-Fowler et al., 2013; Tang et al., 2012; Wang & Sarkis, 2017).

In this regard, an emerging body of research discusses the role of 'innovation' as a key organizational factor in enabling firms to pursue integrated corporate sustainability practice (Hall & Vredenburg, 2003; Hall et al., 2012; Klewitz & Hansen, 2014; Nidumolu et al., 2009). Accordingly, the broadness of the concepts of corporate sustainability and innovation has resulted in divergent views on conceptualizing and operationalizing innovation in sustainability contexts. This is well reflected in the interchangeable use of terms such as 'green innovation' (Chen et al., 2006; Schiederig et al., 2012), 'eco-innovation' (Jones & Corral de Zubielqui, 2017; Pujari, 2006), 'sustainable innovation' (Boons et al., 2013; Bos-Brouwers, 2010) and 'environmental innovation' (Bonte & Dienes, 2013; Horbach, 2008). Despite the use of varying terminology, there is a general consensus in the literature that innovative solutions in terms of processes, products or management practices can help firms to address critical social and/or environmental concerns, as well as to achieve a better economic performance. This financial benefit could be achieved by means of either reducing pollution/waste, product differentiation in environmentally concerned markets, increasing energy and/or material efficiency, or obtaining social legitimacy (Bansal, 2005; Bocken, Short, et al., 2014; Dangelico & Pujari, 2010; Yuan et al., 2017).

In an attempt to advance the convergence of the different terms at the intersection of innovation and sustainability, scholars have started to use the term 'Sustainability-Oriented Innovation' (SOI) (Adams et al., 2016; Schaltegger et al., 2012). What is new with SOI compared to similar terms is that it not only covers all the three aspects of corporate sustainability, but also takes into account the diversity of innovation types in terms of objects (products, processes, management practices, business models) and novelty (incremental vs. radical changes). Others, such as Jay and Gerard (2015) and Luqmani et al. (2017), argue that SOI differs from the similar

notions, as well as from the conventional approaches to innovation, by its multiplicity of sustainability purposes and broader impacts on the natural and social systems.

Acknowledging the difficulty that firms encounter in undertaking SOI, research has shown that engaging external stakeholders is a prerequisite for the continuous creation and deployment of innovative solutions for tackling sustainability concerns (Amini & Bienstock, 2014; Hall et al., 2003; Rodriguez et al., 2002; Segarra-Ona et al., 2017). Considering the variety of innovation types and the broad impact of SOI, firms are required to incorporate a diverse set of knowledge in their innovation processes, including knowledge about technologies, regulative standards, societal expectations and market demands (Clarke & Roome, 1999; Ketata et al., 2015; Luyet et al., 2012). Consequently, not only are the primary stakeholders, such as those within the value chain, relevant, but also the secondary stakeholders (e.g. not-for-profit organizations and local communities), who are deemed insignificant for general innovation but can enable firms to overcome the complexity and uncertainty of SOI (Fliaster & Kolloch, 2017; Goodman et al., 2017; Hall & Martin, 2005). Rather than investigating competing perspectives on which stakeholder groups matter more for SOI, this thesis views different stakeholders as complementary sources of knowledge, who may contribute to a firm's innovation and performance in different ways.

1.2 Problem statement and the overall question

The thesis positions itself within the literature on 'stakeholder engagement for SOI' (hereinafter, open SOI) by combining two different, but somewhat interdependent, research themes dealing with stakeholders' contribution to corporate sustainability and innovation. The first research theme builds primarily on the stakeholder theory of the firm (Freeman, 1984, 2010), arguing that the competitive advantage, as well as the long-term survival of firms, depends on their relationship with a wide variety of stakeholders. As concerns corporate sustainability, engaging stakeholders can enable firms to fulfill mutual sustainability interests, as opposed to mere focusing on economic benefits or pure philanthropic practices (Hörisch et al., 2014). Empirical research in this research domain suggests that the trust and common language resulting from long-term stakeholder relationships assist firms in resolving the tension between economic and other dimensions of sustainability (Eccles et al., 2014; Hillman & Keim, 2001). This is because trust and common language act as valuable, rare and inimitable resources, which, according to the resource-based view (RBV) of the firm (Barney, 1991), can generate competitive advantage. Therefore, firms that develop their ability in stakeholder engagement (regardless of whether innovation is the objective or not) seem to be in a better position to address social and environmental concerns (e.g. through obtaining inputs from local communities or customers), while also ensuring their financial benefit.

The second research theme related to open SOI adopts Chesbrough's (2003) open innovation perspective in order to link firms' activities towards gaining external stakeholders' knowledge and their innovation outputs with sustainability impacts. In this respect, the findings indicate that environmental innovators (as a subset of SOI) fuel their knowledge stock from external stakeholders more intensively than general innovators (Cainelli et al., 2015; De Marchi, 2012;

Horbach et al., 2013; Rodriguez & Wiengarten, 2017). This leads us to believe that these types of innovations are more knowledge-intensive. In the same vein, Ayuso et al. (2011), Ketata et al. (2015) and Segarra-Ona et al. (2017) found a similar effect related to firms' external knowledge search on innovations with both environmental and social impacts.

While this line of research has provided some evidence in support of a positive association between stakeholder engagement and innovation outputs some studies have questioned this by arguing that broadly acquired external knowledge can become difficult to manage after a certain point, thereby decreasing its marginal effect on environmental innovations (Ghisetti et al., 2015; Muscio et al., 2017). Wagner (2007) suggests that cooperating too much with what he calls 'environmentally neutral stakeholders' (e.g. raw materials suppliers and industrial customers) might weaken environmental product innovation, as these stakeholders are in favor of channeling research and development (R&D) investment into general innovations that do not necessarily bring environmental advantages.

Moreover, some studies have probed deeper into the phenomenon of open SOI by focusing on collaborations with secondary stakeholders and their direct and indirect roles in innovation processes (Brunner & Marxt, 2013; Fliaster et al., 2017; Goodman et al., 2017; Holmes & Smart, 2009; Ingenbleek & Dentoni, 2016; Wagner, 2011). For example, Brunner et al. (2013) found that besides obtaining access to valuable social and environmental knowledge, business-NGO (non-governmental organization) partnerships could also provide firms with indirect benefits, such as reducing opposing actions from other stakeholders due to the NGOs' positive reputation in society.

Broadening the scope of external stakeholders in SOI does in turn challenge firms to develop particular capabilities, on top of those required for general innovations, in order to manage the knowledge inflow and effective learning. These capabilities range from stakeholder networking and competence mapping before the start of an innovation project, to relational capability and knowledge management during a project (Behnam et al., 2018; Kazadi et al., 2016). More specifically, open SOI capabilities emerge as a result of established routines for stakeholder dialogue (Ayuso et al., 2006; Veldhuizen et al., 2013) and integration of external knowledge within the firm by means of boundary spanning individuals (Holmes et al., 2009) and cross-functional collaboration (Dangelico et al., 2017).

Despite their valuable insights, current studies have some limitations, which primarily emanate from the inconsistency in conceptualizing and operationalizing SOI. First, although scholars have recently set out to go beyond the dominant focus of the open SOI literature on value chain partners, the dearth of quantitative evidence prevents the field from engaging in a more systematic discussion of the possible effects of a diverse set of stakeholders on SOI outputs.

Second, the majority of publications have restricted corporate sustainability, and consequently their definition of SOI, to environmental and/or social aspects. This simplification comes at the expense of ignoring the fact that even though firms consider stakeholder engagement as a means of responding to environmental and/or social concerns, their ultimate aim is to achieve better financial performance through these practices (Greenwood, 2007; Schaltegger et al., 2012).

This restriction has resulted in somewhat conflicting results regarding the effect of certain groups of stakeholders on SOI outputs, for example suppliers (Segarra-Ona et al., 2017), customers (De Marchi, 2012) and research organizations (Bonte et al., 2013). Moreover, ignoring the financial aspect of sustainability limits our knowledge about whether, and in what way, stakeholder engagement improves financial performance, when such a link is not often evident (Laplume et al., 2008) owing to the fact that environmental and social objectives might not always be aligned with firms' economic goals.

Third, concerning the capabilities for undertaking open SOI, we have yet to understand the underlying factors that might promote or hinder the external knowledge flowing into a firm (Adams et al., 2016; Amui et al., 2017), particularly the microfoundations of such capabilities. The few notable exceptions that explore these microfoundations concentrate on SOI projects as the unit of analysis (Behnam et al., 2018; Kazadi et al., 2016), thereby failing to address how capabilities emerge at the firm-level, where sustainability objectives are more extensive. Other than firm-level capabilities, the extent to which firms' closeness to their external stakeholders in terms of knowledge bases and sustainability objectives may condition the flow of knowledge is still an understudied line of enquiry. Considering these research gaps, the overall research question (RQ) of this thesis is:

"Under which conditions and to what extent can engaging external stakeholders improve a firm's SOI outputs and financial performance?"

In order to answer this question, three interdependent papers are employed to investigate the phenomenon of open SOI, particularly its determinants and financial consequences. Common to all these papers is a comprehensive view of SOI and external stakeholders, which can help us to overcome the inconsistency of the previous results regarding the effect of stakeholder engagement on SOI outputs. Adopting such a comprehensive view is particularly important when considering the diversity of sustainability objectives from SOI, which in turn necessitates the engagement of a multiplicity of stakeholders in innovation processes. Therefore, the focus of this work is on exploring a broader set of firm-level capabilities and inter-organizational characteristics that are required to increase innovative outputs in sustainability contexts.

Before moving on to discuss how the three papers answer the overall RQ, section 1.3 provides the motivation behind selecting the Norwegian minerals industry as the empirical focus. Whereas previous studies on open SOI are focused to a large extent on manufacturing industries, such a dedicated study in a resource extractive industry extends the literature by providing insights from business contexts in which sustainability challenges are at their highest levels.

1.3 Empirical focus

Although a universally agreed definition of it does not exist, the minerals industry comprises firms involved in the extraction and primary processing of minerals from bedrock and/or surface deposits (Geological Survey of Norway, 2014). For the purpose of this thesis, the focus is on non-energy minerals due to the distinct characteristics of oil, gas and coal in terms of

resource management and sustainability issues (Azapagic, 2004). Accordingly, the industry can be categorized into four main sectors, which produce a diverse range of minerals (Azapagic, 2004; Geological Survey of Norway, 2014):

- Metallic ores (e.g. iron, copper, nickel, ilmenite and zinc),
- Construction minerals (e.g. sand, gravel and gypsum),
- Natural and dimension stone (e.g. larvikite, granite, marble, slate and masonry),
- Industrial minerals (e.g. calcium carbonates, olivine, nepheline, quartz and graphite).

Mineral firms face dual concerns regarding corporate sustainability. On the one hand, they use non-renewable and often scarce resources provided by nature, which might result in serious sustainability problems including continuous depletion of existing known resources, urbanization and climate change (Andersen et al., 2015; George et al., 2015; GRI, 2011). Moreover, the production and processing of minerals are also associated with certain harmful effects such as pollution (air, water and landfill) and jeopardize the viability of nature-based activities such as herding, fishing and tourism (Govindan, 2015; Suopajärvi et al., 2016). These environmental and social challenges are main causes for mine closures and endanger the economic viability of the industry (Laurence, 2011).

Besides, the prices for many mineral commodities, particularly metallic ores and industrial minerals, are highly volatile due to the fluctuation in market demand and production costs, which has resulted in continuous shrinking of productivity and profit margins (Ernst & Young, 2014). The industry's struggle with such sustainability issues is well reflected in the following quote from a mineral company manager: "(…) so the further development in this industry relies on production processes that are able to increase the yield, decrease the waste materials and pollutants, and make progress in energy efficiency." (Mineral firm interviews, case L, paper 1).

On the other hand, the increasing demand for mineral raw materials in high-tech sectors such as smartphones and aerospace, as well as in the production of environmental technologies (e.g. solar cells and windmills), has led to recognition of the significance of the minerals industry for sustainable development. Accordingly, some firms have already started to seize these opportunities, as highlighted, for example, by one of the interviewees:

"(…) there will be then an increased demand for highly purified minerals that are necessary for production of more sustainable solutions for power production, electric cars, windmills, etc. And to achieve our objectives in product development projects, changes in machinery and enrichment processes are required." (Mineral firm interviews, case J, paper 1).

This discourse has also found its way to policies at both EU and national levels. Securing a sustainable supply of raw materials within Europe is one of the strategic pillars for the EU's Raw Material Initiative, which aims to meet critical needs for growth and jobs in Europe (EC, 2008). This strategic approach is in line with the EU's earlier call for corporate sustainability in this industry through "more secure and less polluting extractive activities while maintaining the competitiveness of the industry" (EC, 2000, p. 3).

Translating the mineral firms' sustainability challenges into innovation objectives, SOI, with its holistic approach to addressing economic, environmental and social concerns, seems to be highly appropriate. Concerning innovation objects, firms' focus has been more on productivity advances and operational efficiency than on product differentiation. However, the relatively slow rate of development and adoption of new technologies, as well as governmental pressures to increase the value added of minerals, are driving firms to invest in innovative products by improving the purity of current mineral products and developing specialized product offerings (Azapagic, 2004; Deloitte, 2016). Innovative practices to address social concerns, such as including social impact analysis in annual reports (Bini et al., 2018) and using design thinking for community integration (Erzurumlu & Erzurumlu, 2015), although still rare, could provide a win-win situation for mineral firms and their societal stakeholders.

Beyond what has been stated regarding sustainability and innovation in the minerals industry in general, the Norwegian context offers a rich case for answering the question raised in this thesis. The new national strategy for the industry is a good example, as clear sustainability objectives are set: "The minerals industry must have a proactive approach to social responsibility, must find the best environmental solutions and must be a positive force for growth in the host municipalities" (Ministry of Trade and Industry, 2013, p. 12).

Further, with regard to environmental and social sustainability, Norway has one of the strictest environmental regulations for granting permits and mine development (Kokko et al., 2015). In addition, it is a high-cost country, in which producers of metals and industrial minerals are facing increasing competition in the international markets. However, the country's innovation system is characterized by the high ability of firms to recognize the challenges and opportunities arising from such situations by searching for solutions from external sources and combining this knowledge with their existing capabilities (Fagerberg et al., 2009). This capability seems to be even more relevant for an SME-dominated industry such as minerals, as organizational flexibility allow firms to respond more efficiently and innovatively to sustainability challenges (Bos-Brouwers, 2010). Besides a long history of benefiting from external knowledge in the global minerals industry (Ala-Härkönen & Rutenberg, 1993; Farooki, 2012), stakeholder theorists (see Strand & Freeman, 2015) posit that institutionalized cultural norms such as trust nurture company-stakeholder cooperation in the Scandinavian business context.

Finally, recent contributions suggest that sectorial and country-level varieties in terms of regulations, market demands and stakeholder pressures could explain firms' SOI activities (Galliano & Nadel, 2015; Horbach et al., 2013; Kawai et al., 2018). By studying Japanese multinational firms in different countries, Kawai et al. (2018) found that the pressure from customers and suppliers regarding environmental concerns affect green product and process innovations, and this effect is amplified in countries with better schemes for environmental stewardship. Indeed, other factors apart from incorporating external stakeholders' knowledge can distort the results observed in the majority of studies within the field of open SOI, which draw on multi-sector datasets from the manufacturing sector of the economy (e.g. Cainelli et al., 2015; De Marchi, 2012; Ghisetti et al., 2015; Wagner, 2011). With a single-industry and

single-country focus, this thesis rules out the effect of such 'confounding' variables to provide industry-specific insights and policies. As far as can be ascertained, the recent study on the Italian wine industry by Muscio et al. (2017) is the only exception that follows the same approach, yet the focus in this thesis on a natural resource extractive sector will contribute to understanding of open SOI in a different context (as discussed earlier in this section).

1.4 Development of the sub-research questions and positioning of the appended papers

Having established the overall RQ and the empirical setting within which this question will be answered, the next task is to develop the sub-questions that are explored in the three separate studies of this thesis, hereinafter referred to as paper 1, paper 2 and paper 3. Table 1 presents an overview of these papers, including their contribution to answering the overall RQ and the main relevant theories used.

Table 1: Overview of the papers and their role in answering the overall RQ

Under which conditions and to what extent can engaging external stakeholders improve a firm's SOI outputs and financial performance?				
Appended papers	**RQs**	**Relation to the overall RQ**	**Theoretical focus**	**Type of data**
Paper 1	RQ1: What are the capabilities, and their underlying skills and routines, that build the absorptive capacity required for SOI in the minerals industry?	Explores the underlying skills and routines that form a firm's capability in recognizing, assimilating and exploiting external stakeholders' knowledge for pursuing SOI	Absorptive capacity	Qualitative
Paper 2	RQ2: What proximity dimensions, i.e., institutional, cognitive and organizational proximities, or any combinations of them, explain the SOI outputs of companies in the minerals industry?	Explains in what ways and to what extent different types of SOI outputs are conditioned upon various aspects of proximity between a firm and its external stakeholders	Innovation in peripheral regions	Quantitative
Paper 3	RQ3: To what extent does stakeholder engagement affect a firm's SOI outputs? RQ4: To what extent do SOI outputs mediate the association between stakeholder engagement and financial performance?	Explains the extent to which stakeholder engagement affects SOI outputs, and whether these outputs condition the impact of stakeholder engagement on financial performance	Stakeholder theory and RBV	Quantitative

In combination, the thesis can be best put into a "consensus-creation" frame (Hollenbeck, 2008), as it contributes to enhanced understanding of the phenomenon of open SOI by overcoming some of the inconsistencies in previous findings. This lack of consensus has in turn caused concerns among both the scientific community and practitioners regarding external stakeholders' effects on innovation and financial performance. To restrict the boundaries of the

debates surrounding these effects, the thesis identifies various research gaps that are overlooked in the literature on open SOI, and aims to fill these by drawing on different theoretical stances, as described below. Spotting something neglected in the literature is the most prevalent way of constructing research questions based on current studies (Alvesson & Sandberg, 2011); a blank area on the knowledge map makes it imperative for scholars to develop knowledge about this neglected area and thus add something to the relevant literature.

Paper 1 uses qualitative data to explore the capabilities, as well as their underlying skills and routines, which condition a firm's ability to benefit from external stakeholders' knowledge in SOI contexts. It is generally accepted that undertaking an open approach towards SOI requires specific capabilities that are different from what a firm might already possess regarding its general innovations (Adams et al., 2016; Behnam et al., 2018; Kazadi et al., 2016; Watson et al., 2017). However, as discussed in section 1.2, empirical evidence on these capabilities are scarce, and mostly ignore the multiplicity of stakeholders and sustainability aspects. In particular, we have yet to understand the processes through which SOI capabilities emerge at the firm-level, and the underlying skills and routines (as the microfoundations) that shape these capabilities. To inform this research gap, paper 1 adopts a process view of absorptive capacity, which involves recognition, assimilation and exploitation of external knowledge (Lane et al., 2006). It suggests that four types of capabilities underlie these processes: (1) keeping abreast of changes in technologies and markets; (2) increasing awareness of social issues; (3) facilitating internal knowledge dissemination; and (4) piloting new, innovative solutions.

Paper 2 studies the conditional effects of stakeholder engagement on SOI from an inter-organizational angle, in comparison to paper 1, which focuses on the internal capabilities that can condition such effects. Compared to general innovations, firms are relatively more 'distant' from their external stakeholders in SOI, as sustainability knowledge spans different areas of technology, regulations, societal expectations and market demands, which are not usually within firms' existing knowledge bases (Clarke et al., 1999; Ketata et al., 2015; Luyet et al., 2012). Diverse and sometimes conflicting interests between a focal firm and stakeholders might also hinder effective knowledge exchange (Hörisch et al., 2014). While co-locations in industrial clusters and geographical proximity to knowledge organizations could generally assist firms in overcoming some of the above issues (Gertler & Wolfe, 2006; Torre & Gilly, 2000), mineral firms' localization in peripheral regions adds to the challenge of recognizing and assimilating external knowledge. By building on non-geographical proximity dimensions (Boschma, 2005) as the theoretical anchor, paper 2 explains how and to what extent organizational, institutional and cognitive proximities condition the effect of stakeholder engagement on different types of SOI.

Paper 3 takes a step forward towards examining the association between stakeholder engagement and SOI by linking these variables to firms' financial performance. First, the paper builds on stakeholder theory to explain the extent to which transactional and relational interactions with external stakeholders affect SOI outputs. This contribution adds to the current literature on open SOI by empirically examining the association between engaging a diverse

set of stakeholders and innovative outputs. Second, it addresses the conflicting results in previous studies regarding whether stakeholder engagement is beneficial in terms of profitability (Laplume et al., 2008). This is achieved by borrowing from RBV, specifically its extension, the natural resource-based view (Hart, 1995; Hart & Dowell, 2011), to explain the role that SOI can play in enabling a firm to continuously respond to sustainability challenges (via addressing stakeholders' needs), while improving its competitiveness. The paper concludes by identifying SOI as a full mediator in the association between stakeholder engagement and financial performance. Therefore, it suggests that external engagement activities do not directly link to such performance, but the benefit begins to appear once a firm is able to transform the acquired knowledge from external stakeholders into innovative outputs.

Accordingly, these three papers contribute to answering the overall RQ in various but interdependent ways. The first and second papers provide insights into the conditions in which stakeholder engagement can be beneficial for SOI, focusing on internal and inter-organizational factors. The third paper, therefore, positions SOI itself as a mediating condition that can assist firms to draw financial benefits from stakeholder engagement practices. Furthermore, the second and third papers establish an empirical link between stakeholder engagement and SOI outputs. In paper 2, various proximity dimensions are used to test whether stakeholder engagement is conducive to different types of SOI, namely process, product and social innovations, while in paper 3 stakeholder theory informs the hypotheses concerning whether different types of engagement (relational or transactional) assist a firm to augment its SOI outputs.

To answer the overall RQ, the remainder of the thesis is structured as follows: section 2 presents the theoretical background; section 3 describes the overall methodology as well as the specific research designs used in the appended papers; section 4 summarizes the three papers; and finally section 5 discusses the findings and implications of the thesis for research and practice.

2 Theoretical background and literature review

As discussed in section 1.4, the three papers in this thesis set out to study the different internal, inter-organizational and external factors that relate to the engagement of external stakeholders and affect SOI and financial performance. Consequently, the papers employ different theoretical frameworks, covering large bodies of literature on organizational capabilities, absorptive capacity, innovation in peripheral regions, proximity dimensions and inter-organizational relationships. Therefore, instead of presenting frameworks that are explained accordingly in each of the individual papers, in the following section the overarching perspectives and theoretical insights that are common throughout the papers will be presented.

To identify the literature on open SOI within which the thesis is positioned, the three generic concepts of corporate sustainability, external stakeholders and innovation are relevant. Therefore, the theoretical perspectives that lay the basis for the work emerge at the pairwise intersections of the three terms; namely, stakeholder engagement for sustainability, SOI and open innovation. Subsequently, the open SOI literature is where these three overlapping concepts meet (Figure 1).

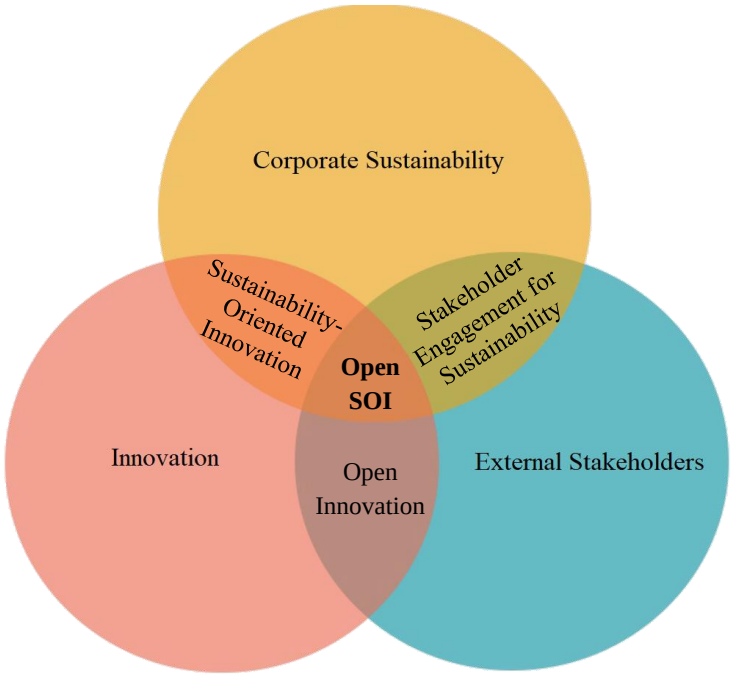

Figure 1: Cross-section of concepts shaping the research field of open SOI

In the remaining part of this section, the three generic concepts, as well as their pairwise intersections, will be briefly reviewed. Finally, a descriptive account of the literature on open SOI is presented, followed by a thematic analysis to identify the open issues in the literature and formulate the overall purpose of the thesis.

2.1 Corporate sustainability

Before defining corporate sustainability, it is necessary to have a clearer understanding of the term ‘sustainable development’ and the way it translates into business level practices. Apart

from some divergence in the early years after the introduction of the concept by the World Commission on Economic Development (WCED), the literature nowadays unanimously cites the definition of the well-known Brundtland report: "A development that meets the needs of the present without compromising the ability of future generations to meet their own needs" (WECD, 1987, p. 8). Inspired by this report, several initiatives, including the World Business Council for Sustainable Development (WBCSD) and The Global Reporting Initiative (GRI), facilitated the efforts to put sustainable development into action. As stressed in the original conceptualization, and as followed up by these initiatives, environmental protection, social equity and economic prosperity are the three interconnected principles of sustainable development; sustainability will not be achieved by ignoring any of them (Ranald, 2002).

Corporate sustainability, as the equivalent of sustainable development at the business level, has received increasing attention from organization and management scholars, who refer to the important roles firms play in achieving sustainable development in larger social systems (Amini et al., 2014; Bansal, 2002, 2005; Dyllick & Hockerts, 2002; Ebner et al., 2006; Gladwin et al., 1995; Hahn et al., 2015). For example, Bansal (2002) asserts that firms' support is crucial for implementing sustainability objectives, since they use natural, human and capital resources (productive resources) to provide a better life for human beings (including themselves). Similarly, Ebner et al. (2006) discuss sustainable development and corporate sustainability through the lens of macro-level and micro-level sustainability orientation, in which firms' environmental and social behavior, as well as their financial performance, can have positive or negative effects on the sustainability of the society within which they are embedded.

In this regard, it is important to understand that corporate sustainability requires a firm to aim for simultaneous improvements in economic, environmental and social aspects (Bansal, 2005; Dyllick et al., 2002). However, pursuing such an integrated approach to corporate sustainability is not easy in practice, due to the tensions that may arise between the ways sustainability is perceived by a firm and its socially/environmentally concerned stakeholders (Gao & Bansal, 2013; Hahn et al., 2015). While the majority of firms undertake social and environmental practices as a means of creating more profits, such activities might not necessarily be deemed to be sustainable by those stakeholders (Bansal, 2002).

On the one hand, from a business perspective, it is necessary that the (financial) benefit from social and environmental practices outweighs the cost of being involved in them, thereby creating what the literature refers to as a 'business case for sustainability' (Schaltegger et al., 2006). On the other hand, external stakeholders expect firms to show environmental and social commitment beyond a pure focus on reducing negative impacts, by, for instance, creating employment or developing products with environmental benefits (Dyllick et al., 2002; Gao et al., 2013; Jennings & Zandbergen, 1995). Thus, pursuing an integrated corporate sustainability approach should create a win-win situation, with mutual benefits for shareholders and external stakeholders (Hörisch et al., 2014), in which firms maximize the economic value from natural resources in an environmentally friendly manner, which also contributes to social welfare and economic growth at the society level. Rather than differentiating between perspectives with

varying degrees of emphasis on particular sustainability aspects, this thesis adopts an integrated approach towards corporate sustainability, which entails combining environmental and/or social objectives with profit seeking motivations. The following section will briefly discuss the range of sustainability issues and corporate sustainability practices to further clarify the interdependency between economic, environmental and social sustainability.

The environmental aspect of corporate sustainability highlights the impacts of firms' activities on their natural environment, dealing primarily with negative environmental footprints such as resource use and pollution (emissions and waste materials) (Baumgartner & Ebner, 2010). Due to the insufficiency of natural resources, especially non-renewable ones, business activities are required to decrease their resource use, while maintaining the product yield at least at the same rate. In addition, increasing awareness about the limited capacity of the planet to absorb excess waste and emissions has led to consideration of the natural environment as a crucial factor in sustainable development (Laurence, 2011). Accordingly, firms are undertaking environmental management practices through either pollution control (e.g. waste disposal) or more proactive pollution prevention at its source (e.g. using cleaner technologies) in order to eliminate production inefficiencies (Hart, 1995; Muscio et al., 2017).

Although firms are prone to lock-in situations, in which they only consider the efficiency-improving potential of environmental sustainability, such practices may also result in better product quality and competitive advantage in the marketplace (Chang, 2015; Porter et al., 1995; Pujari, 2006). In this regard, integrating environmental sustainability into business operations calls for solutions that are based on identifying the negative and positive environmental impacts of a product throughout its entire life cycle (Amini et al., 2014; Aragón-Correa et al., 2008). To illustrate this, one example could be a mineral company that is involved in production of high quality silicon to be used in solar cells. It could be able to address environmental concerns even after product delivery to its customers, as the final solution (in this case, a solar cell) will eventually reduce the use of non-renewable resources.

The social aspect of corporate sustainability is rooted in how business activities respond to societal needs, including human welfare, incorporating social interests in decision-making, preserving the environment, creating jobs and tax revenues in the community, and fairly treatment of employees (Gladwin et al., 1995; Steurer et al., 2005). As such, social sustainability comprises internal and external drivers, as reflected in employee welfare and the concerns of external stakeholders (Lozano, 2015). For the purpose of this thesis, the focus will be on both the internal and external aspects of social sustainability, since the outcomes of improvement (or possibly lack of improvement) in one of these aspects cannot be separated from the other. For instance, responding to internal health and safety requirements is necessary for improving social reputation outside a firm, but is not sufficient, as the firm is also required to fulfill the needs and expectations of the local community and NGOs in order to be perceived to be socially sustainable.

Due to the increasing incidence of shutdowns and slow-ups in mining projects resulting from failure to address social concerns, integrating social sustainability into daily operations is

nowadays an important means of obtaining the so-called 'social license to operate' (Prno & Scott Slocombe, 2012; Suopajärvi et al., 2016). This entails obtaining societal approval from a broader range of stakeholders in society, such as the general public and social media, through active participation and dialogue, thereby moving beyond the limited focus on compliance to legal frameworks enforced by national and international authorities (Herremans et al., 2016; Kokko et al., 2015). In a case study of the minerals industry in several countries located in Northern Europe, Suopajärvi et al. (2016) found that social sustainability should be examined through a temporal view that takes into account both short-term and long-term responses to societal needs. They further elaborate that whereas local communities expressed serious concerns about nature-based livelihoods and indigenous rights, their future expectations centered on contributions to economic development via, for instance, better infrastructure and employment opportunities.

Therefore, although it is not always easy for firms to relate their environmental and social practices to tangible profits, the economic viability of mineral firms seems to be contingent on their ability to provide economic prosperity and social equity at the society level (Azapagic, 2004). As shown above, environmental assessment is also an essential factor in obtaining the social approval required for the long-term survival of firms (Bansal, 2002). Subsequently, the quest for integrated corporate sustainability enables firms to develop resources and capabilities that are essential for success in this quest (Aragón-Correa et al., 2008; Bansal, 2005; Cai et al., 2012; Eccles et al., 2014; Hillman et al., 2001; Sharma et al., 1998; Waddock et al., 1997). Stakeholder relationships and innovation are among the most cited resources and capabilities in this respect.

2.2 Innovation

Innovation as a general term has been interpreted and understood in many different ways. For the purpose of this thesis, innovation is defined as "the search for, and the discovery, experimentation, development, imitation and adoption of new products, new production processes and new organizational setups" (Dosi, 1988, p. 222). While several other definitions exist, they tend to agree that innovation is both a process and an outcome (Crossan & Apaydin, 2010). As also indicated in Dosi's definition, innovation as a core business process involves scanning the environment to identify threats and opportunities, deciding on an appropriate response to change drivers, implementing the chosen solution and finally learning from this process in order to improve the firm's ability for future innovations (Tidd et al., 2005). Such processes will potentially result in measurable outcomes that could be distinguished in terms of objects (products, processes and organizational practices). Moreover, the adopted definition from Dosi captures three important aspects of innovation that have implications for how the term is used throughout this thesis.

First, this study considers innovations regardless of their degree of novelty, which in extreme terms include completely incremental and radical innovations (Henderson & Clark, 1990). Radical innovation refers to disruptive changes in the introduced product/process and/or market mechanisms by means of developing completely new knowledge, whereas the incremental

specifies modest changes by combining existing knowledge bases (Gatignon et al., 2002). In the case of sustainability, this distinction has led to a lively debate in the literature. Some scholars support the idea that social and environmental changes have to be radical in order to tackle major challenges such as global warming and poverty (Bos-Brouwers, 2010; Kennedy et al., 2017). Others, although not rejecting the importance of transformations at a systemic level, argue that social and environmental sustainability could also be achieved through innovative solutions that are 'relative improvements' to existing products and processes (De Marchi, 2012; Galliano et al., 2015; Wagner, 2011). Consequently, innovations in sustainability contexts, like innovations in general, occur on a continuum from the incremental to the radical (Klewitz et al., 2014). This perspective seems to be more realizable in practice, since limiting innovations to radical ones overlooks the positive social/environmental impact of innovations that are introduced by applying modest changes to existing products or processes via internal (experimentation and modification) and external (imitation and adoption) mechanisms.

Consideration of these two mechanisms directs us to the second feature of Dosi's definition, the locus of innovation and the necessity to conduct a range of internal and external activities. Even though the primary focus of this thesis is on external knowledge, it does not exclude the roles that internal activities play for innovations to take place. While recent years have seen a rapid shift from pure internal innovation activities to networks and systems of innovation (Chesbrough, 2003; Powell et al., 1996; von Hippel, 2005), firms' ability to locate, transform and exploit externally acquired knowledge is still of utmost importance (Cohen & Levinthal, 1990; Lane et al., 2006). Therefore, the internal capabilities required to benefit from externally developed knowledge will be equally weighted and studied in this thesis.

Third, it is important to consider different types of innovation based on the human resources that are involved in innovation processes. In this respect, a distinction has been made between the Science, Technology and Innovation (STI) mode, and the Doing, Using and Interacting (DUI) mode (Jensen et al., 2007). While the former relies on the latest scientific and technological knowledge, which is often developed by personnel involved in R&D processes, the latter is the result of the continuous experimentation and learning-by-doing that takes place on the production floor (Bogers & Lhuillery, 2011; Fitjar & Rodríguez-Pose, 2013). Both STI and DUI modes of innovation are significant. as they enable us to have a better understanding of the range of knowledge sources within a firm, particularly in low- and medium-tech industries that rely less on R&D-based knowledge (Arundel et al., 2008; Santamaría et al., 2009). However, the lack of sufficient R&D and non-R&D knowledge in such industries in itself explains the necessity to acquire external knowledge.

To conclude, the term 'innovation' in this thesis denotes a broad conceptualization, in which radical vs. incremental, internally vs. externally originated, and R&D-based vs. non-R&D-based innovations are taken into account, without explicitly differentiating between various types of innovation in these dichotomies. This is in alignment with how SOI is defined in this study, as a subset of innovation that encompasses different innovative outcomes, irrespective

of whether they are technological or managerial, with these innovations necessitating certain degrees of openness to external stakeholders.

2.3 External stakeholders

During the recent decades, the shifting focus of managers, from maximizing the return for shareholders to acknowledging the necessity to consider a broader range of external actors, has led to the emergence of the 'stakeholder theory of the firm' (Freeman, 1984). Broadly speaking, "a stakeholder is any group or individual who can affect, or is affected by, the achievement of a corporation's purpose" (Freeman, 2010, p. 9). According to this theory, firms are embedded in a wide array of different stakeholders, including the traditional value chain partners, local communities, competitors, governmental authorities, environmentalists and interest groups, employees, and investors, amongst whom business activities should pursue strategic directions that create value for all of these individuals and groups.

For the purpose of this thesis, the focus is on external stakeholders, i.e. those who are outside organizational boundaries (thus excluding employees) and do not have ownership of the firm in any way (thus excluding owners, investors and shareholders). Moreover, since stakeholders are here perceived as a means of having access to external knowledge for innovation purposes, universities are included because of their essential contribution to knowledge creation and dissemination. In line with the literature that deals with external sources of knowledge and innovation (see Greco et al., 2016; Laursen & Salter, 2006; Rauter et al., 2017), these exclusion and inclusion criteria leave six different groups of stakeholders: suppliers, customers, NGOs/interest organizations, competitors/firms in other sectors and industries, public authorities and universities. However, the term 'stakeholder' instead of the more general ones such as 'external knowledge sources' is deliberately used to mark the fact that these groups and individuals "have a stake in the activities that make up the business" (Freeman et al., 2007, p. 3). The 'stake' in this thesis refers to the social, environmental and economic benefits that these stakeholders can make when a firm achieves its corporate sustainability objectives.

By acknowledging firms' limited resources (e.g. human, financial), a central strand of inquiry within the literature on stakeholder theory has been made to provide firms with insights into groups of stakeholders that deserve more attention. One of the earliest contributions in this regard is the distinction that Clarkson (1995) made between primary and secondary stakeholders. In his view, primary stakeholders are those groups or individuals whose involvement is crucial for firms' survival. By contrast, secondary stakeholders are not engaged in transactions (often economic) with firms and as such do not directly affect firms' survival prospects, but can nonetheless damage daily business operations. The former typically comprises suppliers, customers and public authorities, while the latter includes all other stakeholders such as interest organizations and universities (Freeman et al., 2007; Steurer et al., 2005). This classification was taken a step further by Mitchell et al. (1997), who identified power, legitimacy and urgency as the three main indicators of stakeholder salience. They further posit that these stakeholder attributes are not steady; i.e., stakeholders could gain more

importance during a certain time period due to, for instance, increased urgency in responding to their needs or concerns.

However, considering corporate sustainability, recent research has found the growing importance of so-called secondary stakeholders, thereby suggesting that such crude distinctions have a blurring effect as far as environmental and social sustainability is concerned (Evans et al., 2017; Hall et al., 2005; Onkila, 2011). As discussed in section 2.1, addressing these concerns, which consequently implies satisfying the needs of wider groups of stakeholders such as local communities and NGOs, is nowadays of increasing significance for firms' survival in the long term. Instead of focusing on the attributes of stakeholders, scholars are calling for research that returns to the original unit of analysis in stakeholder theory, which is the attributes of the 'relationships' with stakeholders (Fliaster et al., 2017; Hörisch et al., 2014). This research gap will be particularly acted upon in paper 3.

2.4 Conceptualizing sustainability-oriented innovation

Innovation is widely accepted as an important determinant of firms' economic success (Crossan et al., 2010; Faems et al., 2010; Piening & Salge, 2015). Similarly, new technologies, products and organizational practices play a key role in addressing social and environmental issues (Arnold, 2017; Hart, 1995; Holmes et al., 2009). Therefore, the quest for corporate sustainability is increasingly resulting in innovation activities across different firms and industrial sectors (Gjoksi, 2011; Hall et al., 2003; Nidumolu et al., 2009). This has led to the emergence of several concepts in the scientific literature that deal with innovation in sustainability contexts. The main concepts used to date are green innovation (Chen et al., 2006; Schiederig et al., 2012), eco-innovation (Jones et al., 2017; Pujari, 2006), sustainability innovation (Boons et al., 2013; Bos-Brouwers, 2010), environmental innovation (Bonte et al., 2013; Horbach, 2008) and sustainability-oriented innovation (SOI) (Adams et al., 2016; Hansen et al., 2009). Table 2 presents selected definitions of these terms in the literature.

While the terms refer to a roughly similar phenomenon, they can be distinguished in terms of emphasis on different aspects of sustainability (Calza et al., 2017; Klewitz et al., 2014; Rauter et al., 2017). For example, whereas green innovation and environmental innovation seek to integrate environmental and economic improvements, SOI broadens this scope by incorporating social performance into the previously mentioned aspects. Moreover, other terms such as sustainability innovation ignore the importance of economic purposes and thereby fail to provide a holistic view of sustainability from a business perspective. Therefore, for the purpose of this thesis, SOI is used to signify innovative products, processes and organizational practices, through which the three multiple goals of corporate sustainability can be pursued.

Concerning the social aspect of SOI, innovation could appear on a continuum of purposes, from conflict resolution to the creation of social values (Murphy et al., 2012). In this regard, scholars in the field of corporate social responsibility (CSR) has emphasized that integrating social needs into organizational practices can enable firms to find solutions with combined economic and social benefits, thus moving beyond purely philanthropic purposes (Altuna et al., 2015; Jamali

et al., 2011; Segarra-Ona et al., 2017). By applying this perspective in a study of mineral firms in the UK, Bini et al. (2018) suggest that showing social commitment (to gain social license to operate) is an important driver for firms that set out to innovate their communication processes with societal stakeholders.

Table 2: Selected definitions of terms related to innovation in sustainability contexts

Term	Definition
Green innovation	"Hardware or software innovation that is related to green products or processes, including innovation in technologies that are involved in energy saving, pollution prevention, waste recycling, green product design, or corporate environmental management" (Chen et al., 2006, p. 332)
Sustainability innovation	"Sustainability innovation addresses environmental and social improvements compared to the present state and in terms of progress. In this sense, they minimize the social and environmental harm and rebound effects caused by the innovation based on the current knowledge and cultural norms." (Arnold, 2017, p. 180)
Social innovation	"A novel solution to a social problem that is more effective, efficient, sustainable, or just than existing solutions and for which the value created accrues primarily to society as a whole rather than to private individuals." (Murphy et al., 2012, p. 1701)
Eco-innovation	"Changes to the production process that decrease the product's impact on the natural environment and/or increase intra-generational or inter-generational equity." (Blum-Kusterer & Hussain, 2001, p. 301)
Environmental innovation	"The production, application or exploitation of a good, service, production process, organizational structure or management or business method that is novel to the firm or user and which results, throughout its life cycle, in a reduction of environmental risk, pollution and the negative impacts of resource use compared to relevant alternatives." (Kemp & Pearson, 2008, p. 7)
Sustainability-oriented innovation	"Making intentional changes to an organization's philosophy and values, as well as to its products, processes or practices to serve the specific purpose of creating and realizing social and environmental value in addition to economic returns." (Adams et al., 2016, p. 181)

In the same vein, the significant pressure on firms to minimize their negative environmental footprint has led to increasing investment in technologies and products with the potential for minimizing pollution and waste throughout the production processes and overall product lifecycle (De Marchi, 2012; Hart, 1995; Rodriguez et al., 2017; Sharma et al., 1998). These innovations also have an inherent effect on the social aspect of corporate sustainability, since environmental impact is at the core of societal expectations (Gjoksi, 2011; Suopajärvi et al., 2016). SOIs with primary environmental objectives cover a range of different classifications, including technological vs. managerial (Peng & Liu, 2016) and cleaner production vs. end-of-pipe technologies (Muscio et al., 2017). Concerning the latter dichotomy, existing research (see Bonte et al., 2013; Dixon-Fowler et al., 2013; Smith et al., 2010) highlights that cleaner production technologies have relatively greater potential to reduce environmental hazards,

since they prevent intensive resource use and/or pollution at the source of discharge, instead of employing control measures at the end of the production processes.

Nonetheless, different categories of SOI based on whether the primary objective is social or environmental sustainability, or any other distinctions within these categories (e.g. technological and managerial types of environmental SOI), should not be seen as limitations to how an innovation can be qualified as being sustainability-oriented. Therefore, in line with the broad definition adopted for SOI in this thesis, and a recent systematic literature review by Klewitz et al. (2014), three general types of SOI are included in all three papers: process, product and organizational (social) innovations.

Whereas SOI has received increasing theoretical and practical attention during recent years, it is still of relevance to ask what the specifics of SOI are and it differs from general innovations (De Marchi, 2012; Luqmani et al., 2017). The literature has so far focused on three facets of SOI, which can also act as barriers to firms' involvement with these innovations: 1) balancing the multiplicity of sustainability dimensions and pathways; 2) the double externality problem; and 3) added complexity and uncertainty.

First, as discussed in section 2.1, corporate sustainability, and hence SOI, require firms to adopt an integrated approach in which economic, environmental and social objectives are pursued simultaneously. In this respect, firms must develop innovation capabilities at different levels of process, product and social practices, in such a way that any improvement in one sustainability aspect does not, in any event, cause a negative effect on any other aspect of sustainability (Hart, 1995; Jay et al., 2015). For example, if a mineral firm attempts to introduce asphalt aggregates with better possibilities for recycling and reuse, while continuing to produce high levels of air emissions, it would then face a challenge to make potential customers believe in its environmental responsibility, and thus fail to benefit financially from its product innovation. Accordingly, it is important to note that when talking about SOI, environmental and social improvements are not an 'accidental side effect' of general innovation practices, but should be at the core of a firm's business activities.

Second, the 'double externality problem' that is commonly used in the literature on environmental innovation (as a subset of SOI) can also apply to the broader context, such as SOI. In his influential paper, Rennings (2000) posits that such innovations produce positive spillovers in both the development and implementation phases, hence discouraging firms to invest in them. More specifically, in addition to the issue of knowledge spillovers (to competitors) during the development stage, which is common to all innovations, SOI produces an additional externality, as it generates social and environmental benefits (primarily for society) that are hard to be reaped in financial terms. Therefore, the role of regulative frameworks to punish harmful environmental and social impacts is crucial in incentivizing firms that may lose their competitive advantage in the market due to the higher costs resulting from SOI practices (del Rio et al., 2015; Horbach et al., 2013; Rennings, 2000). Nonetheless, as discussed in section 2.1, firms operating in industries such as minerals have to address social

and environmental issues, no matter what the strength of such regulative frameworks is, as low performance in these aspects can directly affect their survival in the long term.

Finally, and importantly, it is the added complexity and uncertainty associated with undertaking SOI that differentiates it from general innovations (Hall et al., 2003; Sharma, 2005). Complexity arises as a result of the socio-technical diversity inherent in sustainability contexts (Clarke et al., 1999), where incorporating environmental and social considerations requires knowledge about technologies, regulative standards and societal expectations (Adams et al., 2016; Ketata et al., 2015). Uncertainty, on the other hand, points to the financial risks of SOI. Social and environmental improvements might be achieved at the expense of increasing the cost of processes and products, which could result in the market and system failures of these innovations (Foxon & Pearson, 2008). SOI, with its potential impact on wider groups of stakeholders, may create conflict situations due to the opposing interests between the focal firm and its stakeholders, for instance local communities (Hall et al., 2005; Watson et al., 2017). Therefore, it is likely that the knowledge required for SOI is relatively more distributed among different actors in the innovation system, hence requiring the engagement of a diverse range of external stakeholders in innovation processes. This theme will be discussed in detail in the following sections.

2.5 Stakeholder engagement for sustainability: beyond managing stakeholders

The emergence of stakeholder theory has given rise to studies that enquire into firms' relationships with external stakeholders and the consequences of such relationships. As stakeholder theory requires firms to respond to the needs and expectations of a wide variety of stakeholders (Freeman, 1984, 2010), scholars have paid considerable attention to investigating in what ways, if any, external stakeholders affect different aspects of corporate sustainability performance.

Within this body of work, two research streams are evident. In the first, research has focused on firm-level and institutional determinants of practices directed towards reducing/eliminating the negative influences of specific groups of external stakeholders on overall firm performance (González-Benito & González-Benito, 2010; Kassinis & Vafeas, 2006; Sharma & Henriques, 2005). These studies frame the association between corporate sustainability and stakeholders based on Frooman's (1999) description of the resource interdependence between a firm and its stakeholders, in which the firm strives to manage those stakeholders (via undertaking sustainability practices) who can directly or indirectly influence its access to critical resources (e.g. financial, human, raw materials).

For example, Sharma et al. (2005) found that in the Canadian forest product industry, firms are most likely to adopt innovative environmental management practices when the managerial perception of threats coming from environmentalists and/or customers is high. Indeed, the substantial investments required to implement advanced environmental management (and its negative impact on short-term gain) impede firms from acting (environmentally) sustainably, unless, for instance, it is possible that customers will cancel their purchase orders.

The second research stream goes beyond such a pure focus on controlling stakeholders' negative influences, and instead tends to use the term 'stakeholder engagement'[2] to indicate a more optimistic outlook of stakeholders' role in corporate sustainability (Aragón-Correa et al., 2008; Choi & Wang, 2009; Eccles et al., 2014; Hillman et al., 2001; Roome & Wijen, 2006; Sharma et al., 1998). In this case, stakeholder engagement is defined as "practices that the organization undertakes to involve stakeholders in a positive manner in organizational activities" (Greenwood, 2007, pp. 317-318). Empirical studies in this area have employed the RBV, or occasionally its extension, the natural resource-based view (NRBV) (Hart, 1995), to maintain that involving external stakeholders in efforts to alleviate environmental and social issues gives birth to valuable, rare and inimitable assets, which in turn assist firms in achieving higher financial performance.

In their study of automotive SMEs in Spain, Aragón-Correa et al. (2008) highlight that mutual understanding arising from collaborative relationships with external stakeholders enables firms to show more proactive approaches in environmental management and to achieve better financial performance relative to their competitors. Eccles et al. (2014) adopted a more inclusive view, by adding social issues to the sustainability aspects examined in the previous study. In this regard, they used a matched sample of US companies and found support for their hypotheses, suggesting that firms with higher sustainability performance do engage external stakeholders more frequently in daily operations, and that the high level of trust between them is a source of persistent competitive advantage by avoiding costly conflicts.

While both of the research areas discussed above have contributed substantially to understanding of stakeholders' role in corporate sustainability, the latter is in harmony with this thesis, which assumes a positive contribution of stakeholders in innovation processes, with the aim of creating mutual benefits for firms and their external stakeholders. For a firm and external stakeholders that have an economic stake in its performance (such as suppliers), this benefit arises in the form of cost savings or increased income, whereas other stakeholders take advantage of social and environmental improvements, in the form of either decreased negative impacts on the natural or social environment, or increased values in these respects.

2.6 Open innovation: leveraging on external stakeholders' knowledge

Since the introduction of 'open innovation' by Chesbrough (2003) over fifteen years ago, the concept has received great momentum from scholars across different scientific disciplines, even outside business and management fields (Chesbrough & Bogers, 2014; West et al., 2014). As the concept has been under development throughout the years, definitions abound. Nonetheless, Chesbrough et al. (2014, p. 17) synthesize the original and the most recent descriptions, defining open innovation as "a distributed innovation process based on purposively managed knowledge flows across organizational boundaries, using pecuniary and non-pecuniary mechanisms in line with the organization's business model". Thus, it should be noted that

[2] Although some studies in this domain use other terms such as 'stakeholder management', their set of descriptions clearly point to the characteristics of stakeholder engagement defined in this thesis.

openness implies inflows and outflows of knowledge, as well as a variety of practices for knowledge flow that might not necessarily involve monetary exchange.

At the core of open innovation is the understanding that knowledge is widely distributed among various stakeholders in the business environment, and that firms can, and should, use these external stakeholders as well as their internal knowledge base (Laursen et al., 2006; Robertson et al., 2012). This new paradigm of innovation management has challenged the traditional 'closed' and 'vertical' modes of innovation, by suggesting that the increased mobility of skilled workers, and less control of unwanted spillovers to other firms, are shrinking firms' margins from investment on internal resources, such as R&D (Chesbrough, 2003). However, the crude distinction between firms which are or are not open has received criticism from scholars, who argue that thye extremely closed mode of innovation does not occur in reality (Trott & Hartmann, 2009). Instead, it is now widely accepted that different degrees of openness exist, and that firms can be placed on a continuum from closed to open innovators (Dahlander & Gann, 2010; Lazzarotti & Manzini, 2014). This thesis follows the same logic in investigating the extent to which firms' reliance on external stakeholders affects their innovative outputs.

Firms can generally employ three core processes of open innovation (Enkel et al., 2009; Gassmann & Enkel, 2004): enriching their internal knowledge base through exploration and acquisition of knowledge from external sources (outside-in); using external pathways to exploit abandoned ideas and unutilized internal knowledge (inside-out); and joint knowledge development and commercialization by collaborating with complementary innovation partners (coupled). Gassmann et al. (2004) further elaborate that while all these processes represent an open innovation strategy, they are not equally important for all firms and in all business contexts. For example, the outside-in process seems to be highly important for firms in low- and medium-tech industries that expect knowledge spillovers from their machinery suppliers and/or customers. By contrast, the inside-out process better suits large and/or research-driven firms, whose aim is to commercialize innovations before competitors. Similarly, Chesbrough and Crowther (2006) evidence that firms in mature industries focus on the outside-in dimension of open innovation in order to complement their internally developed knowledge. In light of these contributions, open innovation in this thesis centers on the outside-in and coupled processes, as these include (wholly or partly) the flow of knowledge 'into' a firm.

The outside-in dimension is often categorized into acquiring and sourcing practices according to whether they are pecuniary or not (Dahlander et al., 2010). Acquiring involves practices such as outsourcing R&D services and technology acquisition, through which a firm purchases knowledge (also in the form of embedded knowledge in technologies) and expertise from the market, such as from suppliers, universities and commercial research institutes. Sourcing, on the other hand, refers to monitoring the outside business environment and absorbing the available knowledge without exchange of money.

The coupled process requires firms to engage in a simultaneous 'give and take' of ideas and knowledge with external stakeholders, either via formal mechanisms such as strategic alliances or socially constructed relationships, such as informal networks (Faems et al., 2008; West et

al., 2014). Compared to the outside-in process, the collaborative arrangements used in the coupled process can provide access to complex and tacit knowledge that is not usually available through search mechanisms or market transactions (Spithoven et al., 2013). However, due to the increasing cost of being involved in such collaborative relationships, which can weaken the positive effect of open innovation on performance outcomes (Faems et al., 2010; Greco et al., 2016), a combination of outside-in and coupled processes seems to be an appropriate strategy for firms to optimize their external innovation sources.

2.7 Towards identifying the research field of open SOI

Sections 2.1 to 2.6 presented the theoretical concepts that underlie the research field of open SOI. To proceed with the development of the theoretical framework, this section seeks to identify the empirical evidence available from peer-reviewed publications that jointly focus on corporate sustainability, innovation and external stakeholders. This is accomplished through a systematic literature review focusing on current findings regarding the extent to/conditions under which stakeholder engagement is associated with innovative outputs.

2.7.1 Literature review process

The review process is based on a systematic literature review approach (Tranfield et al., 2003), which aims to provide a synthesized account of the literature by means of a transparent and reproducible process. To find the publications relevant to the research field of open SOI, a procedure was followed consisting of three main steps: (1) identifying articles from databases according to the search terms; (2) screening abstracts followed by a full-text analysis to ensure their eligibility; and (3) cross-referencing and additions from other sources (Moher et al., 2009). Figure 2 illustrates these steps and the number of publications found/omitted at each step.

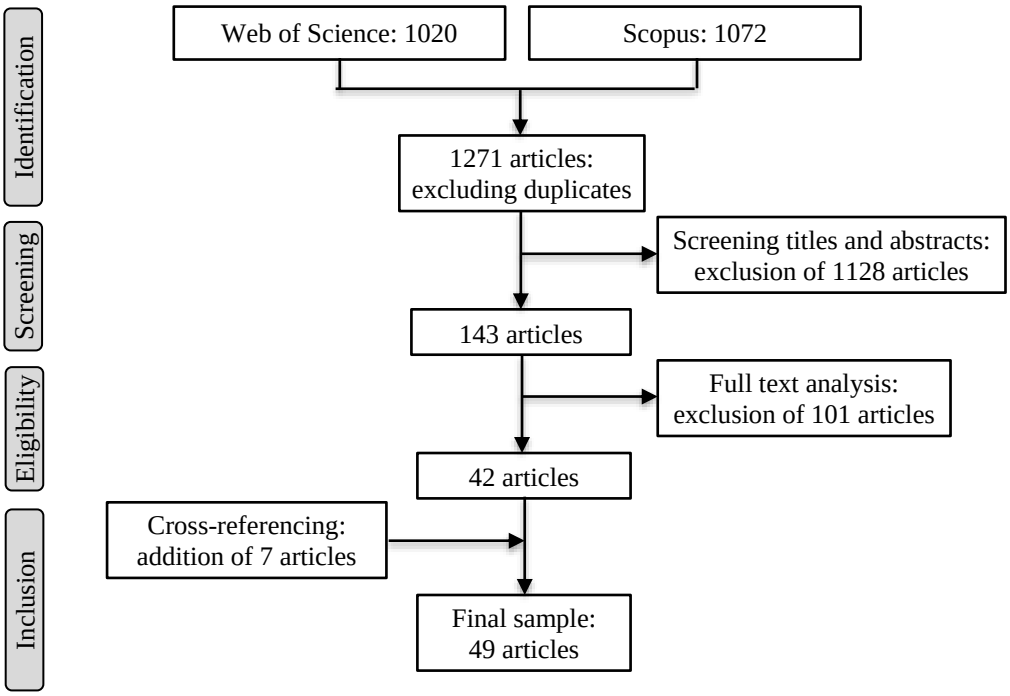

Figure 2: Flowchart of the literature review process

In the first step, several search strings were created by combining a variety of keywords related to the scope of the literature on open SOI and its three generic underlying concepts, i.e. corporate sustainability, external stakeholders and innovation (Table 3). The keywords were selected by consulting recent systematic literature reviews on the topic of SOI (Adams et al., 2016; Klewitz et al., 2014; Rauter et al., 2017; Watson et al., 2017) as well as several iterations between the search terms and results. In this step it was important to create a broad search strategy so that all relevant articles could be identified. Next, separate searches (with identical search strings) were conducted in Web of Science and Scopus, the two largest databases of peer-reviewed literature in social sciences. More specifically, a search was made for publications whose title, abstract or keywords contained at least one of the keywords from each of the three concepts (by using the Boolean operator AND). This process yielded 1020 and 1072 hits from the two databases respectively. After omitting the duplicates, this step returned 1271 unique articles.

Table 3: Search strings for the literature review

Concept	**Title, abstract, keywords include …**
Corporate sustainability	sustainab* OR environmental OR green OR CSR OR "corporate sustainab" OR eco?efficien* OR "circular economy" OR "social responsib*"
Innovation	innovat* OR "cleaner production" OR R&D OR "research and development"
Engaging external stakeholders	stakeholder* OR "external knowledge*" OR partner* OR "open innovation" OR "user innovation" OR collaborat* OR cooperat* OR co?creat*

In the second step, i.e. screening, the titles and abstracts of the publications were reviewed according to a set of inclusion and exclusion criteria, as presented in Table 4. The aim was to ensure that the final sample for review met all the requirements for relevance to the overall RQ of the thesis. In this regard, only empirical studies published after 1987 (when publication of the Brundtland report popularized the term ‘sustainable development’) were included. Moreover, although it was inevitable to include search terms such as green or social responsibility due to the varying terminologies used in the literature for referring to SOI or its subsets (see section 2.4), only studies that considered the economic and at least one of the environmental and social aspects of corporate sustainability qualified for the final sample. Accordingly, 143 articles remained at the end of the preliminary screening phase.

To check the eligibility of these publications, full-text analysis was conducted against the same set of inclusion and exclusion criteria, which returned 42 articles. The majority of omissions in this step were due to two main reasons. First, some articles, although referring to innovation in their titles, abstracts or keywords, used the term as a general concept, rather than providing any qualitative or quantitative measure of what it entailed. Second, on some occasions, the term sustainability was conceptualized exclusively in the sense of social and/or environmental issues, which did not meet the comprehensive view of corporate sustainability in this work. In the final step, the 42 shortlisted articles were cross-referenced with their references to find other

relevant publications, which resulted in seven additional articles. Therefore, the final sample comprised a total of 49 articles.

Table 4: Inclusion and exclusion criteria for identification of relevant papers

Criterion	Inclusion	Exclusion
Research type	Empirical	Conceptual studies, literature reviews, editorials
	Peer-reviewed published in scientific journals	Conference proceedings, book chapters, books, editorials
Language	English	Any other language
Time period	1987 to 2018 (May 31th)	Before 1987
Relevance	▪ Economic and environmental/social aspects of sustainability ▪ Open and sustainability-oriented innovation ▪ Includes measures of innovative outputs (products, processes, patents, etc.) ▪ Engages external stakeholders' knowledge for innovation ▪ Private sector	▪ Technical studies within environmental technologies (e.g. CO2 reduction) ▪ Exclusively considers environmental and/or social sustainability ▪ 'Environment' not used for the natural environment ▪ Generally refers to innovation ▪ Collaboration with stakeholders not relevant to this study (e.g. funding agencies) ▪ Engagement with internal stakeholders (e.g. employees) ▪ Stakeholders relationships with the aim of controlling their impact ▪ Non-private sectors (e.g. education system)

For the analysis phase, a data extraction form that included general (title, author, publication year and outlet) and specific information (research question, theoretical lens, empirical setting, open innovation processes, types of stakeholders, SOI measure, summary of findings) was used in order to facilitate the analyses. The results of the descriptive and thematic analyses for the final set of 49 articles will be presented in the following sections.

2.7.2 Descriptive account of the literature on open SOI

As expected, the literature on open SOI is spread over a broad range of publication outlets, research methods, empirical settings, stakeholder types and SOI outputs. Therefore, these items are used to provide a descriptive analysis of the literature on open SOI.

2.7.2.1 Journals and year of publication

In line with the recent reviews on the topic of SOI (Adams et al., 2016; Klewitz et al., 2014; Rauter et al., 2017; Watson et al., 2017), the reviewed articles are distributed widely across 21 journals. As shown in Figure 3, the *Journal of Cleaner Production* and *Business Strategy and the Environment* stand out as the top publishing journals for open SOI, accounting for more than 30% of publications. By applying Web of Science categories, it is not surprising that the majority of publishing journals on open SOI are situated in the subject area of *environmental science*. However, journals within the *management* subject area, especially *innovation*, such as

Industry and Innovation, *R&D Management* and *Research Policy* have also shown an increasing interest in publishing studies that apply open innovation to the context of corporate sustainability.

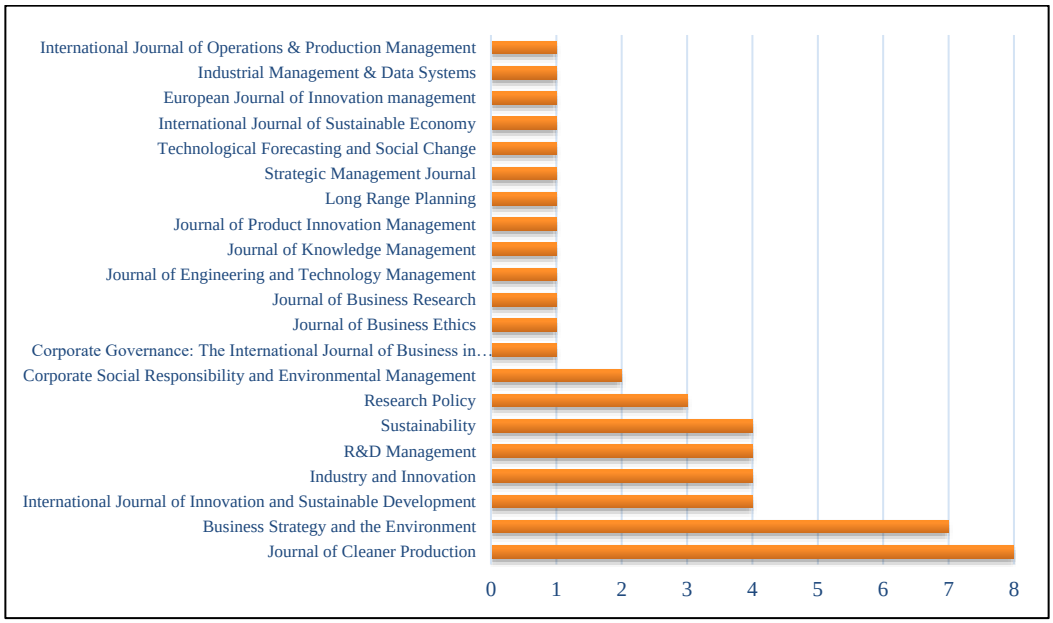

Figure 3: Publishing journals on open SOI

Although the beginning of the time period for the literature search was set to 1987 (marking the formal introduction of sustainable development), it took more than ten years until the first publication on the topic of open SOI appeared in *Strategic Management Journal*. Interestingly, this weak trend continued for another ten years, even after the popularization of open innovation and other theoretical underpinnings related to the use of external stakeholders' knowledge. Indeed, as shown in Figure 4, more than 85% of publications are from 2011 and onwards, with 36 articles in the last 5 years.

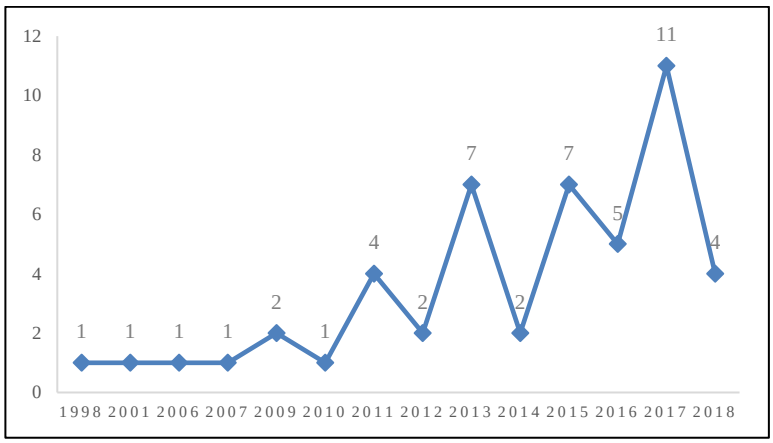

Figure 4: Distribution of publications on open SOI in the last 20 years

Although not very strong yet, which does in turn support the purpose of this thesis to contribute to the literature on open SOI, the trend observed in recent years shows the growing importance of stakeholder engagement in SOI in research and practice. This is also evident by delving

deeper into the publications in the first ten years (1998-2008), in which stakeholders' role in innovation processes was studied as a peripheral topic, usually in combination with other determinants of SOI, while in recent years it has become a central topic of investigation in the literature on open SOI.

2.7.2.2 Research methods and empirical focus

The second set of indicators used to offer a descriptive picture of the review articles are the research methods and empirical foci of the literature. Applying a qualitative vs. quantitative dichotomy, the latter approach dominates the literature on open SOI, in which the number of articles based on quantitative methods are almost double those that use qualitative ones (30 vs. 17). Among the reviewed articles, only two (Bocken, Farracho, et al., 2014; Sharma et al., 1998) use mixed methods, by collecting data through interviews and author-designed surveys. Figure 5 illustrates the distribution of reviewed articles according to their research methods.

More in-depth examination of the two main categories of quantitative and qualitative studies indicates that within the first group, scholars mostly rely on standard innovation or sustainability surveys, which are often designed for purposes other than examining SOI. In this regard, they draw on data from the Community Innovation Survey (CIS) at the European level, or its national versions, such as the Technological Innovation Panel (PITEC) in Spain and the Mannheim Innovation Panel (MIP) in Germany, and consequently measure the impact of reported innovative outputs on environmental and/or social sustainability. A caveat of this approach is that it assesses the sustainability-related effects of all the innovations a firm has developed or adopted, and thereby might overestimate SOI outputs. The same issue applies to general sustainability surveys such as the Dow Jones Sustainability Index (DJSI), which conceptualize SOI in terms of a firm's orientation towards conducting innovative practices and which consequently run the risk of being too subjective (Ayuso et al., 2011).

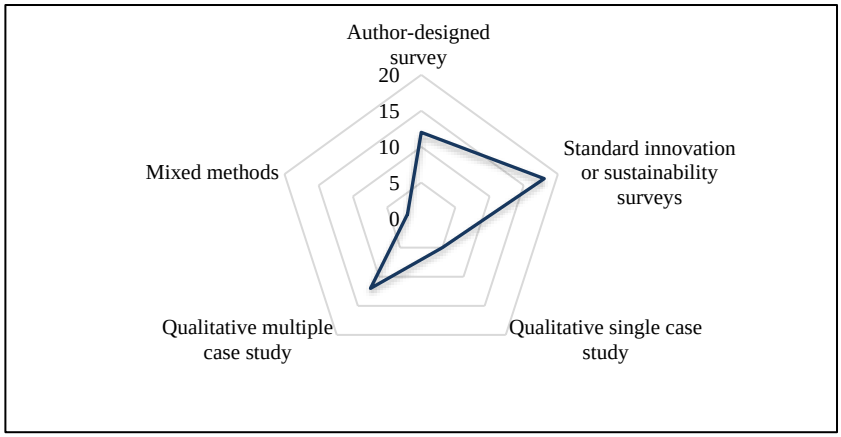

Figure 5: Frequency of research methods used in the reviewed articles

Investigating the empirical foci of the literature on open SOI indicates that similar to the scientific literature on innovation at large (Andersen et al., 2015), resource extractive industries are highly underrepresented compared to other sectors in the economy. As shown in Figure 6, only 6% of the articles (equivalent to three) in the sample opted to study firms in resource

extractive industries, namely oil and gas (Sharma et al., 1998), wine production (Muscio et al., 2017) and agricultural firms (Ingenbleek et al., 2016). On the other hand, almost 90% of the articles (exclusively or in combination with the services sector) include manufacturing firms across different sub-sectors.

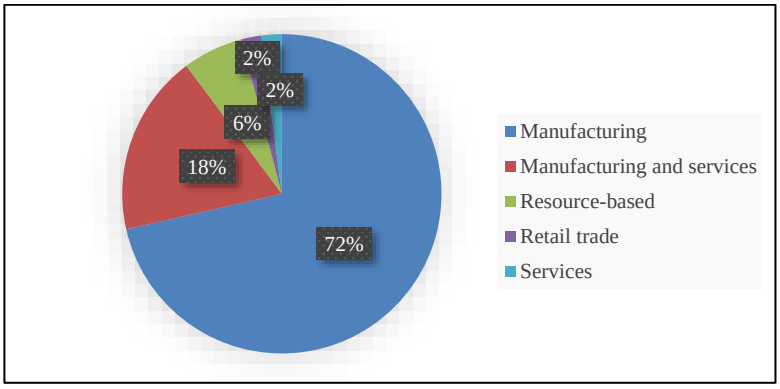

Figure 6: Distribution of reviewed articles according to their empirical foci

Resource extractive firms, due to their strong connection with sustainability issues (George et al., 2015; Sharma, 2005), can provide complementary insights into different aspects of stakeholder engagement in SOI. Moreover, as discussed in section 1.3, studies that build on data across various subsectors within manufacturing are likely to report erroneous results regarding the effect of external stakeholders' knowledge of SOI outputs, as this effect might be partly due to the sectorial variance in terms of regulations and market demand. However, if controlling for these variances, multisector studies allow for comparison between different industries and thereby contribute to the open SOI literature by demonstrating the need for customized policies and firm-level practices.

2.7.2.3 Groups of stakeholders and SOI outputs

Studies on the topic of open SOI deal primarily with value chain partners as stakeholders in firms' innovation outputs. As summarized in Figure 7, customers and suppliers attracted the highest attention in the reviewed articles, often in cases where scholars aimed to explore how cooperation with these stakeholders helps firms to overcome the difficulties regarding the development of product innovations with positive environmental and economic effects. There also exist studies that exclusively focus on suppliers or customers, which argue that their integration into SOI processes leads to better knowledge for addressing environmental sustainability.

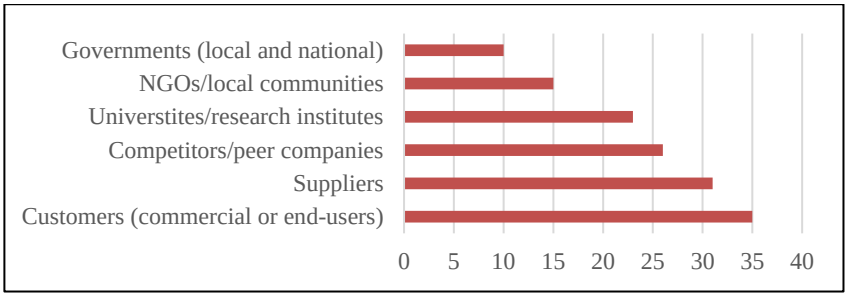

Figure 7: Main groups of stakeholders included in the reviewed articles

However, scholars have recently gone beyond the prevalent focus of the open SOI literature on value chain partners and taken into account secondary stakeholders such as NGOs and governmental authorities, sometimes as a sole stakeholder group, but typically in combination with customers/users. An important feature of these studies is their emphasis on the social aspect of sustainability in SOI, and the opportunity for firms to engage users and NGOs in innovation processes in order to understand their needs and expectations of an ultimate product/service. A handful of studies in the literature assume the relevance of a wider range of external stakeholders in SOI, and include both traditional value chain partners and secondary stakeholders in their research. Despite their fruitful results, a caveat still applies to this group of studies, as they restrict SOI to including innovations that address the environmental aspect of sustainability, which prevents this research field from engaging in a more systematic discussion of the possible effects of a diverse set of stakeholders on SOI outputs.

The last item that is considered for describing the reviewed articles is the type of innovation outputs addressed in them. As discussed in section 2.4, SOI encompasses product/service, process and organizational innovations (Klewitz et al., 2014), with all these types of innovation necessary for tackling corporate sustainability challenges (Adams et al., 2016). Figure 8 illustrates that 94% of the articles in the sample consider product and/or process innovations for assessing the effect of stakeholder engagement. Putting it negatively, the vast majority of publications on open SOI have ignored organizational innovations that involve using "new organizational methods in the firm's business practices, workplace organization or external relations" (OECD, 2005, p. 55), which can particularly affect social sustainability (Altuna et al., 2015; Mirvis et al., 2016). This shortcoming is due primarily to the difficulty of measuring this type of SOI, as capturing the social aspect of business practices, particularly with an innovative focus, is a complex challenge.

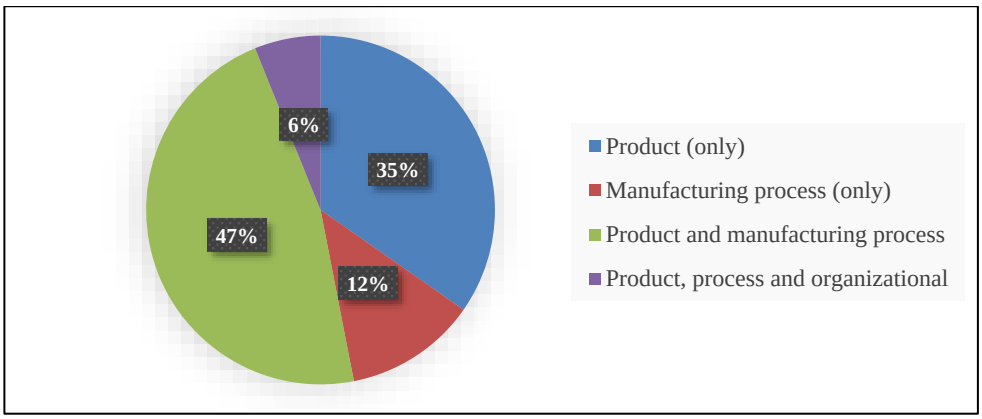

Figure 8: SOI outputs considered in the sample of reviewed articles

Considering the types of stakeholders and SOI in the literature, even the few studies that adopt a holistic approach to different innovation outputs are not comprehensive in terms of the various types of stakeholder that can contribute to these outputs. More specifically, among the three published works which take a holistic SOI approach, Jones et al. (2017) focus exclusively on universities, Rodriguez et al. (2017) augment this study by including suppliers, whereas Peng et al. (2016) adopt a multiple stakeholder approach, but still overlook NGOs and universities.

2.7.3 Thematic analysis and strands of literature on open SOI

In order to provide a state-of-the-art review of the literature on open SOI, a detailed thematic analysis was conducted by using the NVivo software package. In this regard, special attention was paid to the findings regarding the internal capabilities required for open SOI and open innovation processes. Table 5 presents an overview of the 49 articles reviewed, including a brief summary of their findings. Before discussing these particular findings, the main theoretical foundations of the literature will be introduced in the following section.

2.7.3.1 Theoretical foundations of the open SOI literature

The literature on open SOI has employed a variety of theories to argue for an association between stakeholder engagement practices and innovations that in one or another way target corporate sustainability objectives. Nonetheless, two theories, which are used separately or in combination, dominate the literature: 1) RBV and its extensions, i.e. NRBV and dynamic capabilities theory; and 2) stakeholder theory.

RBV is the most acknowledged and regularly used theory in the reviewed articles. According to this theory, a firm requires a unique collection of resources, including physical assets, human capital and organizational procedures, in order to pursue strategic options that can improve its efficiency and effectiveness (Wernerfelt, 1984). Moreover, Barney (1991) asserts that to provide firms with competitive advantage over time, resources should be valuable, rare and inimitable (or imperfectly imitable). Rodriguez et al. (2002) suggest that stakeholder engagement meets all the above conditions, as it enables 1) exploitation of opportunities/neutralizing threats by responding better to market and social demands (valuable); 2) the obtaining of a mixture of complementary knowledge that is not often possessed by a large number of competitors (rare); and 3) the building of relationships that are socially complex and path-dependent (inimitable).

Within the literature on open SOI, RBV has been mostly used to distinguish between environmental and non-environmental innovators based on their levels of efforts to access external stakeholders' knowledge (Cainelli et al., 2015; Dangelico et al., 2013; del Rio et al., 2015; Rodriguez et al., 2017). For example, Cainelli et al. (2015) highlight the key role of knowledge created outside a firm for developing environmental products and processes, considering the greater technological complexity of these innovations. Their results show that Spanish manufacturing firms with reported environmental innovation relied more (compared to general innovators) on knowledge obtained from value chain partners and universities, in the form of both knowledge created in networks, and embedded knowledge in technologies/patents. To investigate how knowledge resources unfold in SOI, Rodriguez et al. (2017) adopt a more advanced conceptualization of RBV, by arguing that knowledge resources (including internal and external ones) lead to such innovations through a two-stage process: they allow firms to develop process innovativeness capability, and this is further combined with knowledge gained via R&D cooperation to develop environmental innovations.

Table 5: Summary of the reviewed articles

Study	Main finding(s)*
Albort-Morant et al. (2018)	Firms' capabilities in transforming and exploiting external knowledge positively mediate the effect of acquisition and assimilation capabilities on green process and product innovation performance.
Altuna et al. (2015)	To adopt new products and services aimed at social sustainability, managers should demonstrate a significant capability in involving non-profit organizations as a source of ideas for new innovation projects.
Arcese et al. (2015)	Sustainability challenges in the food sector have urged firms to embrace a consumer-centric approach to innovation by using different open innovation tools to incorporate consumers' knowledge into innovation processes.
Arnold (2011)	Firms use a variety of open innovation methods, ranging from ideas contests to community development workshops, which could be differentiated according to their degree of interaction with external stakeholders. Engaging stakeholders through open innovation tools could also be perceived as a means of gaining legitimacy and improving corporate image.
Arnold (2017)	Mechanisms and tools to integrate external knowledge might have an influence on the innovation outcome and sustainability issues.
Ayuso et al. (2006)	Stakeholder dialogue and knowledge integration can be regarded as the capabilities necessary to capture stakeholder knowledge and transform it into innovative products, services, processes or strategies.
Ayuso et al. (2011)	Engaging with key stakeholders in firms has a positive impact on their innovation orientation towards sustainability. However, the impact disappears when controlling for the existence of knowledge management practices.
Behnam et al. (2018)	In product or service types of SOI, mainly the lead organization should possess/develop OI capabilities, while in product-service system development, key actors, not merely the lead organization, should build (collaboratively) the capabilities.
Bhupendra and Sangle (2018)	Among primary stakeholders, firms mainly collaborate with value chain partners to upgrade from pollution prevention activities to product stewardship.
Blum-Kusterer et al. (2001)	▪ Consumers are proven to be significant in determining eco-innovations. ▪ NGOs are found to be relatively insignificant for innovation.
Bocken, Farracho, et al. (2014)	SMEs engage (mostly) with customers and suppliers to generate novel ideas. Due to their limited budget, they have found creative ways, such as student placements, to generate ideas required in the front-end of innovation activities.
Bonte et al. (2013)	There is a positive relationship between using information sources and environmental innovations. However, neither cooperation nor external acquisition of technologies are associated with increasing innovations.
Bos-Brouwers (2010)	A general orientation towards SOI is observed, although not necessarily in a systemized way, and cooperation with various stakeholders ranging from value chain partners to knowledge institutions, peer companies and local governments.

Study	Main finding(s)*
Brunner et al. (2013)	▪ Mutual benefit and motivation are crucial for long-lasting and successful business-NGO partnerships. ▪ Business-NGO partnerships do not always originate from CSR issues but also through monetary benefit or the need to become sustainable.
Cainelli et al. (2012)	Environmental innovations are stimulated by firms' interaction with universities and business suppliers, but not with customers and competing firms.
Cainelli et al. (2015)	Green innovators fuel their innovation efforts through inter-organizational relationships more intensively than other innovators, considering both the co-development of innovation through networking (external resources) and the acquisition of externally developed resources (hybrid resources).
Chen and Hung (2014)	Structural and cognitive capital lead to relational capital, which in turn increases green innovation performance.
Dangelico et al. (2013)	Collaboration and acquisition of know-how do not play a significant role in integrating environmental issues into manufacturing processes, whereas external sourcing does. By contrast, collaboration and acquisition significantly affect the integration of environmental issues at the product level, while external knowledge sourcing is less relevant for this output.
Dangelico et al. (2017)	External knowledge sourcing has a positive and significant effect on green innovation capability, showing that firms (in addition to investing in environmental R&D or enhancing cross-functional collaboration) need to explore new environmental knowledge and competencies from outside.
De Marchi (2012)	▪ R&D collaboration is more important for environmental innovations than other innovations. ▪ Some categories of collaborators are more effective for EIs, particularly suppliers and universities, whereas the user effect does not vary between environmental innovations and other innovations.
De Marchi and Grandinetti (2013)	Highly green innovators (whose innovative activities have resulted in several environmental benefits) interact the most with external organizations, especially with universities and research centers.
del Rio et al. (2015)	Environmental innovators, compared to non-environmental ones, have a higher tendency to combine internal and external knowledge sources for their innovation activities.
Doluca et al. (2018)	▪ Environmentally neutral stakeholders are the most important collaboration partners for family and non-family firms. ▪ Family firms are more stable and less volatile regarding their collaboration with stakeholders (of different degrees of environmental concerns). The two categories show equal levels of SOI performance.
Du et al. (2016)	Using social media tools in gathering technical information amplifies the positive effect of sustainability orientation and customer focus on NPD, whereas these moderation effects do not hold for market information.
Fliaster et al. (2017)	Secondary stakeholders such as opinion leaders in local communities play a significant role in radical SOI as they can establish new supporting relationships, introduce the innovator to a new business environment, and create a new ecosystem.

Study	Main finding(s)*
Frey et al. (2013)	Knowledge networks are able to considerably spur and prompt SMEs' efforts and commitments towards innovation, both by increasing their knowledge and awareness, and by providing specialized support for developing innovation capability.
Galliano et al. (2015)	The influence of firms' spatial environment on eco-innovation intensity varies according to the sector. Sectors dominated by SMEs benefit mostly from external relationships with other firms in the same value chains (customers and/or suppliers) and with institutional stakeholders such as universities.
Ghisetti et al. (2015)	Increasing the intensity of external knowledge sourcing (to whatever extent) is beneficial for environmental innovations, but broadening the scope of sourcing can become difficult to manage after a certain point, and might even discourage firms from adopting an environmental innovation. Going beyond a binary view (environmental innovation or not), and extending the portfolio of environmental innovations benefits from both broad and intensive external knowledge sourcing.
Goodman et al. (2017)	▪ Stakeholders might play eight different roles in SOI processes: as stimulator, initiator, broker/mediator, concept refiner, legitimator, educator, context enabler and impact extender. ▪ Secondary stakeholders can be highly proactive in stimulator and initiator roles.
Hansen et al. (2011)	By crossing the market and environmental impacts of submitted solutions from user communities, the authors develop an eco-impact-innovativeness grid in which the majority of submissions fall into the incremental and radical conventional cells. Although the radical category can have a high market impact resulting in substantially better economic performance, both of these categories are perceived as having low impacts on environmental sustainability.
Holmes et al. (2009)	Firms with a narrow engagement scope aim to exploit the skills and resources of NGOs, while those with a broad or an undefined engagement scope are more exploratory and use the collaboration to search for new innovation opportunities.
Horbach et al. (2013)	In France, universities, consultants and conferences are more important for eco-innovators than for other innovators. In Germany, a similar picture can only be observed when the social aspect of innovations is excluded from the analytical model.
Ingenbleek et al. (2016)	CSR-related absorptive capacity is a critical factor that explains the relationship between firms' embeddedness in secondary stakeholder networks and innovation.
Jones et al. (2017)	Only knowledge accessed via human resource transfer (e.g. employment of new graduates) has a significant positive influence on innovativeness, which in turn positively relates to firm performance.
Kazadi et al. (2016)	Before an SOI project starts, firms require capabilities for stakeholder networking and stakeholder competence mapping. In an ongoing project, important capabilities are stakeholder relationship management and stakeholder knowledge management.
Kennedy et al. (2017)	The authors observe the advantages of technology super-scouting, which entails monitoring the outside environment to find new/potential uses for a SOI. In addition, continuous dialogue with customers and peer companies enables the firm to evaluate its solutions at an early stage, which critically reduces the risk and uncertainty of innovations.
Ketata et al. (2015)	Both broadening the scope of external knowledge sourcing activities and increasing their intensity are important for SOI.

Study	Main finding(s)*
Laperche and Picard (2013)	R&D collaborations are an important means of harnessing the complexity of environmental service innovations. These collaborations are characterized by a certain degree of organizational flexibility, proactivity of the focal firm to shape networks of partners, and the increasing number of partners during the innovative projects.
Mothe and Nguyen-Thi (2017)	Persistent efforts in external knowledge acquisition are associated with a firm's propensity to introduce environmental innovations.
Muscio et al. (2017)	Broadening the scope of knowledge sourcing and increasing its intensity are curvilinearly related to propensity of developing eco-innovative products. Such a relationship does not hold true for process innovation.
Peng et al. (2016)	Managerial risk awareness negatively moderates the effect of knowledge acquired from local governments and business networks on eco-management and eco-product innovations. Managerial cost-benefit awareness negatively moderates the effect of knowledge acquired from business networks on eco-management innovation, but positively moderate its effect on eco-process innovation.
Rodriguez et al. (2017)	Environmental innovativeness capability is the result of a two-sequence process. First, internal and external R&D, acquisition of machinery, software, patents and licenses, and R&D cooperation with suppliers are deployed into process innovativeness capability. Then, this capability is extended and bundled with the knowledge brought in by R&D cooperation with public research institutions to develop environmental innovativeness capability.
Segarra-Ona et al. (2017)	Collaboration with competitors, customers and external consultants is significant for the social orientation of innovations, while suppliers' knowledge is not considered important for this purpose.
Sharma et al. (1998)	The unique organizational capabilities resulting from proactive environmental strategies (including stakeholder engagement capability) account for more than half of the firms' variance in competitive advantage (including innovation).
Wagner (2007)	▪ In addition to cooperating with predominantly environmentally concerned stakeholders, avoiding excessive cooperation with environmentally neutral stakeholders is also important to enable environmental product innovation. ▪ Cooperation with environmentally concerned and environmentally neutral stakeholders does not affect environmental patents.
Wagner (2009)	User integration and cooperation with fringe stakeholders positively affect radical SOI.
Wagner (2011)	Cooperation with fringe stakeholders has an effect on process innovations as well as on the level of the novelty of innovation.
Yang and Park (2016)	Diverse sources of external knowledge, although having positive main effects on innovation outcomes, negatively moderate the relationship between a firm's intended environmental sustainability and its actual achievement of SOI.
Zimmerling et al. (2017)	By involving users in SOI, firms do not only tap the knowledge of users' needs, but also the solution knowledge that provides the basis for new product functionalities or service components.
* For papers that study other aspects of SOI, only the findings relevant to this thesis (external stakeholders' engagement in SOI) are presented.	

Moreover, theories such as NRBV and dynamic capabilities, which have their foundations in RBV, have also found their way into the research on open SOI. The former theoretical framework drew management scholars' attention to the limitations as well as the possibilities that lie in the natural environment, which is ignored in RBV (Hart, 1995). By emphasizing the increasing importance of environmental and social issues in gaining competitive advantage, this theory implies that key resources such as stakeholder integration enable firms to integrate these issues in developing sustainable products and processes (Hart, 1995; Hart et al., 2011).

In one of the first attempts to test this assumption of NRBV, Sharma et al. (1998) found that joint problem solving and information sharing with secondary stakeholders in the Canadian oil and gas industry was a key determinant of a set of firm-level outputs, including product and process innovations. However, in industries such as telecommunications, which are not generally associated with direct impacts on the natural environment, firms rely on the knowledge exchanged within their value chain to develop SOI, while also highlighting their achievements through various media channels to build a positive reputation (Bhupendra et al., 2018). Therefore, NRBV assumptions should be considered with caution in different industry contexts which have various degrees of impact on the natural environment; this relates to the extent firms' competitive advantage is dependent on capabilities emerging from positive relationships with the natural environment.

The dynamic capability theory, as the second extension of RBV, holds that in addition to their endowed resources, firms need to "renew their competences so as to achieve congruence with the changing business environment" (Teece et al., 1997, p. 515). In this regard, changes in technologies, regulative frameworks and societal needs, as features of sustainability contexts, require continuous reconfiguration of internal and external resources and competencies (Amui et al., 2017; Aragón-Correa et al., 2008). The reviewed articles that build on this theory evidence the existence of certain organizational processes as the microfoundations of dynamic capabilities (Teece, 2007), including internally focused (Behnam et al., 2018; Kazadi et al., 2016), externally focused (Kennedy et al., 2017; Ketata et al., 2015) and a combination of internally and externally focused processes (Ayuso et al., 2006; Dangelico et al., 2017).

As for internal processes, establishing shared visions and intra-organizational communication to integrate the externally acquired knowledge is of utmost important for SOI (Dangelico et al., 2017; Kazadi et al., 2016). Concerning external processes, Kennedy et al. (2017) reveal that building trust-based relationships to secure a continuous dialogue with external stakeholders, particularly in the early stages of product/process development, can reduce the risk of failure in addressing social and environmental issues. Despite the valuable contributions of these recent studies, the full spectrum of capabilities and their microfoundations that enable firms to identify, understand, integrate and exploit external knowledge are yet to be examined.

Alongside RBV and its extensions, stakeholder theory is the other theoretical underpinning that is relatively prevalent in the open SOI literature. Studies in this research stream have mainly focused on exploring how stakeholders with different attributes, including primary and secondary stakeholders (Ayuso et al., 2011; Du et al., 2016; Goodman et al., 2017), or those showing different degrees of environmental/social concerns (Segarra-Ona et al., 2017; Wagner,

2007), affect SOI outputs. Common to both categories is the evidence that not only do traditional stakeholders such as customers and suppliers, but also stakeholders such as NGOs and local communities, possess knowledge and ideas that might affect SOI, either directly (Goodman et al., 2017) or indirectly through general innovation capabilities (Segarra-Ona et al., 2017). Nonetheless, Wagner (2007) suggests that firm managers should adjust their engagement practices according to different types of stakeholders by considering that too much cooperation with those who are not primarily concerned about environmental issues might impede SOI activities.

Application of stakeholder theory is nonetheless limited in the open SOI literature, as most publications emphasize the attributes of stakeholders, which leaves the 'attributes of stakeholder relationships' an understudied area. According to stakeholder theorists, stakeholder engagement can be generally categorized into transactional and relational engagements by considering the reciprocity level of relationships between a focal firm and its stakeholders (Hillman et al., 2001; Jones, 1995). Transactional or one-way interaction implies learning about the needs and expectations of stakeholders without their direct involvement in the knowledge creation process (Herremans et al., 2016), whereas relational or two-way interaction entails knowledge exchange processes between a firm and its stakeholders (Onkila, 2011). Considering that the original conception of stakeholder theory lies in relationships with stakeholders as the unit of analysis (Hörisch et al., 2014), future research should investigate how transactional and relational attributes affect SOI.

2.7.3.2 Internal capabilities required for open SOI

As discussed in section 2.2, although open innovation moves the locus of innovation outside organizational boundaries, it does not by any means dispel the need for internal capabilities required to utilize the externally acquired knowledge. As such, the literature on open SOI has so far investigated a wide variety of internal capabilities and their role in enabling firms to achieve different types of SOI. However, the findings are sparse and fragmented, which makes it too difficult (if not impossible) to understand how these capabilities should be combined in different stages of open innovation, from obtaining external knowledge to making use of it. To fill this gap, this section builds on the theory of absorptive capacity and its three dimensions of recognition, assimilation and exploitation capabilities in order to synthesize the findings from the literature. Table 6 maps these findings, based on the three aforementioned capabilities and their microfoundations.

According to Lane et al. (2006) and Todorova and Durisin (2007), recognition capability enables a firm to identify and understand external knowledge resources. In the second step, assimilation provides the ability to integrate external and internal knowledge, which could result in only a slight change, or in an entire transformation, of a firm's existing knowledge base. Finally, firms should be able to exploit the new knowledge by applying it to their daily operations in order to develop innovations. All in all, recognition, assimilation and exploitation capabilities allow a firm to convert external knowledge into innovative outputs.

Table 6: Insights from the reviewed articles regarding internal capabilities

Capability dimension	Identified microfoundations	Key references
Recognition	Internal R&D	De Marchi (2012); del Rio et al. (2015); Frey et al. (2013); Galliano et al. (2015); Horbach et al. (2013); Ketata et al. (2015); Mothe et al. (2017); Muscio et al. (2017); Rodriguez et al. (2017)
	Competence mapping capability	Behnam et al. (2018); Kazadi et al. (2016)
	Employee training	Bos-Brouwers (2010); Cainelli et al. (2015); De Marchi et al. (2013); Ketata et al. (2015)
	Managerial social and environmental awareness	Ingenbleek et al. (2016); Peng et al. (2016)
Assimilation	Flexible structure and open culture	Ayuso et al. (2006)
	Knowledge management	Ayuso et al. (2011); Kazadi et al. (2016)
	Cross-functional coordination	Dangelico et al. (2017); Ghisetti et al. (2015); Laperche et al. (2013)
	Boundary-spanning	Holmes et al. (2009)
Exploitation	Stakeholder relationship management	Behnam et al. (2018); Kazadi et al. (2016)

The sampled articles reveal various resources, routines and processes that underlie the recognition capability for SOI, including R&D (De Marchi, 2012; Horbach et al., 2013), competence mapping (Behnam et al., 2018; Kazadi et al., 2016), employee training (Cainelli et al., 2015; Ketata et al., 2015) and managerial social/environmental awareness (Ingenbleek et al., 2016; Peng et al., 2016). Among these, the majority of articles consider internal R&D processes as the most prominent component of firms' prior knowledge required for identifying and understanding external knowledge. The technological complexity of SOI, particularly the more radical innovations such as cleaner production technologies, make R&D a more important resource for these innovations than general innovations (Galliano et al., 2015). Others, such as Ghisetti et al. (2015) and Mothe et al. (2017), took a step further and found a moderating role for R&D in the relationship between external knowledge acquisition and innovative outputs, hence claiming that higher degrees of technological knowledge emerging from R&D can reinforce the positive effect that openness has on SOI.

A relatively smaller part of the literature that deals with recognition capability has extended the limited R&D-based view to absorptive capacity and found support for the necessity of other types of organizational routines for improving firms' knowledge base. In this regard, employee training allows smaller firms to compensate for their lack of formal R&D knowledge by updating their personnel on changes in environmental, social and market areas, alongside more general technological knowledge (Bos-Brouwers, 2010). Besides educating employees, the way managers interpret environmental and social issues can have a significant influence on their engagement with external stakeholders. Thus, managers' response to these issues in the form

of directing firms' activities towards innovation in products and processes is predicted by their awareness and understanding of social responsibilities (Ingenbleek et al., 2016) and environmental protection (Peng et al., 2016). Increasing environmental and social awareness among managers can also help their respective firms to establish stakeholder relationships that are based on mutual understanding and common language (Eccles et al., 2014), as crucial components of competitive advantage in corporate sustainability contexts.

Next to recognition capability, the review also highlighted the existence of various microfoundations for assimilation capability. Although it is widely agreed in the literature that intra-organizational relationships support the integration of external and internal knowledge, researchers suggest different processes and routines to augment such relationships, which can be differentiated in terms of their formality. The first group includes formal organizational processes such as knowledge management (Ayuso et al., 2011; Kazadi et al., 2016) and cross-functional coordination (Dangelico et al., 2017; Ghisetti et al., 2015; Laperche et al., 2013), whereas the second considers informal processes such as boundary spanning (Holmes et al., 2009) and nurturing open culture (Ayuso et al., 2006).

For example, Dangelico et al. (2017) highlight that facilitating collaborations between specialized environmental units and functional departments (e.g. R&D and marketing), as well as within the functions will increase the probability of designing products that address environmental and economic sustainability. Instead, in the case of firm-NGO collaborations, boundary-spanners act as conduits of knowledge in an informal way, as they explore external opportunities and 'travel around' different functional departments to exchange ideas and solutions (Holmes et al., 2009). It is important to note the fact that formal and informal mechanisms of integration do not work in all firms and in all situations, hence factors such as levels of hierarchy and trust should be taken into account in choosing the most appropriate process for assimilation capability. However, jointly pursuing formal and informal processes, for example knowledge management and nurturing open culture, seems to be an appropriate strategy, but has yet to be examined in the literature.

The final capability, exploitation, has received minimal attention from researchers in the field of open SOI. As shown in Table 6, only two studies have recently investigated stakeholder relationship management as a microfoundation for the capability of utilizing external knowledge in SOI. Both studies base their empirical setting at the project level and argue that in an ongoing SOI project, a firm should be able to retain its relationships with external stakeholders in such a way that secures the exchange of knowledge until the desired project outcome is achieved (Behnam et al., 2018; Kazadi et al., 2016). As more tensions could arise (particularly between firms and secondary stakeholders such as NGOs) in the later stages of innovation projects, when firms aim to apply the integrated knowledge into the development of tangible outputs, trust and commitment to shared goals play a key role in the ultimate success of innovations (Behnam et al., 2018). Considering the restricted scope of SOI and corporate sustainability in specific projects, broader firm-level studies are needed to provide a more complete understanding of other microfoundations of exploitation capability.

2.7.3.3 Open innovation processes

It would be expected that all three processes of outside-in, inside-out and coupled open innovation are investigated in the literature on open SOI. However, among the reviewed articles, none reflects on the inside-out process, which is nonetheless in line with the focus of this thesis on outside-in and coupled processes. Therefore, in this section, the findings from the literature are discussed in general according to these processes and the different types of stakeholders included in each one. In between the main processes of outside-in and coupled open innovation, a small strand of research has focused exclusively on open innovation tools (methods) to explore how these processes are implemented in a more practical way. The three papers on the latter topic will be discussed first.

Among the three aforementioned studies, the research conducted by Arnold (2017) highlights that SOI can particularly benefit from four types of open innovation tools: innovation workshops, sustainability-related web communities, ideas contests and dialogue. She defines these tools as enablers of collaboration between a firm and its external stakeholders, particularly customers, NGOs and society at large. In her view, special attention should be paid to the level of interaction in these open innovation tools, which can consequently influence external knowledge transfer and learning abilities from this knowledge (Arnold, 2011). For example, workshops and web communities allow firms to interact intensively with external stakeholders and to have access to their tacit knowledge about environmental and social issues. Accordingly, Hansen et al. (2011) focus exclusively on ideas contests as an open innovation tool with a medium level of interaction, in order to examine its suitability for generating SOI. In this regard, they develop a matrix crossing market and environmental impacts of innovations, in which the most advanced SOIs are placed in the upper right-hand cell. However, their findings do not show a great contribution from such contests for SOI, especially concerning the environmental impacts of innovations.

Concerning outside-in open innovation, the widespread belief in the literature on open SOI is that both external knowledge sourcing and the acquisition of knowledge embedded in technologies/R&D services are beneficial for the propensity of firms to achieve SOI outputs (Cainelli et al., 2015; Frey et al., 2013; Ketata et al., 2015; Rodriguez et al., 2017). Nonetheless, while firms should be able to source/acquire knowledge from a diverse range of external stakeholders, some studies have not found supporting evidence for the positive contribution of certain specific stakeholders, such as suppliers (Segarra-Ona et al., 2017), customers (De Marchi, 2012) and research organizations (Bonte et al., 2013). Such contradictory results can be explained by the various ways SOI is operationalized, as well as the variance in terms of empirical settings. To illustrate this point, Segarra-Ona et al. (2017) measure SOI as an innovation capability that emerges from general innovations in products and processes. Thus, although suppliers' knowledge about products and processes is shown to be significant for general innovations, it does not directly exert any effect on SOI.

Based on these contradictory results, scholars have recently started to build a contingent link between external knowledge sourcing and SOI. In one of these studies, Mothe et al. (2017) assert that although sporadic sourcing activities may result in SOI outputs, firms that

persistently utilize external knowledge in their innovation are in a relatively better position to devise innovative outputs. Indeed, by conducting external knowledge sourcing over time, firms also develop a set of processes and routines (a capability) to diversify their channels of access to external knowledge. Other studies, such as those of Ghisetti et al. (2015) and Muscio et al. (2017), turn our attention to the deteriorating effect of excessive external knowledge sourcing on SOI, since too many external activities limit a firm's resources required for the subsequent stages of knowledge assimilation and exploitation. Thus, instead of a straightforward relationship between outside-in open innovation and SOI, firms should be aware of the limits for and conditional effects of their reliance on external knowledge.

In contrast to outside-in open innovation, which is usually shown to comprise multiple types of stakeholders, the coupled process has been mostly conceptualized as restricted collaboration with specific stakeholder groups, mainly value chain partners and universities (Bonte et al., 2013; Laperche et al., 2013) and NGOs/local communities (Holmes et al., 2009; Wagner, 2009, 2011). The point of departure of these studies is that knowledge in the context of corporate sustainability is not only distributed (hence requires open innovation in general), but is also complex and embedded in socially complex relationships and thereby can be effectively exchanged via two-way interactions between a focal firm and its stakeholders.

2.7.4 Recap of the literature review and the research purposes of this thesis

The above thematic analysis has highlighted a set of imperatives for further research on open SOI, which will be addressed in this thesis. As proposed by the overall RQ and the theoretical background, the study is specifically interested in developing knowledge on the associations between external stakeholders, SOI outputs and financial performance, as well as on the conditions under which these associations can be evidenced. Accordingly, the research gaps identified through the systematic literature review lay the basis for building the theoretical framework (Figure 9), which relates the proposed RQs in the appended papers.

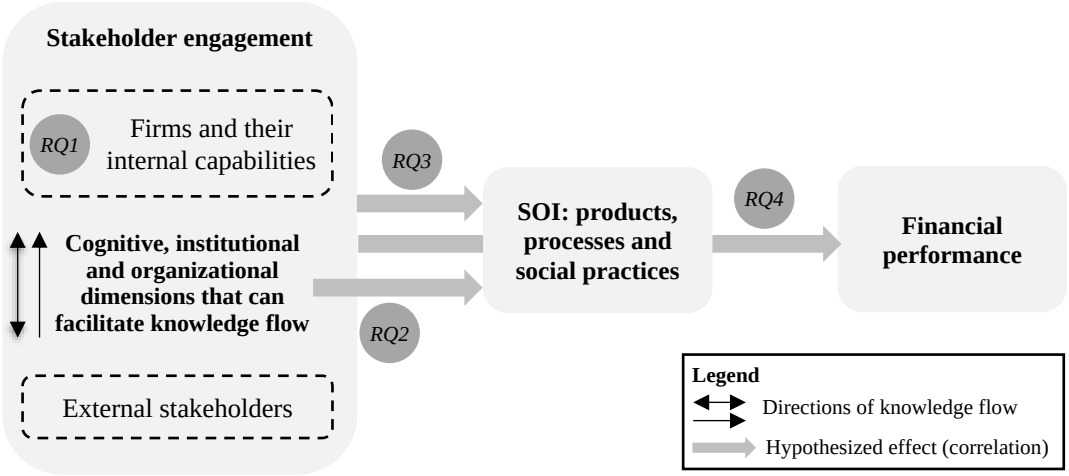

Figure 9: Theoretical framework

First, the review showed the dearth of holistic views on internal capabilities for open SOI, which results in fragmented findings in the literature (see Table 6). This is reflected in the restriction of these capabilities either to a specific step in the process of turning external knowledge into

innovations, or to particular types of external stakeholder such as NGOs. Therefore, paper 1 in this thesis employs an integrative theoretical approach to capability building in open innovation contexts, namely absorptive capacity, and seeks to answer the question (RQ1), "What are the capabilities, and their underlying skills and routines, that build the absorptive capacity required for SOI in the minerals industry?" This theoretical underpinning will then enable us to explore the underlying skills and routines that form a firm's capability in the sequential processes of recognizing, assimilating and exploiting external stakeholders' knowledge for pursuing SOI.

Second, previous research has primarily sought to examine internal and/or external components of open SOI (i.e. capabilities and open innovation processes), which consequently leaves the inter-organizational component understudied. This research gap is particularly relevant to the phenomenon of open SOI, as the flow of knowledge between a firm and its external stakeholders is more likely to be hampered due to the 'distant' knowledge bases and sustainability objectives. In this regard, the theoretical advancements in the literature on proximity dimensions offer promising avenues for research on SOI by describing how cognitive, institutional and organizational distances in firm-stakeholder relationships can be overcome to unfold innovative results, particularly in peripheral economic regions that also lack the advantage of local knowledge spillovers. Accordingly, paper 2 aims to answer the second RQ of the thesis (RQ2), which asks: "What proximity dimensions, i.e., institutional, cognitive and organizational proximities, or any combinations of them, explain the SOI outputs of companies in the minerals industry?"

Third, the thematic analysis showed that existing findings regarding the contribution of different open innovation processes to SOI outputs are far from conclusive. Hence, RQ3 asks: "To what extent does stakeholder engagement affect a firm's SOI outputs?" The answer to this question is pursued in paper 3, which draws on stakeholder theory and formulates outside-in and coupled processes of open innovation as transactional and relational attributes of stakeholder engagement in SOI, and thereby provides a clearer theoretical explanation for why we should expect a link between open innovation and SOI outputs. Paper 3 also deals with another gap in the open SOI literature, which is the scarcity of insights into whether stakeholder engagement and SOI are conducive to financial performance. Among the reviewed papers, only one study (Jones et al., 2017) has conducted empirical examination of such associations, which is nonetheless confined to only universities as external stakeholders. More specifically, the final RQ of this thesis (RQ4) is informed by NRBV, proposing SOI outputs as a critical factor in obtaining financial benefits by practicing corporate sustainability (reflected in engaging stakeholders). This question therefore asks: "To what extent do SOI outputs mediate the association between stakeholder engagement and financial performance?"

In addition, the descriptive analysis of the open SOI literature revealed the limitations regarding the types of stakeholders and SOI outputs in the reviewed articles, as well as the need for single-industry focus to rule out the effect of multisector variances. Therefore, in answering the overall question and sub-questions of this thesis, data from the minerals industry is drawn on to explore the association between engaging a multiplicity of stakeholders and various types of SOI outputs.

3 Research design and methods

This chapter describes the philosophical and methodological approach of the thesis. In doing so, it discusses the way its stance on the ontology and epistemology of the phenomenon under study is applied in practice to inform the research design. Second, a detailed description of the methods used for the data collection and analysis is provided. The variety of techniques used to ensure the validity and reliability of the research instruments are also briefly described.

3.1 Reflections on philosophical paradigms

It is widely accepted that philosophical paradigms lie on a spectrum from positivist to interpretivist approaches. According to positivist ontology, a social phenomenon exists "out there" and can be directly measured, while interpretivism underlines the complexity of social phenomena and aims at gaining interpretive understanding of the multiple realities regarding a single phenomenon (Payne & Payne, 2004). Considering, for example, innovation, a positivist researcher is likely to use purely objective measurements such as patents or investments (e.g. in R&D) to gauge innovative outputs. In contrast, an interpretivist one portrays innovations in the way they are understood by the respective firms and relies on managers' and other stakeholders' interpretations of what innovation entails.

Such an ontological disposition resonates directly with the dominant epistemological views in these two paradigms. As argued by Guba (1990), positivism asserts that it is both "possible and essential" for researchers to remain distant from the phenomenon under investigation in order to eliminate bias from the outcomes. On the other hand, the interaction between researchers and social phenomena is at the heart of interpretivism, as it is the only means of unlocking the perceptions held by social actors about a phenomenon.

While these two paradigms are regarded as extremes concerning their ontological and epistemological views, the paradigm of critical realism is placed in between. Critical realism is close to the positivist view of the objective nature of social phenomena (meaning reality exists), but acknowledges that our knowledge about these phenomena is incomplete and cannot be generalized to every context (Sayer, 1992). Putting it differently, critical realism goes beyond the positivist epistemology regarding the limitation of our knowledge of observable events, hence highlights that we can also know about unobservable entities underlying a phenomenon (Payne et al., 2004). Consequently, the difficulty in establishing the truth of unobservable entities makes our knowledge fallible in the realist school of thought. For example, authors such as Zollo and Winter (2002) assert that while organizational capabilities are not per se observable entities, research can draw on the processes and routines underlying such capabilities to elucidate capability generation over time.

This thesis follows the philosophical assumptions in critical realism due to its strong emphasis on explaining the underlying mechanisms and structures behind social phenomena, rather than uncovering general laws. As stated by Bechara and Ven (2007, p. 61), critical realism maintains "a mind independent, stratified reality consisting of underlying structures and mechanisms that determine how things come to behave". The view held in this thesis is that firms' practices

regarding SOI comprise a set of entities, structures and mechanisms that generate specific innovative outputs. These structures and mechanisms include, but are not limited to, combinations of physical (e.g. minerals, technologies), social (e.g. employees, their interactions) and organizational (e.g. relationships with external stakeholders) entities.

However, considering the complexity of SOI and the varying causal power of these mechanisms in various situations, the aim of this thesis is not to predict innovative or economic results, but instead to explain under what conditions and how such results come about (Sayer, 2000). Indeed, while the complexity of SOI and its underlying mechanisms (as the reality) hinder us from gaining a perfect understanding of what causes (and results from) SOI, the explanatory knowledge created in the thesis is the result of continuous cross referencing between the theories and empirical data. This is achieved by employing an abductive research design to explain the different internal (firm capabilities), external (transactional and relational attributes of firms' engagement with their stakeholders) and inter-organizational (the extent of firms' proximity to their stakeholders) mechanisms underlying SOI. The following section describes how such an abductive approach is implemented in the appended papers.

3.2 Research design

The purpose of making philosophical assumptions is to facilitate the move towards choosing the appropriate method(s) for data collection and analysis, or, as Saunders et al. (2009) put it, to "peel away" the outer layers of the research onion in designing the research process. Figure 10 illustrates how the different elements of research design in this thesis are mapped according to the research onion model. In what follows in this section, the choices of reasoning approach, research strategies, methodology and data collection techniques are discussed, considering critical realism as the adopted philosophical paradigm (the outermost layer of the research onion).

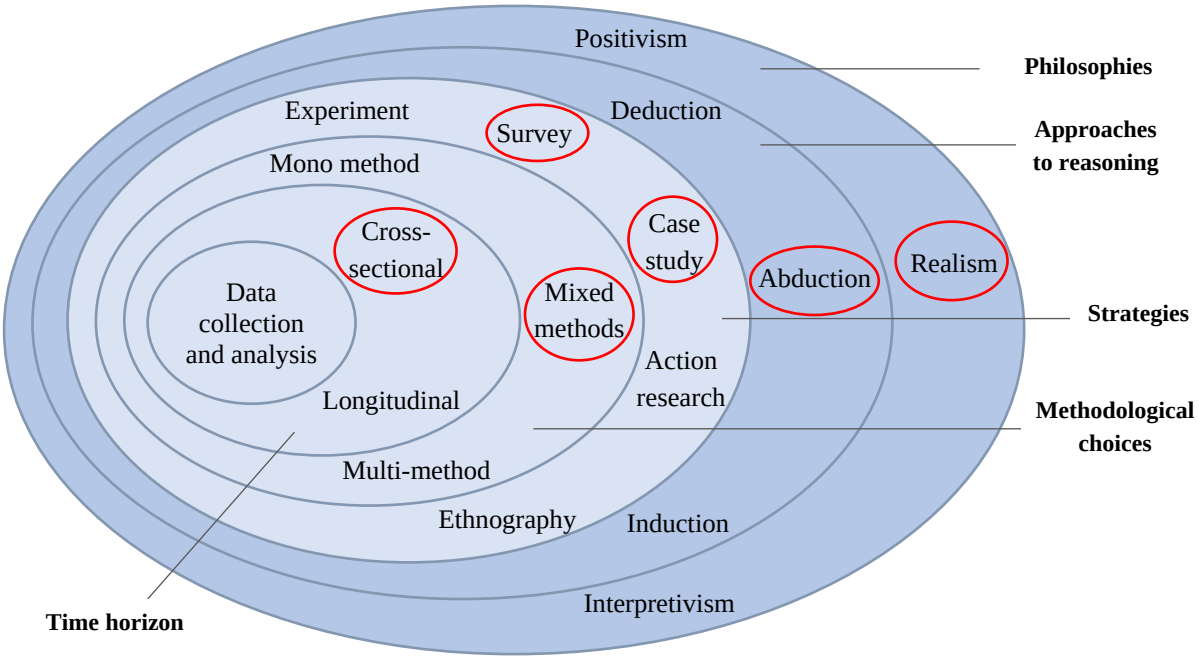

Figure 10: Elements of the research design in the thesis, based on Saunders et al. (2009)

As concerning the approach to reasoning, the three papers in the thesis employ an abductive approach, although in different ways, to explain the phenomenon of open SOI. In paper 1, absorptive capacity, and particularly its underlying processes of recognizing, assimilating and exploiting external knowledge (Lane et al., 2006) is used as the theoretical underpinning for the empirical qualitative case study. In such studies, this line of reasoning merges the strengths of deductive and inductive approaches by means of starting from a general theory as a source of inspiration, and subsequently drawing on insights from the data to provide explanations for why particular patters are observed (Bergene, 2007). As abduction requires consideration of alternative theories and explanations of observed patterns, the thematic analysis in this paper was conducted by means of consecutive and recursive processes of coding and classification in order to continuously move between emerging capabilities and data material. Moreover, the paper employs a theoretical sampling approach (Eisenhardt & Graebner, 2007), such that cases were selected based on their potential to provide in-depth knowledge to inform the theory, instead of being driven by practical considerations.

In a somewhat different manner regarding abduction, while papers 2 and 3 basically test theories with quantitative data, the hypotheses developed in these papers are inspired by a priori knowledge of the authors of the empirical setting and SOI phenomenon. Indeed, theories are applied by sensing the empirical world, in contrast to a deductive approach that proceeds from an already known theory to develop a set of testable hypotheses. Adopting a purely deductive approach runs the risk of only conveying the 'truth' that already exists in a general theory and thereby does not reveal the underlying similarities and anomalies between different cases (firms, in this thesis) that are of interest in social science (Reichertz, 2014). This is particularly important from a critical realist point of view, in which social phenomena are considered too complex to be understood by pure descriptions of correlational or causal effects. For example, in paper 2, although the literature highlights the importance of all aspects of proximity in inter-organizational relationships (Aguiléra et al., 2012; Boschma, 2005), previous observations regarding the peripheral localization of mineral firms have informed the theoretical framework of this paper and its focus on non-geographical dimensions of proximity, compared to the geographical alternative.

As shown in Table 7, which summarizes the methodological choices and analytical techniques used in the thesis, it was decided to conduct a qualitative case study and an industry-wide survey to obtain the data. Based on the discussion in section 1.4, the RQs in this thesis were generated by identifying and constructing critical gaps in the literature on open SOI. However, such a 'gap-spotting' approach should not be juxtaposed with quantitative data collection techniques (such as surveys), nor with the deductive hypothesis-testing line of reasoning (Alvesson et al., 2011). Qualitative researches should also convince their readers by illustrating gaps in the current understandings, which in turn necessitates the building or elaborating of theories (Pratt, 2009). Thus, the overall aim of the thesis to fill certain gaps does not set any limit regarding the use of both qualitative and quantitative data; this choice is justified by the different research objectives pursued in the appended papers.

Table 7: Overview of the different elements of research design in the appended papers

	Paper 1	Paper 2	Paper 3
Research objective	Exploring the underlying skills and routines that form a firm's capability in recognizing, assimilating and exploiting external stakeholders' knowledge for pursuing SOI.	Explaining in what ways and to what extent different types of SOI outputs are conditioned upon various aspects of proximity between a firm and its external stakeholders.	Explaining the extent to which stakeholder engagement affects SOI outputs, and whether the latter conditions the impact of stakeholder engagement on financial performance.
Research strategy	Embedded single-case study.	Survey	Survey
Data sources	16 semi-structured interviews. Annual reports, news and data from conference presentations and internet documents.	101 responses to the online questionnaire designed by the author.	101 responses to the online questionnaire designed by the author. Sales values and operational profits obtained via Proff® (the openly accessible database of accounting data in Norway).
Analysis technique	Thematic analysis by following three steps of open, axial and selective coding in NVivo.	Logit regression by SPSS.	Ordinal and linear regression, as well as analysis of mediation using the Preacher-Hayes bootstrapping technique in SPSS.
Validity, reliability and model robustness checks	Developing interview protocol. Creating case database. Asking for interviewee feedback on the transcripts. Considering rival explanations. Using a theoretical framework.	Using established measures to the greatest extent possible. Conducting a pilot study. Considering and testing alternative variable measurements and model specifications.	Using established measures to the greatest extent possible. Conducting a pilot study. Considering and testing alternative variable measurements and model specifications. Using time-lagged data for financial performance.

Hence, although all three papers in the thesis raise "what" type of questions, they imply two different meanings considering their particular objectives: exploratory and explanatory (Yin, 2009). The former, as in RQ1, requires in-depth knowledge beyond the surface of any construct or variable in order to enable us to reveal how a phenomenon comes about. As we were interested in revealing capabilities, either those owned/developed by an individual firm, or those that emerge at the interaction with peer companies (at the industry level), an embedded single-case study strategy was used in paper 1. To collect data from the cases, insights from

semi-structured interviews with firm managers were combined with published company reports and other available materials. Section 3.3.1 describes the interview process in detail.

On the other hand, a larger amount of data was necessary to study the relationships between various determinants of SOI, innovative outputs and financial performance in order to answer the explanatory "what" type of questions raised in papers 2 and 3. In this regard, a survey strategy allowed the collection of quantitative data across the entire industry. Other research strategies such as experiment or archival data are not very possible (if not impossible) considering the geographical spread of mineral firms in Norway, as well as the lack of data on their innovation and stakeholder engagement activities on a large scale. Section 3.3.2 presents the activities undertaken to design the questionnaire and to administer the quantitative data collection.

3.3 Data collection and data analysis

Concerning the methodological choices, the thesis is in a general sense mixed method research on open SOI. That is, while both qualitative and quantitative data are collected, each are subsequently analysed using qualitative and quantitative techniques (Saunders et al., 2009). However, as discussed in section 3.2, these techniques are not combined in the individual papers, as specific types of data (quantitative or qualitative) were needed to address different objectives (exploratory and explanatory) in them.

3.3.1 Semi-structured interviews and thematic analysis

As shown in Table 7, the first objective of the thesis is to explore the capabilities and their underlying microfoundations that enable mineral firms to undertake SOI. Considering the complexity of SOI capabilities, and in line with other studies in the field of open SOI (e.g. Brunner et al., 2013; Driessen & Hillebrand, 2013), a theoretical sampling strategy was employed to include firms with a certain level of innovation activities, as well as demonstrating a track record of success in engaging external stakeholders in these activities.

In doing so, a three-stage process was followed: first, considering the above criteria, an initial list of 40 Norwegian mineral firms was nominated based on the insights obtained from publications such as industry analysis and company reports. This list was then reduced to 27 by means of reviewing media outlets (mostly newspapers and company websites) and observations made at events such as the annual meeting of the Association of Norwegian Mineral Industry. Finally, the list was discussed with three independent industry experts working in the association, Mineral Cluster Norway and a consulting company. This led to the exclusion of five more firms, leaving a list of 22. Throughout this process, contextual factors were deliberately taken into account that could have effected firms' level of stakeholder engagement and innovation activities, hence an attempt was made to ensure that firms operating in different sub-sectors and geographical locations were represented in the study.

Next, the chief executive officers (CEOs) of these firms were approached for interview. An email containing a brief description of the purpose of the study and the desired structure for the interview (duration, tentative date, etc.) was sent to these managers, of whom 16 agreed to

participate in the research. Although showing their interest to participate, half of the 16 CEOs suggested another manager in their respective firms, explaining that the theme of the interview was of greater relevance for particular functional managers. This line of argument was also aligned with the adopted research design, as the intention was to capture data from informants who were indeed embedded in the phenomenon (Gioia et al., 2013), with the hope that their experience-based interpretations would provide knowledge of the characteristics of capabilities and innovation practices. Consequently, the interviewee in some case firms was a manager directly responsible for innovation activities, for example the sales manager, R&D manager, production manager or business development manager. An overview of the interviewees is presented in Appendix 1.

The aim of the interviews was to obtain insight into the routines and processes that firms use to develop recognition, assimilation and exploitation capabilities. Therefore, it was necessary to have a set of predetermined questions that could help reveal the emergence of these capabilities. Nonetheless, the need to consider a certain degree of flexibility in the interviews was also recognized, since asking follow-up questions or omitting irrelevant ones in some cases should be allowed in order to obtain the full range of data required for analysis (Qu & Dumay, 2011). Hence, a semi-structured approach was adopted, as this is more suitable for establishing a balance between a focus on pre-determined topics and a flexible flow, the latter being important to give the interviewees the chance to use their own words and to elaborate on the details of their capability building processes. A variety of open, probing and specific questions was developed on topics related to drivers of innovation, knowledge-exchange mechanisms and internal processes for building capabilities. Despite the differences between interviews regarding the content and the flow of questions, an interview protocol (see Appendix 2) containing a common set of questions, together with a procedural explanation of the interview, was sent to the interviewees prior to the interviews.

Considering the wide geographic dispersal of the case firms, and the probable logistic issues involved in visiting them in person, all the interviews were conducted via Skype. Compared to other remote methods such as telephone interviewing, Skype has the advantage of face-to-face connection with the informants, which is important for increasing the responsiveness of the interviewees and building a good rapport (Deakin & Wakefield, 2014). Moreover, following the suggestions of Qu et al. (2011), the interviews began with a brief reiteration of the purpose of the research, and the interviewees were asked if they had any questions before starting the interview. However, terms such as ‘sustainability’ were purposely avoided during the interviews and further elaboration on stakeholder engagement in SOI was saved until the end of conversations.

The recorded interviews were transcribed immediately after each interview. This allowed them to be summarized and issues or topics identified which needed to be taken into account in the next interview. As concerns analysis of the interview material, NVivo software package was used to perform the three steps of coding: open coding, axial coding and selective coding (Dougherty, 2002; Gioia et al., 2013). First, the data were read independently and concepts and expressions related to sustainability drivers, different types of SOI, internal capabilities and

external sources of knowledge were searched for. In the second phase, our discussions about the similarities and differences between these concepts across the different cases, as well as several rounds of consultation with the literature, led to identification of a set of second-order codes. Finally, the material was reviewed and recoded by using the codes from the second step to clarify the emerging themes and their relationships.

To improve the quality of the methods employed for collection and analysis of the qualitative data, Yin (2009) argues for the importance of establishing research reliability and validity. Regarding reliability, he suggests two specific practices: developing an interview protocol and creating a database containing all the case material, which were both done in this thesis. For validity, he differentiates between construct, internal and external aspects. The former entails avoiding the use of subjective conceptualizations and judgements. In doing so, the transcripts were sent to the interviewees to obtain their feedback and further reflections. Furthermore, when available, the interview data were triangulated with other data materials (such as annual reports, news and data from conference presentations and internet documents) to check the convergence of informants' explanations with the objective information.

Concerning internal validity, particular attention was paid to similarities and dissimilarities between emerging concepts in the different case firms, thereby enabling us to consider rival explanations for an observed pattern. For example, while the majority of informants pointed to the importance of sharing experiences among co-workers in a specific unit/function for assimilating external knowledge, such routines were not perceived to be of high relevance when the acquired knowledge was highly multidisciplinary. On these occasions, our findings instead highlight the significance of intra-firm communication channels across, for example, technical and market divisions. For external validity, although the intention was not to generalize the findings, using absorptive capacity as a general theory could assist in extending the findings to other similar contexts.

3.3.2 Survey and regression analysis

The first step in collecting the quantitative data was to produce a database of firms that should be included in the survey. As argued in section 1.3, firms operating in the four non-energy sectors of the minerals industry in Norway serve as the empirical setting for the study. These firms are classified under divisions 7 (mining of metal ores) and 8 (other mining and quarrying) of the International Standard Industrial Classification (ISIC) published by the United Nations (2008). A search was made for these two firm categories listed in the Norwegian register of business enterprises (Foretaksregisteret), in which all firms are required by law to register. This search resulted in 690 hits (in October 2015). From this, 193 firms were shortlisted based on two criteria: first, their establishment date must have been at the latest January 2013, since the survey covers the period 2013-2015. Second, in accordance with established innovation surveys such as CIS, they must have had five or more employees, a figure which is considered as a rough proxy for having a certain level of human resources available for innovation and stakeholder engagement.

Therefore, the final population comprised 193 firms operating in four different sectors of the Norwegian minerals industry. It was purposely decided to take a census of all these firms instead of using sampling because of the heterogeneity of the population, which necessitates inclusion of all its small segments (Daniel, 2012). For example, using the proportional sampling method based on firm size, geographical location or minerals sector might have led to the undesirable exclusion of firms with specific characteristics (e.g. large firms or those in the High North region), which can behave differently in relation to innovation and stakeholder engagement. Having established this list, the next step involved obtaining the firms' contact information (including email address, postal address and phone number), since a complete and updated list of email addresses was not available through either the register or other authorities (such as the Norwegian Directorate of Mining). This was done by inspecting firms' websites or their social media pages. At the end of this stage, a complete database of 193 firms, including their contact information, was generated to be used for collecting data through a questionnaire.

The second step in the survey process was to develop the questionnaire. Due to the comprehensiveness of the research topic, a web survey was considered more appropriate (compared to mail or telephone surveys) in order to provide firms with flexibility, both in preparing for questions and reviewing their answers before submitting the questionnaire (Saunders et al., 2009). Accordingly, the tailored design method developed by Dillman et al. (2014) was closely followed for the phrasing of questions, testing the questionnaire, configuring the online survey instrument and contacting the target population. As argued in section 2.7.2.2, concerning the inability of existing surveys to capture open SOI activities, it was necessary to customize the pool of items that were available from these surveys against the dependent and independent variables in the thesis. Therefore, an extensive review was conducted of the literature on proximity dimensions, open innovation, stakeholder theory and SOI, which resulted in the refinement of the constructs and structure of CIS to be used. An overview of the questions used in the survey is presented in Appendix 3.

Subsequently, a web survey was designed using the online survey platform Questback. For clarification, definitions were provided of concepts such as innovation and collaboration, which might be interpreted differently by the respondents. Then, a personalized email invitation was sent to the CEOs of the identified 193 firms, with a link to the online questionnaire. The email package and the questionnaire were administered in Norwegian to ease the communication with the firms. Included in the email were also: 1) a cover letter that provided a brief description of the research background and motivation; and 2) a supporting letter from the Secretary General of the Association of Norwegian Mineral Industry to encourage firms to participate in the survey.

During the survey period from February to April 2017, a total of 101 companies provided complete responses, representing a response rate of 52%. Two rounds of reminders followed up the original e-mail, each sent two weeks apart. Moreover, follow-up contacts were made by phone in order to fill in the missing data. The non-responders were also contacted by phone; in some cases the person who had received the email refused to participate in the research because of time limitations or fear of information leakage. Figure 11 shows the number of responses

received at each stage of the data collection. Similar to the interviews, while most questionnaires were answered by the CEOs (82 of 101), some of them referred the survey to another manager in their respective firms who was directly responsible for innovation activities, including the R&D manager, regional manager, production manager or health, safety and the environment (HSE) executive. The survey data are available through the open data repository at UiT The Arctic University of Norway (Ghassim, 2018).

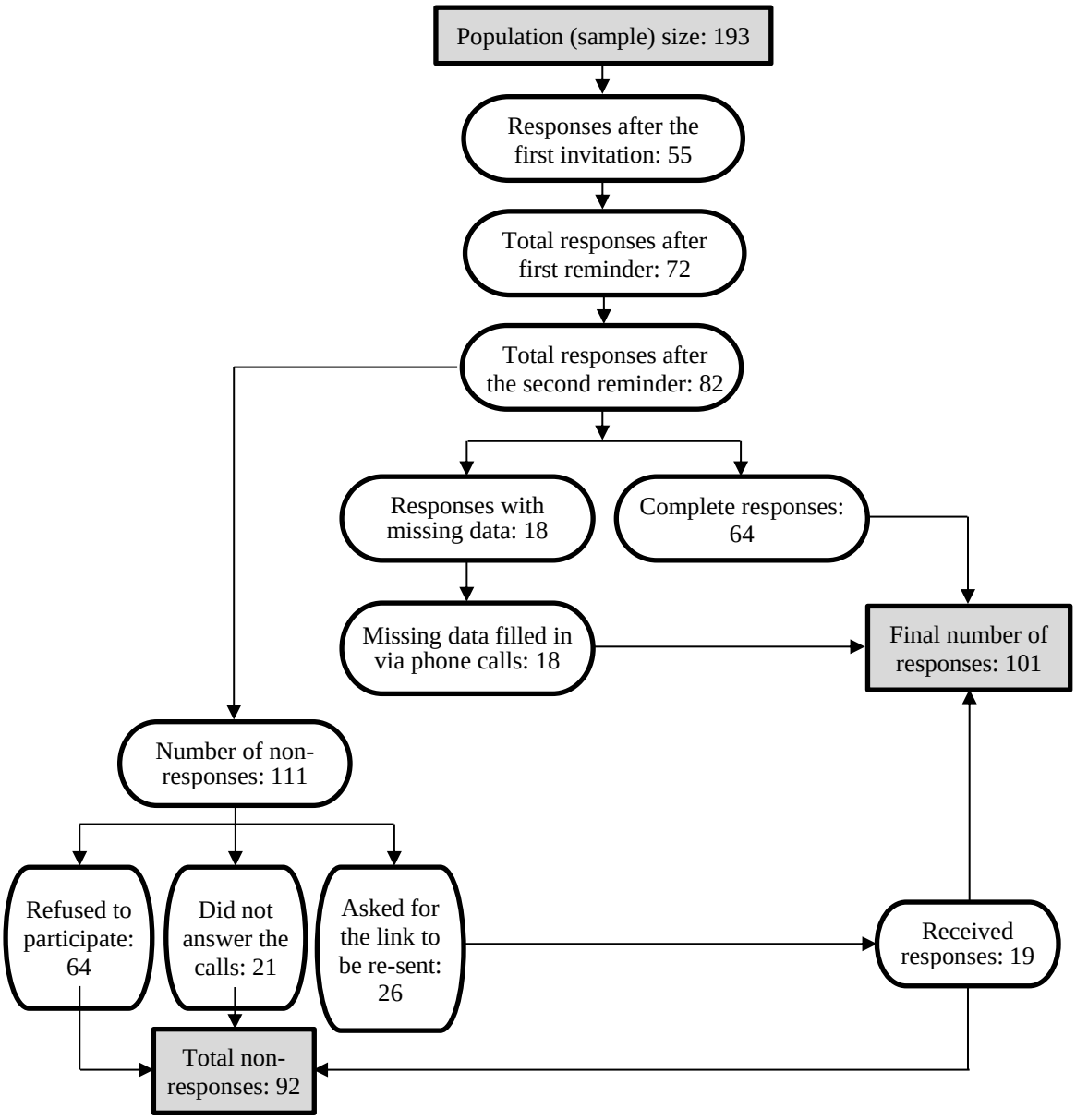

Figure 11: Flowchart illustrating responses at the three stages and the overall (non-)responses

Despite their advantages in reducing the cost and time required for data collection and analysis, web surveys are prone to lower response rates compared to telephone or mail surveys (Dillman et al., 2014). To face this issue, two specific actions were undertaken to increase the respondents' engagement in the survey: first, initial contacts were made with selected firms from different mineral sectors during the annual meeting of the industry that is organized by the Association of Norwegian Mineral Industry. Second, a synopsis of the preliminary results

from the interviews was published on the association's website and social media pages to increase awareness of the research. These actions collectively helped in obtaining a response rate higher than the average in management and organization studies, which is around 30% (Saunders et al., 2009). Moreover, no significant differences were found between the non-respondents, early and late responses (including the two subgroups of respondents after the reminder email and those after the follow-up phone call) in terms of firm size, sales value and innovation outcome. As such, non-response bias was not an issue in the study.

To analyse the data obtained via the survey, SPSS software was used as the primary tool for conducting descriptive and regression analyses. Logit, ordinal and linear regression techniques were employed according to the nature of the dependent variables, namely SOI outputs and financial performance. In paper 2, the aim is to explain in what ways and to what extent organizational, cognitive and institutional dimensions of proximity between a firm and its external stakeholders affect SOI outputs. More specifically, one area of interest is examining the likely association between these dimensions of proximity and different types of SOI, i.e. process, product and social innovations. Three dummies were then created for each of these innovation outputs, given a value of 1 when a firm had reported innovation during the period 2013-2015. Therefore, the binary measures used for the dependent variables led to use of logit models to regress the hypothesized effect of proximity dimensions.

Paper 3 pursues a dual objective, which in turn necessitates development of two separate general regression models that lay the basis for the ultimate mediation analysis: first, an ordinal model to explain the extent to which stakeholder engagement affects SOI outputs, and second, a linear model to examine whether these outputs have any impact on financial performance. In the first general model, SOI outputs is the dependent variable, which is measured along a 4-point scale (0 to 3), on which 0 indicates no innovations in the three categories of SOI and 3 specifies at least one type of innovation in each of the categories. In the second model, SOI outputs act as the independent variable, and financial performance, which is measured by a firm's return on sale, serves as the dependent variable. Having established these two paths, testing the mediation hypothesis deals particularly with examining the size and significance of the indirect link (that goes through SOI outputs) between stakeholder engagement and financial performance. To this end, the Preacher-Hayes bootstrapping technique, which is an add-on macro in SPSS, was used.

The final task remaining with regards to the survey was to examine its construct validity, since a modified version of CIS was developed by including a broader range of external stakeholders, as well as using specific proxies for SOI. According to Dillman et al. (2014), a validity examination method that combines cognitive interviews with a small pilot study is helpful in determining whether the respondents have the same understanding of the questions and instructions as the researcher. Accordingly, prior to data collection, a draft of the questionnaire was sent to six CEOs from the sample firms and two industry informants, who were interviewed about the understandability of the items and concepts in the questionnaire. This test resulted in some minor adaptations and reformulations of questionnaire items.

Given the possible sensitivity of the results to the measures used for the variables, model robustness was checked by changing the measures and subsequently running a different regression technique. For instance, in paper 3, ordinal regression was used to examine the effect of stakeholder engagement on SOI outputs, which is measured along a 4-point scale. For the robustness check, SOI was also measured as a nominal variable (meaning that different levels of SOI output have not a natural ordering) and the analysis was run using the multinomial logit model, which produced very similar results to those obtained from ordinal regression.

4 Summary of the papers

This chapter provides brief summaries of the three papers appended to the thesis, including their backgrounds, empirical studies, main findings and contributions.

4.1 Paper 1: Understanding the micro-foundations of internal capabilities for open innovation in the minerals industry: a holistic sustainability perspective

The discussion throughout this thesis emphasized that achieving sustainability in the minerals industry requires a holistic approach to innovation, which necessitates a purposive inflow of knowledge from various external stakeholders. While providing a myriad of opportunities, this open approach to innovation could also be challenging, in that mineral firms need to have sufficient absorptive capacity, i.e. the capability to utilize external knowledge internally. As also elaborated in section 2.7.4, existing studies have not paid sufficient attention to the extensiveness of such capability in SOI contexts. Therefore, this paper builds on a process view of absorptive capacity including 'recognition', 'assimilation' and 'exploitation' of external knowledge, and sets out to explore the skills and routines (microfoundations) that underlie a firm's capabilities in these three components of absorptive capacity.

The paper conducts an embedded single-case study of 16 mineral firms in Norway. Semi-structured interviews with firm managers form the basis of analysis, for which the emerging themes were coded and classified via a consecutive and recursive process. The findings point to the firms' efforts in acquiring knowledge from key external stakeholders including suppliers, customers, social communities and NGOs, research organizations and other firms in their industry. The necessity to engage such a wide range of stakeholders does in turn make it inevitable that they develop four types of capabilities in accordance with the recognition, assimilation and exploitation components of absorptive capacity. First, a capability in *keeping abreast of changes in technologies and markets* is developed based on employees' prior educational and professional experience, as well as new recruitment and training programs. Next, *increasing awareness about social issues* complements the previous capability towards identifying and understanding (recognizing) different types of technical, market and social knowledge. Third, the data indicate that arranging periodic meetings and encouraging peer-to-peer interactions within and between different functions assist the firms in *facilitating the internal knowledge dissemination* required to integrate the acquired external knowledge internally (assimilating). Fourth, firms improve their ability in applying the new knowledge (exploitation) by means of *piloting new, innovative solutions* that comprise experimentation, small-scale testing and the maintenance of external relationships to receive appropriate feedback on their innovations. At the higher level, the capabilities for recognition and assimilation accrue to the industry as a whole when the intermediary organizations, meeting arenas and informal employee networks contribute to strengthening the mutual understanding between firms and external stakeholders.

Besides addressing the dearth of research on SOI capabilities, this detailed study provides insights into the building blocks of absorptive capacity in business contexts, where innovation is more than simply conducting R&D activities and pursuing commercial objectives.

4.2 Paper 2: Sustainability-oriented innovation in the minerals industry: an empirical study on the effect of non-geographical proximity dimensions

Compared to the previous paper, that studies the internal capabilities that condition a firm's benefits from external stakeholders, paper 2 shifts the focus to the inter-organizational factors that are at play when considering the flow of knowledge and innovation. To this end, the paper underlines that the difficulty in recognizing and assimilating external knowledge in SOI contexts (due to the diversity of knowledge areas and sustainability objectives) is especially visible in peripheral regions that are characterized by limited knowledge spillover. The results of such a double obstacle pose significant challenges to firms, bearing in mind that most of the knowledge required for SOI (particularly technical and social) is highly uncodified and thus likely to be dependent on geographical proximity between firms and external stakeholders. The paper then posits that in the absence of such proximity, the importance of non-geographical dimensions of proximity is paramount for SOI. Therefore, it hypothesizes that cognitive, organizational and institutional proximities are positively related to different types of SOI outputs. Cognitive proximity explains the similarity between knowledge bases, while organizational proximity refers to the degree of coordination between firms and external stakeholders. Institutional proximity comprises formal and informal dimensions that signify similarity in "rules and laws" and "cultural norms and habits" respectively.

The empirical analysis in this paper draws on the survey data from 101 mineral firms in Norway, as discussed in section 3.3.2. To test the hypotheses, the paper uses logit models and regresses the effect of cognitive, organizational and institutional proximities on process, product and social innovations in separate models; the last model for each type of SOI examines the cumulative effect of all the aforementioned proximity dimensions. The results corroborate previous studies (De Marchi et al., 2013; Ketata et al., 2015), in that *cognitive proximity* (measured by employees' level of education) is *significant for process and product types of SOI*, but it also extends the literature by revealing the effect of two different education types (master's and above vs. bachelor's and vocational training) on these innovative outputs. *Organizational proximity* (measured by the number of collaborations beyond the local region) is found to be *significant for implementation of social innovations*, which is in line with previous literature that argues for the importance of mutual communication in creating social values (Ayuso et al., 2006). Finally, the two dimensions of institutional proximity increase the probability of SOI, although *formal rules and laws can enable process and product innovations*, whereas *informal norms only trigger the social type of SOI*.

The contribution of this paper lies in extending the literature on innovation in peripheral regions by taking into account a more complete range of innovations that are necessary for development in such regions. Moreover, the empirical studies in this domain have focused primarily on a single type of proximity, and hence the combined effect of various dimensions of proximity on innovation have remained understudied. However, the observed positive signs for combined proximity dimensions should be further examined in the future research to examine whether they generate complementary or substitution effects on SOI outputs.

4.3 Paper 3: Linking stakeholder engagement to profitability through sustainability-oriented innovation: a quantitative study in the minerals industry

The emerging literature on stakeholder engagement is mostly qualitative, and the few studies that have employed a quantitative design are far from conclusive due to their contradictory results. Adding to this inconsistency is the lack of knowledge about the potential financial benefits from engaging in stakeholder relationships and pursuing SOI, which may in turn impede managers' ability to fully recognize the value of such engagements for their firms' survival in the long term. Therefore, the overarching purpose of paper 3 is to explain the extent to which stakeholder engagement affects SOI outputs, and whether firms with higher engagement and reported innovations do also observe superior financial performance. To this end, the paper combines the survey data used in the previous paper with firms' financial data obtained via Proff® (the openly accessible database of accounting data in Norway).

An important deficiency in the few quantitative studies is that the hypotheses regarding the association between stakeholder engagement and SOI are built on empirical insights from earlier studies, instead of being theoretically informed. To remedy this, paper 3 draws on stakeholder theory and distinguishes between two main types of stakeholder engagement, namely *transactional and relational interactions* (Hillman et al., 2001; Jones, 1995), and argues for their positive effects on augmenting a firm's SOI outputs through two different mechanisms. In the transactional, or one-way, interaction process, the primary intention of the firm is to learn about the needs and expectations of stakeholders without their direct involvement in the learning processes, whereas relational, or two-way, interactions entail the co-creation of knowledge through exchange processes between a firm and its stakeholders. Therefore, it seems likely that transactional engagement is not per se beneficial for innovation due to its inability to provide timely access to the relevant external knowledge. However, paper 3 proposes and shows that *frequent transactions* are positively related to SOI, as they involve a time dimension that adds to the depth of these relationships, and hence enable a firm to obtain access to valuable knowledge such as established solutions from competitors or weak signals related to social and environmental issues. Relational interactions, on the other hand, rely on the trust and mutual commitment arising from collaborations and are inherently deep enough to provide firms with the required knowledge. As a result, *engaging a diverse set of stakeholders* through relational engagement improves the odds of achieving higher SOI outputs.

Concerning the financial benefit from stakeholder engagement and SOI, our hypotheses are based on the resource-based view (RBV) of the firm and argue that SOI outputs are typical examples of valuable, rare and inimitable assets, as they enable a firm to continuously respond to rapidly changing business environments by addressing the needs of a wide range of external stakeholders. Nonetheless, the paper posits that *stakeholder engagement is not directly associated with superior performance* as their (financial) benefit begins to appear once they are able to transform the acquired knowledge from external stakeholders into innovative outputs. The results from testing *a full mediation model* support the above hypotheses.

Paper 1

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Understanding the micro-foundations of internal capabilities for open innovation in the minerals industry: a holistic sustainability perspective

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ABSTRACT

It is indisputable that achieving sustainability in the minerals industry requires a holistic approach to innovation that utilizes the breadth of knowledge found outside the industry. While providing a myriad of opportunities, this open approach to innovation would also be challenging in that companies need to have sufficient absorptive capacity, i.e. the ability to 'recognize', 'assimilate' and 'exploit' external knowledge when developing their processes and products. Despite recent theoretical advances, we do not yet fully understand the determinants of these three components of absorptive capacity for innovations aimed at sustainability. By employing a qualitative design with data obtained from 16 interviews conducted within Norway's minerals industry, this study explores the skills and routines that comprise micro-foundations of the capabilities for absorptive capacity. The analysis reveals that, in order to achieve recognition, companies need to firstly keep abreast of technological and market changes that emanate from sustainability transition, and secondly increase their awareness about social issues. Accordingly, assimilation depends on the established routines for facilitating dissemination of internal knowledge, whereas exploitation occurs by means of the piloting of innovative new solutions. This paper contributes to the sustainability-oriented innovation literature by demonstrating how companies in sustainability-sensitive industries could benefit from various types of external knowledge in their innovation activities. It also provides some insights into the nature of open innovation and absorptive capacity beyond high-tech industries and research and development-based knowledge.

1. Introduction

The ever-increasing pressure on the global minerals industry[1] to align sustainability and profit has raised the importance of a transition that includes the economic, environmental and social aspects of the business in this sector (Lei et al., 2013). Recent years have evidenced growing interest among policymakers and businesses regarding the key role that innovation plays in moving towards sustainability transitions, particularly in energy-intensive and environmentally sensitive businesses such as the minerals industry (OECD, 2011a; Smith et al., 2010; Song and Oh, 2015). In contrast to the limited outcomes from traditional approaches to innovation, an integrated sustainability-oriented innovation (SOI) allows companies to "make intentional changes to their products, processes or practices to serve the specific purpose of creating and realizing social and environmental value in addition to economic returns" (Adams et al., 2016, p. 180). By employing SOI, companies could address the environmental and social aspects of sustainability in a more proactive and strategic way, hence going beyond myopic practices such as pollution control and the reduction of social risks (Hart, 1995; Onkila, 2011). For example, responses to the imperative of reducing waste and pollution have shifted from just mandatory compliance with legal regulations to innovative actions such as creating value from waste and sustainability reporting (Bocken et al., 2014). In economic terms, whereas the mineral industry's margin from productivity advances and operational efficiency is shrinking, a broader approach to innovation could provide opportunities to meet new market demands from green industries and to gain social acceptance by creating new channels of interaction with societal stakeholders (Deloitte, 2016; Klewitz and Hansen, 2014; Nidumolu et al., 2009).

Research has shown that successful innovation requires organizational capabilities to build and reconfigure various types of knowledge resources (Rothaermel and Hess, 2007; Teece, 2007). Concurrently, sustainability transition signifies rapid changes in technologies, market demands, environmental regulations and social expectations (Lozano, 2015) which in turn require continuous modification in the knowledge base of firms (Teece, 2007). Moreover, tackling environmental and

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[1] Following Upstill and Hall (2006), we define the minerals industry as 'companies engaged in exploration, extraction and primary processing of minerals'.

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social issues increases the necessity to understand the needs and impacts of a wide variety of stakeholders regarding innovation outcomes (Hall and Vredenburg, 2003; Sharma, 2005). To this end, companies are increasingly adopting open innovation, which is defined as "a distributed innovation process that involves purposively managed knowledge flows across the organizational boundary" (Chesbrough and Bogers, 2014). Examples in the mineral industry that evidence such an open approach to innovation are Anglo American's open collaboration forum (Waller, 2014), LKAB's joint venture with two equipment manufacturer for the development of remote monitoring technology (Westergren and Holmström, 2012), the involvement of local communities in gold mining in Central America (Erzurumlu and Erzurumlu, 2015) and the intensive collaboration regarding Elkem Solar Silicon (Ceccaroli and Tronstad, 2016).

As open innovation moves the locus of innovation outside organizational boundaries, innovation capabilities will depend on the absorptive capacity of firms, i.e. their ability to utilize externally acquired knowledge (Cohen and Levinthal, 1990; Lawson and Samson, 2001). We follow the definition of Lane et al. (2006) of absorptive capacity, which suggests a sequential process of 'recognize, assimilate and exploit' for building this capacity. In their view, prior knowledge of individual employees shapes the basis of understanding external knowledge, while integrating it with the existing knowledge base creates new knowledge outputs for developing innovations. Considering SOI, the diversity of external knowledge required to conduct process, product and social innovations necessitates various internal skills and routines in order to learn from a diverse range of external linkages (Adams et al., 2016). SOI-related capabilities are extensive and typically outside an individual firm's existing resource base (Lozano, 2007), especially when considering small mineral companies (Milanez and de Oliveira, 2013). Therefore, it is crucial for companies to identify skills and routines that underlie the different stages of recognizing, assimilating and exploiting different types of external knowledge.

Existing studies in this domain have not paid sufficient attention to the specificity of capabilities for innovation in sustainability contexts, particularly through a perspective that considers the comprehensiveness of SOI by taking into account all three aspects of sustainability transitions (Amui et al., 2017; Chen, 2016). For instance, Ayuso et al. (2006) proposed stakeholder dialogue and knowledge integration as the organizational capabilities required to absorb external knowledge, and introduced a set of structural and cultural mechanisms that facilitate the development of these capabilities. However, one caveat to this finding is the limited conceptualization of absorptive capacity that has led to other underlying mechanisms being ignored, such as employees' prior knowledge. In a quantitative study, Albort-Morant et al. (2016) used empirical data from the Spanish automotive industry to substantiate the fact that learning and integrating capabilities are important for success in environmental innovations. However, their standard measure of 'capability' may have handicapped their findings, as SOI capabilities are believed to differ from those for traditional innovations.

Considering the above, there is a need to enhance our knowledge of the specific skills and routines for undertaking SOI that help firms to move through the processes of recognizing, assimilating and exploiting external knowledge. Thus, this paper aims to answer the following research question: what are the capabilities, and their underlying skills and routines, that build the absorptive capacity required for SOI in the minerals industry? Accordingly, we use an exploratory case-study design (Yin, 2009), with data from 16 companies in Norway that form the empirical setting for this research.

By identifying the micro-foundations of capabilities (i.e. the underlying routines for building them) that are essential for SOI, this study contributes to the recent debate about how various (and somewhat conflicting) aspects of sustainability can be realized through internal and external learning mechanisms for innovation (Amui et al., 2017; Watson et al., 2017). Moreover, our fine-grained analysis of the determinants of absorptive capacity responds to the call for more research into the intra-organizational building blocks of this construct (Lewin et al., 2011). As scholars have paid scant attention to determinants beyond research and development (R&D)-based knowledge (Vega-Jurado et al., 2008) or innovations with non-commercial purposes (Murphy et al., 2012), our empirical insights from the Norwegian minerals industry reveal some specific aspects of absorptive capacity when pursuing an innovation approach that entails both commercial benefits (for companies) and non-commercial benefits (for society).

The remainder of the paper is structured as follows: the next section provides an overview of the empirical setting; Section 3 describes the theoretical background; Section 4 deals with the research design and methodology; Section 5 presents the results of the case study; and Section 6 discusses the findings and implications.

2. The empirical setting: Norway's minerals industry

The Norwegian minerals industry produces a diverse range of minerals of various commodity types. The ore minerals sector dominated the industry until some decades ago, while industrial minerals, natural stone and construction minerals have gradually gained increasing importance in terms of employment and sales value. By production volume, Norway is among Europe's most important producers of olivine, nepheline, titanium minerals, iron ore, marble, quartz and flake graphite (Geological Survey of Norway, 2016). Furthermore, the country has promising potential for increasing the supply of minerals required for growth in green and high-tech industries such as renewable energy, the manufacturing of electric cars, electronics and aerospace.

Despite its historical presence, the size of the Norwegian minerals industry is quite small compared to other mineral-rich countries or the other domestic natural resource-based industries, such as oil and gas. In 2015, the industry had $\approx$ 6000 employees, distributed over 690 companies operating $\approx$ 1000 mines and quarries. It had a turnover of roughly USD 1.55 billion (NOK 13.3 billion) in 2015, of which $>$ 50% was from export markets. Even though the direct contribution of the minerals industry to Norway's gross domestic product (GDP) is very small ($\approx$0.4% based on data from 2015), a recent analysis showed that the minerals value chain (considering manufacturing of mineral-based products, excluding oil and gas) contributes 12% of total GDP in Norway (The Science Park in Bodø, 2017). In addition, this industry has had a significant development effect in several peripheral regions of Norway, in terms of both direct employment and growth of local supplier industries (Smeds et al., 2016).

According to Siggelkow (2007), empirical settings for single-case research should provide a unique opportunity to obtain first-hand knowledge about the phenomenon under study. We consider that the Norwegian minerals industry, owing to some of its characteristics, makes an attractive case for a study of capability building and an open SOI approach. According to the Norwegian government's strategy for this industry, "efficient, socially responsible and environmentally-friendly operation" should be at the core of development, and that new knowledge, cooperation and technological improvements should play an important role in realizing these intentions (Ministry of Trade and Industry, 2013). The openness of the economy and the relatively high proportion of small and medium-sized enterprises in the minerals industry – with a consequently limited internal knowledge base – will then favor a focus on externally oriented learning.

As shown in Table 1, addressing higher productivity growth and stricter environmental requirements by means of technological developments has led to a continuous improvement in key economic and environmental indicators. Moreover, while measures to ensure that companies act in a socially responsible way have yet to be developed, the government has exerted extra effort through the new Mineral Act to ensure the protection of nature-based activities related to herding and fish farming that are part of the livelihoods of the locals. Concerning market situations, geographical proximity to the European market and

Table 1
Productivity, energy and emission intensities in the Norwegian minerals industry during 2013–16.
Source: Statistics Norway

Indicator	Year			
	2013	2014	2015	2016
Labor productivity (ktonnes/employee)	15.60	16.14	17.59	20.91
Energy intensity (GWh/billion NOK income)	154	133	122	112
Emission intensity (ktonnes of CO_2 equivalent/ billion NOK income)	40.05	39.41	36.88	34.23

access to a long coastline constitute competitive advantages for export-oriented mineral companies in Norway. In innovation terms, this has made knowledge exchange easier, especially in the case of linkages with process and manufacturing industries.

3. Background and theoretical framework

Following the OECD (2011b), sustainability transition denotes moving towards a form of industrial growth where triple-bottom-line objectives (i.e. social, environmental and economic) are taken into account. This multidimensional growth emphasizes the demand for innovative solutions that not only bring economic advantage, but also improve social well-being and decrease detriments to the natural environment (Smith et al., 2010). For the purpose of this paper, we define innovation as "the search for, and the discovery, experimentation, development, imitation and adoption of new products, new production processes and new organizational setups" (Dosi, 1988, p. 222). Accordingly, SOI comprises product, process and social innovations (Klewitz et al., 2014) that may originate either inside or outside a firm's boundary.

The following subsections provide the theoretical groundwork that directed our purpose to explore which internal capabilities the minerals industry should develop in order to pursue an open innovation approach in its SOI activities.

3.1. The broadening scope of external learning linkages for SOI

In recent decades, learning processes and innovations have increasingly become shared activities in industrial settings. Innovation is currently the result of interactions among various actors as components of an innovation system (Fagerberg et al., 2009). According to this open innovation paradigm, a company should be able to manage knowledge inflows and outflows across its boundaries (Chesbrough, 2003), yet the inward flow is more significant in non-high-tech settings such as the minerals industry (Bartos, 2007). In this respect, companies may gain access to external knowledge via two basic mechanisms, namely transactional and collaborative relationships (Greco et al., 2016); whereas the former implies monitoring the outside environment and/or sourcing technologies on a market basis, the latter represents active partnerships to develop new knowledge and innovation.

While companies can generally acquire knowledge from different external sources, a central topic in the literature has been to identify the main sources of knowledge inputs for innovation in different industries. A pioneering idea in this respect is the taxonomy provided by Pavitt (1984), which groups firms into three categories, namely supplier-dominated, production-intensive and science-based. In Pavitt's view, the first category of firms is mainly dependent on the flow of knowledge from suppliers and, to a lesser degree, from large customers and research organizations, whereas engineering service providers and R&D institutions are the essential knowledge providers for the second and third categories, respectively. In a similar vein, Asheim and Gertler (2005) make a distinction between industries with analytical and synthetic knowledge bases and go on to argue that firms in the first category draw substantially from basic science and knowledge produced in research organizations, while those with a synthetic knowledge base mostly interact with their suppliers and customers.

Regardless of different classifications, scholars seem to agree on a dependency between external knowledge sources and the type of knowledge they provide for innovation activities (i.e. technical, scientific, market, etc.). Existing studies suggest that companies rely on their suppliers to obtain technical knowledge related to process innovations, either in the form of knowledge embedded in technologies or by buying engineering services (Robertson et al., 2012). In the minerals industry, collaborative technology development projects could benefit both the mineral company and the equipment supplier by lessening the risk of failure, providing complementary access to financial resources and allowing the possibility of testing prototypes in a real operational setting (Lager et al., 2015). Moreover, managers in this industry are increasingly focusing on outsourcing their non-core activities (Morris et al., 2012), which could result in more flexibility in their linkages with suppliers compared with collaborative arrangements that require deep involvement and shared commitments.

As for knowledge about markets, existing customers and potential markets at large are the main sources of insight that drive innovative product solutions (Bogers and Lhuillery, 2011). Owing to the scarcity of mineral raw materials and their importance in global supply chains, manufacturing industries are reportedly concerned about relationships with their suppliers of raw materials (George et al., 2015). Moreover, interaction with raw-material suppliers is considered a crucial factor for the sustainability of product life cycles and ultimate market success. Pujari (2006) highlights the role of early-stage interaction with suppliers in maintaining a good reputation and increasing eco-efficiency and product quality. Not surprisingly, there is a shortage of research on such interactions from the perspective of the minerals industry. More attention to this shortfall is particularly important when considering the rise in the importance of rare earth and industrial minerals for applications in high-tech and renewable industries (Wang et al., 2017), which calls for an investigation of the dynamics of learning from (potential) customers for these mineral products.

Although not a main focus in non-high-tech sectors, innovation-based development in the minerals industry also requires the establishment of linkages with research organizations (Andersen et al., 2015). Industry–university interactions in such sectors create the applied knowledge required to address specific process- or product-related issues (Asheim et al., 2005). These interactions have proven beneficial for sustainable innovation through learning that happens via both formal collaborations, for example R&D projects, and informal relationships between scientists and industrial personnel (De Marchi, 2012; Grimpe and Fier, 2010). The supply of human capital and engineering services from universities could also contribute to industrial development in mining regions (Figueiredo and Piana, 2016) which, among other positive consequences, would improve both the reputation and social responsibility of the companies concerned.

Beyond technical, market and scientific knowledge, the emerging literature on SOI points to the importance of societal stakeholders for innovation success, particularly those innovative outcomes that target social rather than commercial values. Drawing on several case studies in the UK, Holmes and Smart (2009) demonstrated the value of interacting with non-profit-making organizations as a source of knowledge on societal issues. Successful management of mining projects in the realm of stricter socio-environmental regulations is dependent on interactive communications with local stakeholders (Corder, 2015). This is in accordance with the results of a growing literature which draws on the concept of 'social license to operate' (Prno and Scott Slocombe, 2012) to argue that disregarding the interests and expectations of locals endangers both productivity and efficiency gains in this sector. Suopajärvi et al. (2016) conducted an in-depth empirical study to show that approaches towards social sustainability should go beyond reactive practices (such as the transparency of waste management activities)

and further involve the community in the early stages of planning for mine development.

Nevertheless, the literature on external learning linkages to the minerals industry is rather sparse and is mainly focused on interactions with suppliers in user–producer relationships, which consequently do not reflect the industry's need for a broader approach towards innovation and sustainability. Our perspective in considering various types of knowledge relevant to SOI, including technical, market, scientific and social knowledge, and their respective external sources, could provide some insights into how firms respond to the broadening scope of learning linkages by developing their internal skills and competencies.

3.2. Internal capabilities for absorbing external knowledge

The above discussion suggests that various types of external knowledge sources are conducive to innovation, which may result in an expectation that learning and innovation are automatic results of exposure to an external environment. However, studies have found that these outcomes should not always be taken for granted. Instead, deliberate efforts and adequate amounts of 'internal' knowledge and competence are required to build the capacity for effective learning from these linkages (Zollo and Winter, 2002). This school of thought refers to a firm's absorptive capacity, a concept coined by Cohen and Levinthal (1990) and defined as the capability to utilize knowledge originating outside the firm. The term 'capability' is central to this conceptualization as it points to the 'dynamic' nature of absorptive capacity, which not only captures firms' resources (skills and knowledge competencies) but also their reconfiguration by means of organizational routines in order to comply with changes in the outside environment (Teece, 2007).

Since its introduction, absorptive capacity has undergone significant examinations regarding its definition, measurement and underlying processes. For the purpose of this paper, we follow recent contributions that have specifically advanced this construct by (1) developing a process-based view of it and (2) extending it beyond R&D-based knowledge and commercial innovations. Regarding its definition and construct clarification, it is generally accepted that absorptive capacity is a multidimensional concept comprising three sequential processes: recognizing, assimilating and exploiting the external knowledge (Lane et al., 2006). Accordingly, our theoretical framework (Fig. 1) proposes that firms should develop recognition, assimilation and exploitation capabilities in order to convert external knowledge into different types of SOI, which are driven by various sustainability-related objectives.

Firstly, recognition capability enables a firm to identify and understand external knowledge resources. In the second step, assimilation provides the ability to integrate acquired and internal knowledge, which could result in only a slight change or in an entire transformation of the existing knowledge base (Todorova and Durisin, 2007). Finally, firms should be able to apply the new knowledge in their operations in order to improve performance.

Generally, firms use different routines for accumulation of these three capabilities, which depend to a large degree on the source of knowledge and its R&D intensity. While early investigations relied on the R&D activities of firms to examine their degree of absorptive capacity, there is growing support for the contribution of other types of skills and routines to this capacity (Bogers and Lhuillery, 2011; Vega-Jurado et al., 2008). Nevertheless, for technological changes in products and processes, R&D activities play an important role in developing the scientific knowledge base of a firm and thereby improving the capability to exploit the external knowledge acquired from research-based organizations (Horbach, 2008). Besides R&D, direct involvement in manufacturing processes and engineering activities can also trigger incremental innovations which, in most cases, can be applied to problem-solving strategies regarding specific product or process requirements (Hervas-Oliver et al., 2012). Similarly, Bogers and Lhuillery (2011) adopted a functional perspective to show that, in addition to R&D, marketing- and manufacturing-related practices in a firm also absorb the relevant external knowledge required for product and process innovations.

At an intra-firm level, recognition and assimilation capabilities could also be enhanced by linkages between competitors or firms from different sectors within an industry. In this regard, both informal interactions via employee networks and formal collaborations in the form of strategic alliances have proved to be useful (Dantas and Bell, 2009; Madhok and Osegowitsch, 2000). Therefore, whereas R&D activities lead to the creation of new knowledge, technological innovations also rely on capabilities beyond R&D that are created by combinations of already existing knowledge by means of 'learning by doing and using' (Jensen et al., 2007).

On the other hand, non-commercial innovations in terms of improvements in social practices call for an absorptive capacity that differs in terms of its underlying skills and routines. Murphy et al. (2012) delineate that, in the case of external linkages with societal stakeholders, fundamental differences between the expectations of businesses and locals lead to large learning gaps that should be bridged by effective communications. In another study of the absorptive capacity for social innovations, Veldhuizen et al. (2013) maintained that an open culture, employee involvement and an hierarchical structure drive effective dialogue and knowledge integration for sustainable innovations.

The above review reveals the lack of a thorough, fine-grained understanding of recognition, assimilation and exploitation capabilities for SOI. This informs our objective to explore the skills and routines that shape these capabilities.

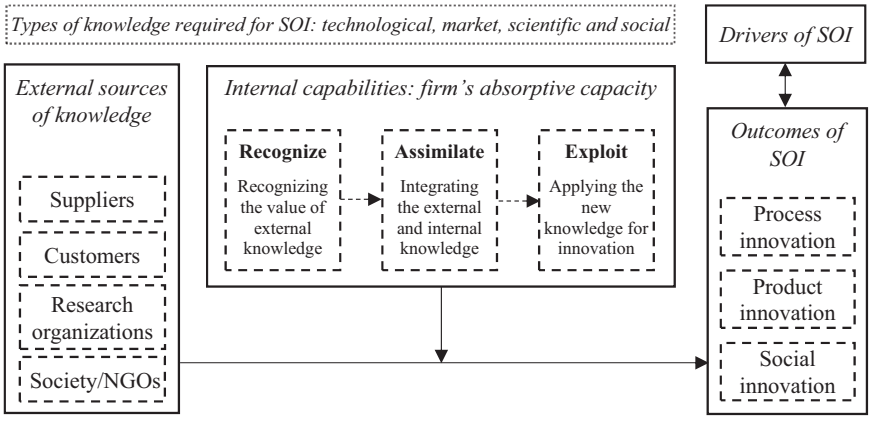


Fig. 1. Theoretical framework. Illustration by the authors according to Lane et al. (2006).

4. Research design and methodology

To answer the research question, we adopted an abductive qualitative approach that is appropriate for elaborating on existing theories where "gaps or oversights need to be filled in" (Pratt, 2009, p. 859). Considering our research question, while the literature argues for the necessity of recognition, assimilation and exploitation capabilities, the mechanisms through which these capabilities unfold in the context of SOI have yet to be thoroughly specified. Thus, our use of abductive reasoning in this paper is that we start from the general theory of absorptive capacity, hence drawing on our empirical insights to re-contextualize this theory in relation to the different capabilities for SOI. Accordingly, an embedded single-case design (Yin, 2009) is used to study various mineral companies as the subunit for our eventual unit of analysis (the industry). This allows the industry to be maintained as the target of the study for exploring the accumulation of capabilities, while at the same time investigating the micro-foundations of these capabilities at firm level by doing a comparative analysis among the companies. Regarding the subunit of analysis (embedded companies), we employed a theoretical sampling strategy (Emmel, 2013) to select cases that could provide in-depth knowledge of the phenomenon under study. Insight derived from reviewing available documents such as industry analyses and annual reports was combined with observations made at the annual meeting of the industry to select companies with certain degrees of internal and external innovation activities. We deliberately took into account a variety of cases in terms of sectors and geographical locations in Norway. Consequently, a list of 22 potential sample cases was prepared, of which 16 companies agreed to participate in our research.

The informants in this study have an executive responsibility for innovation activities in their respective companies. The aim is to capture data via people who are embedded in the phenomenon (Gioia et al., 2013), with the intention that their experience-based interpretations can provide knowledge of the characteristics of capabilities and innovation practices in their companies. None of the authors knew the informants beforehand, and nor did they have any relationships or engagement with the companies. To collect the required data, we prepared a list of questions that revolved around drivers of innovation, various knowledge-exchange mechanisms and internal processes for building innovation capabilities. We deliberately did not use the term 'sustainability' during the interviews to avoid potential social desirability bias. This list of questions, together with a procedural explanation of the data collection, led to the development of an interview protocol (see Appendix A) that supports the reliability (replicability) of our research (Yin, 2009). The first author conducted the interviews via Skype, which enabled a close face-to-face connection with the informants, regardless of their geographic dispersal (Deakin and Wakefield, 2014). The interviews lasted on average one and a half hours, and were conducted during a 6-month period in 2016.

All the interviews were recorded and transcribed, and totaled 220 pages of single-spaced text. We used the NVivo software package to carry out the analysis in three main phases, i.e. coding, classification and cross-tabulation. Based on the principles of inductive thematic analysis (Gioia et al., 2013), we followed a consecutive and recursive process of coding and classification. Firstly, the authors read the data independently and looked for concepts and expressions related to sustainability drivers, different types of SOI, internal capabilities and external sources of knowledge. This first-order analysis led to the identification of 86 distinct concepts. In the second phase, we discussed the similarities and differences between these concepts across the cases in order to classify them under fewer themes, which left us with 27 distinct groups, which we called second-order themes. Then, after several recursive processes of consultation with the existing literature, these themes were reduced to seven ultimate constructs. In the third and final phase of the analysis, the relationship between the emerged constructs was tabulated in a co-occurrence matrix, which indicates pieces of data that receive two specific codes. This matrix has the advantage of providing both qualitative and quantitative (i.e. how many times a co-occurrence is evidenced) insights, allowing us to look for patterns that link SOI types with drivers of sustainability, external linkages and internal capabilities. Appendix B presents an example section of the data structure to illustrate the emergence of ultimate constructs from first-order codes, together with an overview of the second-order themes.

In order to establish the credibility of our findings, we considered two strategies to check for construct and external validity (Yin, 2009). Firstly, the transcripts were sent to the interviewees to obtain their feedback and further reflections. When available, the interview data were triangulated with other information from each company (such as annual reports, news and data from conference presentations and internet documents) to check the consistency of the data. In the case of inconsistencies, we asked the informants for clarifications and comments concerning specific points. Secondly, the multiple cases embedded in our holistic case enabled us to apply replication logic (Yin, 2009, p. 54) by means of looking for similar (literal replication) and contrasting (theoretical replication) results across our cases, thereby increasing the generalizability of our findings to other similar contexts.

5. Findings

5.1. Descriptive case findings

The companies in our study belong to the four main sectors of the minerals industry in Norway, namely construction minerals, metallic ores, industrial minerals and natural/dimension stones. Among these 16 companies, five are large, six are medium-sized, four are small and one is a micro-enterprise.[2] For reasons of confidentiality, the original names of the companies were changed to the letters A–P and are referred to by these letters throughout the paper. Appendix C presents an overview of the case companies and interviewees.

As shown in Appendix B, the outputs from NVivo provide some descriptive statistics of the data, including the number of times that a specific concept or expression appeared in the transcribed interviews. Considering the different types of SOI in the minerals industry, process innovations seem to be more prevalent (being mentioned 70 times by the interviewees), followed by product and social innovations (58 and 37 references, respectively). Our results indicate that suppliers and research organizations are the most frequent external sources of knowledge used in the Norwegian minerals industry, while companies have yet to establish appropriate mechanisms for gaining knowledge from their societal stakeholders and customers. These external linkages represent a diversity of networks in terms of geographical location, ranging from local societal stakeholders to those that cross national boundaries. Interestingly, the results evidence that local and international networks are used equivalently, which in turn points to the fact that the knowledge required for SOI is geographically dispersed.

In the following, the case study results are presented in three sections based on the related sets of final constructs that emerged from the coding process. The first set demonstrates the link between drivers of SOI activities and their outcomes; the second set discusses the characteristics of linkages with external knowledge sources; and the third section synthesizes the findings around processes for developing absorptive capacity.

5.2. What are the drivers and outcomes of SOI activities in the minerals industry?

Norwegian mineral companies are primarily concerned with innovating within their extraction and production operations. These

[2] Micro, small and medium-sized companies are those with fewer than 10, 50 and 250 employees, respectively (European Commission, 2012).

Table 2
Illustrative quotes regarding the characteristics of external linkages.

Knowledge source	Acquisition mechanisms	Geographical breadth	Illustrative quotes
Suppliers	• Transactional (purchase of machinery, contracting out technical services) • Collaborative (technology development projects)	Mostly within Scandinavia/ European Union	"There is a certain supply of equipment from Scandinavian players, I mean both Sweden and Finland, that have a strong supplier sector for the mining industry which are quite front end-oriented and innovative in many ways." (Company N) "Collaboration [with technology suppliers] is not common, with some exceptions for example (…) because they needed data about the metallurgical properties of our raw material to develop their washing equipment." (Company E)
Customers	• Transactional (monitoring the markets, conferences, on-site visits) • Collaborative (product development projects)	Varied, depending on the target market	"I'm actively taking part in international conferences, so we have a general clue about what is happening in our potential markets and their demand." (Company A) "I think the development of our X product fits very well with the definition of a collaborative relationship as we were in close collaboration with the solar cell manufacturers from the start of that project." (Company J)
Universities/research institutes	• Transactional (outsourcing R&D services, personal contacts with researchers) • Collaborative (R&D projects)	Mostly nationally focused	"We initiated mineral exploration in a very unconventional area where we have collaborators from NTNU and a university in Denmark." (Company B) "At the meetings organized by the industry cluster, people from the research organizations share their knowledge about specific issues of interest for the industry." (Company J)
Society/NGOs	• Collaborative (open meetings with the locals, dialogue with NGOs, form expert groups from local businesses)	Local but in some complex cases extending to national scope	"Before making final decisions, we found and involved those people who were more willing to be engaged and then organized them in several groups to take care of some of the development requirements." (Company P) "We are aware that it will not be enough if the knowledge only goes one way, for example only by distributing some reports." (Company I)

process innovations usually occur in the form of utilizing new technologies and making continuous incremental improvements to existing equipment or processes. While such improvements have been important due to the quest for cost-cutting, pressure from environmental regulations made it inevitable that advanced technologies would be employed. According to case L:

> *"(…) so the further development in this industry relies on production processes that are able to increase the yield, decrease the waste materials and pollutants, and make progress in energy efficiency."*

The above quote signifies a trend in the sample that suggests the existence of three main drivers for process innovations in this industry: reducing emissions and waste; increasing productivity; and improving energy efficiency. Productivity enhancement, which includes factors such as labor, resource and capital, has always been at the top of the agenda for managers in this industry. In Norway, the existence of an attractive oil and gas sector that attracts a large share of funding opportunities, as well as high labor costs, intensifies the importance of productivity for economic sustainability. On the other hand, waste/pollution reduction and energy-efficient strategies are mostly directed towards environmental sustainability through either end-of-pipe solutions such as utilizing water treatment equipment or more proactive and strategic practices, including recovery/reuse processes and the employment of clean technologies.

While the industry is mostly concerned with process improvements, the interview data show that two objectives motivate the companies to undertake product innovations: increasing the quality (purity) of their raw-material products; and finding new applications for the minerals. As the chief executive officer (CEO) of company G remarked:

> *"The idea in our company as our survival strategy was to look into the different ore minerals and investigate what kinds of special applications could be developed for those minerals."*

Moreover, the R&D manager of company J explained what forces them to focus not only on process improvements, but also on new-product developments:

> *"(…) there will be then an increased demand for highly purified minerals that are absolutely necessary for production of more sustainable solutions for power production, electric cars, windmills, etc. And to achieve our objectives in product development projects, changes in machinery and enrichment processes are required."*

Tougher competition in the market for raw materials, especially in the metallic ore and industrial minerals sectors, has urged companies to invest in developing specialized products for niche markets. For example, one company in our sample is involved in developing an entirely new product that can assist in removing nuclear pollutants. In this way, the company will be able to bring environmental value to society while ensuring its competitive advantage in a rather saturated market for standard products.

Besides innovative outcomes in processes and products, we found an increasing awareness about societal issues which, in turn, led to the creation of a third innovation path, i.e. social innovation. As stated by the CEO of company D, whereas creating a better social profile could be achieved as a by-product of improvements in areas such as pollution control, the increasing power of interest organizations requires additional efforts with clearer contributions to social well-being:

> *"During several interactions with stakeholders, we have learned that the community around our mine expects us to provide more jobs in the region. This is now one of our highest priorities that can strengthen our tie with them."*

We conclude that there is a necessity to ensure a 'social license to operate' in order to achieve sustainability in this industry, because insufficiency of social practices might result in having to cease or delay operations at the mine. Therefore, social innovations could enable the minerals industry to obtain social approval as an essential component of their long-term economic sustainability strategy.

5.3. What characterizes external-learning linkages for minerals sustainability?

All the firms in our study had some experience of incorporating external sources in their innovation processes, including suppliers, customers, research organizations and local communities/interest organizations. As depicted in our theoretical framework, we distinguish between these linkages in terms of their knowledge content, i.e. technical, scientific, market and social knowledge. The case study shows that such a variation resulted in using different mechanisms for acquiring external knowledge, as well as reconciling the geographical scope of the knowledge search. Table 2 presents some example quotes to illustrate the knowledge acquisition mechanisms and the geographical breadth of external linkages with the four aforementioned knowledge sources.

In Norway, and as far as our sample represents, linkages between the mineral companies and their suppliers occur mostly on a transactional basis, in the form of buying machinery and technical services. Choosing the right suppliers appears to be particularly appropriate as it enables the mineral companies to gain access to the high-quality knowledge embedded in efficient/clean technologies and/or people. To maximize the benefit from such learning, a firm should exhibit a specific level of internal knowledge that is necessary for implementing and customizing the technologies. Indeed, we found that buying ready-to-use technologies is becoming less common as greater interaction between equipment suppliers and mineral companies (users of technologies) is needed during customization of the final solutions:

> *"When we need equipment, we usually refer to our selected suppliers that are located wherever in the EU. So they come back to us with their offers (…) then we enter into a contract to customize the equipment based on our specific requirements."*

When necessary, relationships with suppliers may turn out to be highly collaborative. The main logic behind collaborative arrangements is to ensure the mutual flow of knowledge between the mineral companies and their suppliers, which in turn emanates from the complexity of knowledge required to develop the final process solution. For instance, in the case of company E (see Table 2), the unconventionality of the raw material has made it inevitable for the company to collaborate closely with its washing equipment supplier and to provide them with access to operational data over a relatively long period. The complexity aspect of knowledge also resonates by broadening the geographical scope of linkages with suppliers, as the need for advanced technological solutions and expertise increases the importance of being aware of global actors and their offerings. Although geographical distance may decrease the ease of knowledge flow, the existence of institutional frameworks such as trust-based culture and policies for promoting partnerships could remove some of the obstacles. As remarked by several companies in our study, closely related cultures and the existence of policy initiatives for nurturing collaboration in the Nordic region are decisive factors for the flow of technology and knowledge from Sweden and Finland, which are the homes of strong supplier industries.

> *"I would say that they [our relationships with suppliers] are more often regional, and by region, I'm thinking about Scandinavia. Sometimes we have contacts in other countries (…) but the point with the Scandinavian partners is that we easily trust each other." – Company H*

While doing business in such a globalized industry does not allow for price competition, the majority of our cases showed their increasing interest in monitoring market changes and product innovations. In most cases, the person responsible for the marketing activities of the company was evidenced to be in charge of monitoring the markets, particularly those in high-tech and/or renewable energy industries. In smaller companies, the CEO plays this gatekeeper role, whereas in larger ones the sales manager/market developer is the one who tries to ensure that the relevant market knowledge is transmitted to the company. Nevertheless, developing radical products pushes downstream linkages to be more collaborative, instead of just a one-way knowledge flow to the mineral companies. This radical nature relates to an entirely new application (e.g. the development of a mineral product for remediation of radioactive waste from the sea) or to advanced technical knowledge (e.g. producing crack-free and low-emission concrete). As noted by company C:

> *"We collaborate a lot with concrete producers. Especially with one of them, we are combining our technical expertise and production employees in order to find out the best possible way to make good concrete."*

The findings on the geographical breadth of downstream linkages show notable variance among companies in the minerals industry. On some occasions, especially in the case of industrial minerals, the knowledge-exchange process occurs in a broadly international domain. This is also the case for complex and radical innovation projects. In contrast, in the case of construction minerals, the physical characteristics of which are to a large extent location-dependent, companies look for market knowledge from customers in their vicinity. Moreover, as customers tend to consider the sustainability of a product's life cycle from the very beginning, it is important to involve them in product development projects at an early stage.

Norwegian research organizations have traditionally played a significant role in creating the scientific competencies required for developing the country's resource-based industries (Fagerberg et al., 2009). As expected, little internal R&D activity in the minerals industry is compensated for by outsourcing the production of scientific knowledge to competent institutions and universities. The Norwegian University of Science and Technology (NTNU) and the Foundation for Scientific and Industrial Research (SINTEF) are the most significant players in this regard. In some cases, mineral companies had some experience of being engaged in collaborative and publicly funded research projects led by a big research organization such as SINTEF or NTNU. However, involvement in large projects requires more internal resources (both financial and human) and trust, and hence the lack of any of these factors could result in a preference for dyadic relationships (i.e. those between a single company and a research organization) rather than those that involve other companies and research organizations.

> *"When we collaborate with a research institution, we share proprietary information about our processes or products. When other companies are a part of a project, we are afraid of losing this information to our competitors." – Company O*

The data signify that the minerals industry is mostly nationally oriented when it comes to scientific linkages. Indeed, the presence of a globally competitive process industry (in terms of both cleanliness and productivity) in Norway has led to the development of strong research groups within the universities/R&D institutes that leverage their internal skills and external networks to supply a large share of the required knowledge in the minerals industry. Nevertheless, in a couple of cases where the aim was to develop advanced products or to undertake patent-driven research, mineral companies opted to involve foreign research organizations. Interestingly, even in these cases, a Norwegian research organization was also part of the collaboration, in order to ease the acquisition and further application of the scientific knowledge.

Our case study also sheds some light on the characteristics of linkages with societal stakeholders. Firstly, we found evidence to argue that companies are incrementally moving towards collaborative knowledge exchange, using mechanisms such as dialogue with interest organizations (e.g. environmental non-governmental organizations [NGOs]) about their environmental impact, which could consequently lead to remedial actions within the operations. Secondly, the degree of organizational involvement is increasing as companies are trying to incorporate knowledge about social issues into various organizational levels and functions in order to address the complexity of absorbing this

type of knowledge. Following the CEO of company B:

> *"Obtaining [social] information is expensive. I don't mean monetary value, but the amount of time and engagement that should be spent. When we want to discuss with the communities, a team including managers, consultants and production engineers has to show up."*

Thirdly, social linkages are found to be geographically limited to where the mine or processing plant is located. This is due to the high local impact of the minerals industry, both in a positive (regional development) and negative (socio-environmental impact) manner. Moreover, social knowledge is mostly intuitive (e.g. the expectations of locals) and based on context-specific experience (e.g. nature-based activities such as fishing or reindeer husbandry) that adds to its tacitness and the difficulty of assimilation. Therefore, geographical proximity to the external sources of social knowledge could assist mineral companies in converting the relevant knowledge into innovative outcomes.

5.4. What capabilities underlie the absorptive capacity for SOI?

Considering the findings presented in Sections 5.2 and 5.3, mineral companies exhibit capabilities that absorb various types of external knowledge (technical, scientific, market and social) in order to practice process, product and social innovations. As the process perspective on absorptive capacity illustrates (see Fig. 1), these capabilities can be categorized under recognition, assimilation and exploitation processes. Our data suggest that four types of capabilities underlie these processes: (1) keeping abreast of changes in technologies and markets; (2) increasing awareness about social issues; (3) facilitating internal knowledge dissemination; and (4) piloting new, innovative solutions. While the first two capabilities focus on identifying and understanding external knowledge (recognition), the third and fourth lay the foundations for integrating it with prior knowledge (assimilation) and applying the resultant new knowledge for innovative purposes (exploitation), respectively. Table 3 summarizes the findings regarding these capabilities and their micro-foundations (underlying skills and routines).

With regard to recognition, mineral companies seem to require a specific degree of *prior knowledge* on related technologies and markets to locate and understand the external knowledge. To follow up the continuous changes in what the potential markets for minerals perceive as sustainable solutions, some cases in our study referred to practices such as participation in conferences, which is not only a knowledge source in itself, but also an arena enabling them to identify other sources of knowledge by means of networking. On these occasions, the market knowledge accrued by the company acts as a facilitator for future knowledge acquisition through the existing network. Moreover, keeping abreast of changes in technologies and markets necessitates an ability to *employ the relevant staff* and *train* them on a regular basis. Our case study shows that understanding the knowledge embodied in technologies plays a central role in innovation activities in this industry. The proper operation of equipment requires a substantial level of prior experience at the individual-employee level that is not available based on existing skills or via user manuals/general instructions. Therefore, companies opt to recruit technicians who, through their earlier careers have the practical skills to work with specific equipment. In cases where some prior knowledge exists, training and continuing education seem to be more prevalent due to the high cost of labor in Norway. On-the-job training has been found to be particularly important for familiarizing staff about the incremental technology developments regarding waste reduction and recycling processes. As noted by company I:

> *"The main reason [to educate employees] has been to adjust our production processes according to the environmental regulations since they are sometimes changing overnight."*

The recognition component of absorptive capacity in our case study demonstrates a specific capability for understanding external social knowledge, referred to here as awareness about social issues. In this regard, we found that acquiring social knowledge relies primarily on the *managers' desire to act ethically*. This desire is a decisive factor for establishing a positive reputation in local communities, which consequently makes them willing to share their knowledge with the mineral companies. In contrast, as noted by company H, companies that only respond to coercive forces (e.g. pressure from the government) are often perceived by societal stakeholders as possessing a lack of responsibility, thereby losing the opportunity to build trust-based relationships and gain access to the valuable knowledge required for continuous improvements in social sustainability.

> *"These [environmental] rules are quite strict in Norway and the government forces us to follow the best practices for tailings disposal (…) but here the challenge is to get the locals to trust in us and collaborate with us."*

Table 3
Illustrative quotes about the micro-foundations of capabilities for building absorptive capacity.

Identified capabilities and micro-foundations		Excerpts from the interviews
Recognition	(1) **Keeping abreast of changes in technologies and markets**	"(…) recruited from northern parts of Sweden and Finland since we purchased new equipment from suppliers in those countries" (Company D)
	– *Prior knowledge base*	"Cooperation with technical colleges for training our employees is helping us to secure the need for competence" (Company C)
	– *Recruiting new technicians and university graduates*	"(…) achieving success when the managers had a passion for resolving social conflicts" (Company K)
	– *Employee training and continuing education*	"(…) the corporate social responsibility (CSR) projects were truly small, so we had to be quite realistic about the target and be specific on the required information to meet those targets" (Company I – regional manager)
	(2) **Increasing awareness about social issues**	
	– *Managers' desire to act ethically*	
	– *Setting specific objectives for responding to social issues*	
Assimilation	(3) **Facilitating internal knowledge dissemination**	"(…) promoted communication inside the company in such a way that it became part of the organizational culture" (Company D)
	– *Sharing experiences among co-workers in a specific unit/function*	"To ensure knowledge sharing among more than one plant, we expect the unit managers to arrange meetings to find a solution" (Company F)
	– *Intra-firm communication channels across technical, market and social knowledge bases*	"To modify our product, we should fully understand a customer's desired specifications for the product, (…) and this knowledge is not something that our marketing people have. Then (…) discuss it internally within the production and R&D departments" (Company G)
Exploitation	(4) **Piloting new innovative solutions**	"In these changes [on the machinery], the employees' knowledge about our minerals and processes is essential to experiment [with] what works and what doesn't work" (Company L)
	– *Experimentation and testing process-related changes*	"(…) to decrease the rest materials by implementing a new technique for drilling and blasting (…), but we had to check with one of our customers first to see whether they are satisfied with the new product" (Company M)
	– *Piloting new products and socially related practices on a small scale*	"After publishing our first sustainability report, we recognized through our meetings with environmental activists that caring about the employees' safety is something that might capture their interest. Then we used this insight in our future communications with them" (Company B)
	– *Maintaining external relationships to receive appropriate feedback*	

The desire to act in accordance with social expectations is then combined with the capability to *set specific social objectives*, as the complexity of environmental and social issues might hinder companies for approaching them at the right time (i.e. prioritizing daily operations due to the lack of sufficient time and financial resources). As seen in cases I and O, breaking down complex issues into specific targets and communicating those targets to the societal stakeholders helped the companies to identify experts or interest organizations as potential sources of social knowledge.

Concerning assimilation, the findings suggest that *internal knowledge dissemination, both within and across different units/functions,* is required to integrate external knowledge with existing skills and abilities. To ensure this integration, some cases in our sample have managed to reach such a level of maturity in internal communication that knowledge sharing became part of their organizational culture. Arranging periodic meetings and encouraging peer-to-peer interactions are perceived to be fundamental parts of assimilation, as a great deal of knowledge about technologies, markets and social issues is tacit and cannot flow easily without face-to-face communications. More interestingly, as pointed out by cases B and N, the necessity for involvement of various functions in the assimilation processes is likely to increase across the spectrum from technological to social knowledge. That is, in order to integrate external market knowledge, technical staff from production and R&D functions should also be involved, as well as those responsible for marketing activities, and for social knowledge, in addition to the above, those in charge of communication with societal stakeholders should also be engaged.

> *"Our systematic view to information from locals or voluntary agencies gives us a good way of improving and making more sense from them (…) they speak a different language that is not easy to understand (…) so different people work together in organized teams." – Company N*

In this respect, knowledge-sharing processes that happen between firms are also crucial. For instance, companies that use similar machinery and technical processes – such as those involved in the metallic ore and industrial minerals sectors – noticed a benefit from sharing their experiences, which in turn resulted in assimilation at an inter-firm (industry) level. Nevertheless, coordinating inter-firm knowledge sharing seems to be challenging for individual companies, and this is where intermediary organizations such as the Mineral Cluster Norway[3] and the Association of Norwegian Mineral Industry[4] are crucial in providing such opportunities.

> *"We are a member of a technical committee in the industry association (…) once we talked about our problems with equipment. This is a problem for the whole industry (…) so our aggregates were used as a case and we get good ideas from other companies." – Company E*

Finally, insights into how companies exploit knowledge resulting from assimilation processes support the existence of three interrelated capabilities: *experimentation*, *small-scale testing* and the *maintenance of external relationships*. As reflected in the quote from case L in Table 3, experimentation represents utilizing a combination of knowledge, particularly on technical solutions, for the purpose of trial and error and incremental changes. In such cases, knowledge gained from elsewhere (training, co-workers, etc.) is combined with prior experiences for further 'learning by doing' and the achievement of innovative outcomes. Similarly, we evidenced that successful product and social innovations need to be tested by users and stakeholders on a small scale, before implementation in larger projects and markets. As noted by the companies themselves, addressing sustainability often entails some trade-off between its different aspects, which in turn necessitates testing an innovative solution before final development and implementation. For instance, achieving a lower environmental footprint may come at the expense of lower product quality (e.g. the durability of a natural stone) and challenges with regard to satisfying customers. Therefore, as the third capability for exploitation depicts, successful exploitation requires the ability to retain external linkages up to the point that the desired commercial or non-commercial (e.g. social) value is created. This capability serves as a feedback loop from the exploitation step to the acquisition of new knowledge from external sources.

6. Discussions

6.1. Discussion of findings

This qualitative study adopted a process view of absorptive capacity to explore the capabilities for recognition, assimilation and exploitation of external knowledge in order to undertake SOI activities. More specifically, attention was directed towards capabilities for pursuing a broad innovation approach, where learning from various external knowledge sources is necessary for economic, environmental and social sustainability. To this end, we demonstrated the knowledge characteristics that condition the use of knowledge-acquisition mechanisms, and revealed a set of skills and routines that contribute to the development of certain capabilities for absorbing the acquired knowledge.

Regarding the mechanisms for knowledge acquisition, we followed the open-innovation literature and differentiated between transactional and collaborative types of relationships with external knowledge sources (Greco et al., 2016). Our findings suggested that, while mineral companies generally take advantage of both of these mechanisms, choosing one or the other depends on the complexity and tacitness of the knowledge, so that high complexity and/or high tacitness are conducive to the use of more collaborative mechanisms. As proposed by Lane et al. (2006), these two knowledge characteristics are important factors as they explain the ease of gaining access to the external knowledge bases. In this regard, while tacitness depicts the extent to which the knowledge can be codified and transferred, complexity refers to how unknown (in terms of a technology or market) a form of knowledge is for a company.

In the case of technical knowledge where suppliers are the major source, the knowledge flow seems to be primarily one-way (towards the mineral companies), unless the suppliers' existing technical solutions and services do not meet the process requirements. In these complex (technological) situations, mineral companies contribute to the production of new knowledge (e.g. washing equipment) by means of providing information and the opportunity to test the equipment in a real operating environment (Lager et al., 2015). Similarly, with regard to scientific and market knowledge, transactional mechanisms have been found to be more prevalent, as collaborations designed to develop these types of knowledge – which are often far beyond a mineral company's knowledge base – could disperse internal resources and have a detrimental effect on the innovation outcomes (Greco et al., 2016). With respect to social knowledge, tacitness plays an important role in motivating the mineral companies to collaborate with their societal stakeholders. Knowledge about social issues and the expectations of locals could not be codified as it involves individuals' perceptions about the impacts of a company (Hall et al., 2003; Suopajärvi et al., 2016). Thus, mutual interactions are necessary for building trust-based relationships, which in turn result in shared understandings about social issues and the expectations of local communities regarding the minerals industry.

For recognizing (understanding) the external knowledge, our data corroborate the importance of prior knowledge within a company for building absorptive capacity (Cohen and Levinthal, 1990). Contrary to the traditional approaches to innovation, SOI necessitates a broader range of prior knowledge regarding technical, scientific and market aspects, as well as a desire by managers to participate in knowledge-exchange processes with societal stakeholders (Sharma, 2005). Moreover, while prior knowledge and a desire by managers to act ethically

[3] http://www.mineralklyngenorge.no.

[4] https://www.norskbergindustri.no/about-us—info-in-english/.

represent static capabilities (i.e. resources), we argue that successful recognition requires dynamic capabilities, such as new recruitment and training, that assist mineral companies to keep abreast of changes in technologies and markets. In his seminal paper, Teece (2007) suggests that rapid changes in the business environment call for continuous modifications to a company's knowledge base. Accordingly, in line with Lozano (2015), our findings indicate that sustainability transition implies rapid changes in technologies, market demands, environmental regulations and social expectations, thereby highlighting the importance of continuous learning through organizational routines such as employee training that consequently increase a company's ability to understand the external knowledge.

Our case study provides supporting evidence for the importance of internal knowledge dissemination as a capability for the assimilation (integration) of external knowledge. The existing literature on absorptive capacity argues that formal and informal mechanisms of knowledge exchange within a company facilitate knowledge dissemination by means of closing the cognitive gap among the employees (Vega-Jurado et al., 2008; Zahra and George, 2002). As formal mechanisms such as using knowledge-exchange coordinators and job rotation have yet to be developed in the Norwegian minerals industry, internal knowledge dissemination hinges on informal peer-to-peer interactions. We further contributed to the existing literature by demonstrating the interrelatedness between the assimilation of different knowledge types in sustainability contexts. While successful integration of technical and scientific knowledge entails interactions between a relatively limited number of employees (mostly those involved in production), combining external market knowledge involves a knowledge exchange between those in charge of production and marketing activities. These cross-functional interactions become even broader in the case of social knowledge (Murphy et al., 2012) which, according to our findings, is of a different 'language' and its further application in innovative activities demands the contribution of several functions within a firm.

Finally, this paper proposes that the exploitation of external knowledge in sustainability contexts rests on appropriate capabilities for testing and piloting innovative, new solutions, regardless of their type (product, process or socially oriented practices). This finding contributes to the debate on the importance of considering commercial and non-commercial interests in SOI processes (Amui et al., 2017; Watson et al., 2017) by showing that long-lasting external linkages with societal stakeholders and customers can create mutual value for both the focal company and its collaborators. As a fundamental capability in such linkages, piloting innovative solutions provides significant feedback to a mineral company, enabling it to align its ultimate solution with the needs of customers and/or societal stakeholders (Murphy et al., 2012).

6.2. Implications for managers and policymakers

Considering the three outcomes of SOI, policymakers and managers should get involved in efforts that go beyond the frequent focus of the minerals industry on process improvements and economic sustainability. Specifically, pursuing a social innovation path to tackle broader sustainability issues calls for policy interventions that aim to increase awareness about social issues (van der Have and Rubalcaba, 2016). Taking a capability perspective, these policies should be directed towards establishing a range of mechanisms for public engagement, from formal acts such as regulations concerning the involvement of minority groups to informal forums for dialogue between the companies, locals and interest organizations. In this regard, the existence of performance evaluation frameworks such as Towards Sustainable Mining in Canada or Finland is crucial in providing key indicators for measuring the effect of social linkages.

Owing to the financial and human resource limitations of individual mineral companies, strengthening industrial clusters and professional associations should be placed at the core of policy support tools to bring together various companies and external knowledge sources. Although the role of innovation intermediaries has rarely been discussed in the context of non-high-tech industries, recent research suggests that these organizations could help companies in the implementation of open innovation by reducing misunderstandings between managers and creating an arena for discussions among the industrial actors, governmental agencies and societal stakeholders (Radnejad et al., 2017). While the intermediary organizations in the Norwegian minerals industry are primarily focusing on forging external links with suppliers and universities, engaging governmental agencies such as Innovation Norway[5] could offer funding and network opportunities to promote links with potential markets for raw materials. Moreover, industrial clusters and associations could act as neutral organizations between the mineral companies and societal stakeholders (e.g. NGOs) by involving the latter in knowledge-exchange arenas regarding social issues.

As for building the absorptive capacity for SOI, managers should extend their organizational capabilities beyond the recognition component, in order to take full advantage of external knowledge. In this regard, firstly, more effort is required to assimilate technical, market and social knowledge that often resides in various functions or individuals within a firm, and which consequently hinders its application in addressing broader sustainability issues via innovative activities (Watson et al., 2017). Accordingly, companies need to combine informal and formal mechanisms for internal knowledge dissemination to respond to the challenge of integrating various types of knowledge into their existing knowledge bases. Secondly, our findings signify the necessity of ongoing external linkages even in the knowledge-application step, in the sense that the new products or practices (as outcomes of the exploitation of new knowledge for innovation) meet the expectations of both the company and its stakeholders. As proposed by Watson et al. (2017), this mutual understanding is particularly important for accommodating varying expectations when economic sustainability runs counter to environmental and social sustainability.

We reiterate that addressing sustainability objectives via innovation is a demanding goal that implies the accumulation of a broad range of capabilities and the efficient functioning of various external linkages. Therefore, policymakers and managers should maintain a balance between policies and strategies for building the four types of capabilities by taking into account the types of innovation outcome and the different components of absorptive capacity.

6.3. Conclusion and future research

To conclude, we believe that this study sheds some light on the determinants of absorptive capacity for innovations aimed at sustainability. By building on the extant literature and a rich empirical insight from the Norwegian minerals industry, we demonstrated how mineral companies can build appropriate capabilities concerning the different components of absorptive capacity, i.e. recognition, assimilation and exploitation. While some skills and routines for building these capabilities exist, more effort is needed to increase understanding about the various types of knowledge relevant to sustainability contexts. More importantly, company-level strategies and national policies should address the issue of strengthening the ability of firms to integrate and apply external knowledge, with the aim of fulfilling different sustainability objectives.

Nevertheless, this study has some limitations. The first concerns the generalizability of the findings to other industrial settings that differ in character from Norway's minerals industry. Therefore, we call for future studies in other resource-intensive industries and national contexts, possibly in countries with dissimilar market and innovation characteristics. In doing so, taking a longitudinal approach is highly preferential as it will allow researchers to examine how these

[5] http://www.innovasjonnorge.no/en/start-page.

capabilities and their underlying routines change over a period of time when firms/industries move through different SOI paths. Second, our approach using qualitative data does not allow for an objective measure of innovation outcomes and of how our interviewees differentiated between incremental and radical innovations. To extend the theoretical understanding, research could employ a quantitative design and use survey-based data to test our arguments. Despite these limitations, we believe that our work makes theoretical and practical contributions to the topic of sustainability in the minerals industry, and could serve as a springboard for future investigations.

Appendix A. Interview protocol for the study

Interviewee: ……..
Company and Position: …….
Date and time: ……...
Duration: ……
Pre-interview comments: …….

Introduction

To facilitate our note-taking, I would like to record our conversation. For your information, only researchers on the project will be privy to the recorded interviews, which will be eventually deleted after they are transcribed.

We have planned this interview to last no longer than one hour. During this time, we have several questions that we would like to cover. If time begins to run short, it may be necessary to interrupt you in order to push ahead and complete this line of questioning. Besides these questions, our line of discussion might raise some extra questions and comments.

You have been invited to participate in this research because you have been identified as someone who has a great deal to share about innovation, knowledge exchange and capability building in the minerals industry. This PhD research project as a whole focuses on the improvement of innovation performance in the industry, with particular interest in understanding how the flow of knowledge and relevant capabilities contribute to that performance. Our study does not aim to evaluate your company's activities or your own experiences. Rather, we are trying to learn more about innovation process, and internal and external practices that are important in this regard.

Interview questions

1. Could you please tell me about the main challenges of your company regarding innovation?
2. How do you deal with these challenges?
3. What are the main opportunities in your business?
4. How can these opportunities be maximized and result in value creation?
5. How does innovation help your company to deal with the challenges and opportunities?
6. Please describe the innovation process in your company.
7. Who are mostly involved in the innovation activities of your company? Both in terms of business units and organizational levels.
8. Please briefly describe how you look for knowledge outside your company.
9. What kinds of practices do you use for bringing in the external knowledge?
10. For which purposes do you use external knowledge in your activities?
11. Could you give me an example of a successful collaboration and a failure example?
12. In your company, what are the internal resources and skills required to do innovation?
13. What motives or purposes are pivotal when you want to choose an external knowledge source?
14. Are there any particular characteristics regarding the type of knowledge you use in your different innovation activities?
15. What are the main knowledge exchange arenas in this industry in Norway?
16. Please briefly describe how knowledge flow happens in those arenas.

Post-interview comments: …….

Appendix B. From second-order themes to ultimate constructs

Drivers of SOI
- Developing specialty products (36)*
- Improving energy efficiency (49)
- Improving employment attractiveness (19)
- Increasing productivity (45)
- Supplying the best quality of raw materials (21)
- Reducing emission and waste (53)
- Obtaining social approval (22)

Capabilities for absorptive capacity
- Recognition – technology/market changes (73)
- Recognition – awareness about social issues (23)
- Assimilation (64)
- Exploitation (31)

Outcomes of SOI
- Process innovation (70)
- Product innovation (58)
- Social innovation (37)

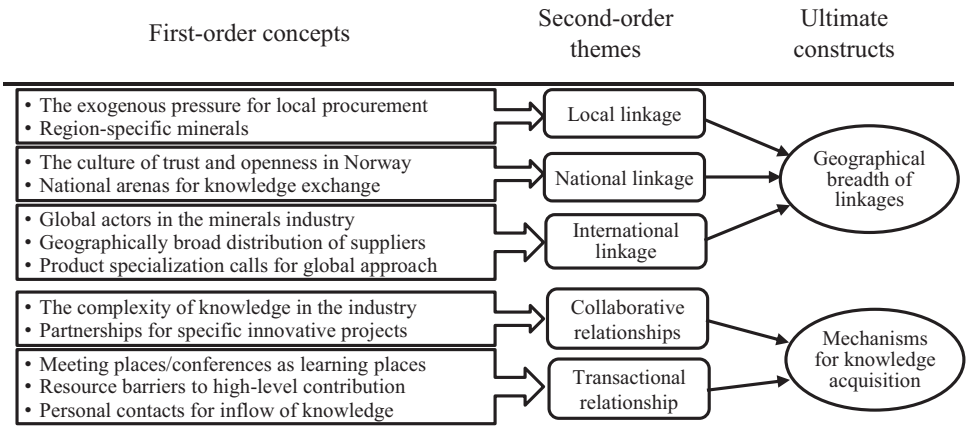
External sources of knowledge
- Suppliers (105)
- Research organizations (92)
- Society/NGOs (47)
- Customers (59)

Knowledge acquisition mechanisms
- Collaborative relationship (57)
- Transactional relationship (54)

Type of knowledge required for SOI
- Technical know-how (65)
- Market knowledge (37)
- Scientific knowledge (52)
- Social knowledge (35)

Geographical breadth of linkage
- Local linkage (40)
- National linkage (35)
- International linkage (42)

*The numbers show how many times the second-order themes were mentioned by the interviewees.



Appendix C. Demographic overview of the interviewees

Company	Sector	Interviewee's position	Date of interview
A	Natural and dimension stone	Sales manager	15.12.2015
B	Metallic ores	CEO	18.12.2015
C	Construction minerals	CEO	21.12.2015
D	Metallic ores	CEO	11.01.2016
E	Construction minerals	Production manager	19.01.2016
F	Construction minerals	CEO	16.02.2016
G	Industrial minerals	CEO	18.02.2016
H	Industrial minerals	CEO	09.03.2016
I	Construction minerals	Regional manager	10.03.2016
J	Industrial minerals	R&D manager	06.04.2016
K	Construction minerals	Production manager	07.04.2016
L	Natural and dimension stone	CEO	08.04.2016
M	Natural and dimension stone	Business development manager	21.04.2016
N	Metallic ores	Chief commercial officer	03.05.2016
O	Industrial minerals	Process development manager	06.05.2016
P	Industrial minerals	CEO	11.05.2016

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social issues increases the necessity to understand the needs and impacts of a wide variety of stakeholders regarding innovation outcomes (Hall and Vredenburg, 2003; Sharma, 2005). To this end, companies are increasingly adopting open innovation, which is defined as "a distributed innovation process that involves purposively managed knowledge flows across the organizational boundary" (Chesbrough and Bogers, 2014). Examples in the mineral industry that evidence such an open approach to innovation are Anglo American's open collaboration forum (Waller, 2014), LKAB's joint venture with two equipment manufacturer for the development of remote monitoring technology (Westergren and Holmström, 2012), the involvement of local communities in gold mining in Central America (Erzurumlu and Erzurumlu, 2015) and the intensive collaboration regarding Elkem Solar Silicon (Ceccaroli and Tronstad, 2016).

As open innovation moves the locus of innovation outside organizational boundaries, innovation capabilities will depend on the absorptive capacity of firms, i.e. their ability to utilize externally acquired knowledge (Cohen and Levinthal, 1990; Lawson and Samson, 2001). We follow the definition of Lane et al. (2006) of absorptive capacity, which suggests a sequential process of 'recognize, assimilate and exploit' for building this capacity. In their view, prior knowledge of individual employees shapes the basis of understanding external knowledge, while integrating it with the existing knowledge base creates new knowledge outputs for developing innovations. Considering SOI, the diversity of external knowledge required to conduct process, product and social innovations necessitates various internal skills and routines in order to learn from a diverse range of external linkages (Adams et al., 2016). SOI-related capabilities are extensive and typically outside an individual firm's existing resource base (Lozano, 2007), especially when considering small mineral companies (Milanez and de Oliveira, 2013). Therefore, it is crucial for companies to identify skills and routines that underlie the different stages of recognizing, assimilating and exploiting different types of external knowledge.

Existing studies in this domain have not paid sufficient attention to the specificity of capabilities for innovation in sustainability contexts, particularly through a perspective that considers the comprehensiveness of SOI by taking into account all three aspects of sustainability transitions (Amui et al., 2017; Chen, 2016). For instance, Ayuso et al. (2006) proposed stakeholder dialogue and knowledge integration as the organizational capabilities required to absorb external knowledge, and introduced a set of structural and cultural mechanisms that facilitate the development of these capabilities. However, one caveat to this finding is the limited conceptualization of absorptive capacity that has led to other underlying mechanisms being ignored, such as employees' prior knowledge. In a quantitative study, Albort-Morant et al. (2016) used empirical data from the Spanish automotive industry to substantiate the fact that learning and integrating capabilities are important for success in environmental innovations. However, their standard measure of 'capability' may have handicapped their findings, as SOI capabilities are believed to differ from those for traditional innovations.

Considering the above, there is a need to enhance our knowledge of the specific skills and routines for undertaking SOI that help firms to move through the processes of recognizing, assimilating and exploiting external knowledge. Thus, this paper aims to answer the following research question: what are the capabilities, and their underlying skills and routines, that build the absorptive capacity required for SOI in the minerals industry? Accordingly, we use an exploratory case-study design (Yin, 2009), with data from 16 companies in Norway that form the empirical setting for this research.

By identifying the micro-foundations of capabilities (i.e. the underlying routines for building them) that are essential for SOI, this study contributes to the recent debate about how various (and somewhat conflicting) aspects of sustainability can be realized through internal and external learning mechanisms for innovation (Amui et al., 2017; Watson et al., 2017). Moreover, our fine-grained analysis of the determinants of absorptive capacity responds to the call for more research into the intra-organizational building blocks of this construct (Lewin et al., 2011). As scholars have paid scant attention to determinants beyond research and development (R&D)-based knowledge (Vega-Jurado et al., 2008) or innovations with non-commercial purposes (Murphy et al., 2012), our empirical insights from the Norwegian minerals industry reveal some specific aspects of absorptive capacity when pursuing an innovation approach that entails both commercial benefits (for companies) and non-commercial benefits (for society).

The remainder of the paper is structured as follows: the next section provides an overview of the empirical setting; Section 3 describes the theoretical background; Section 4 deals with the research design and methodology; Section 5 presents the results of the case study; and Section 6 discusses the findings and implications.

2. The empirical setting: Norway's minerals industry

The Norwegian minerals industry produces a diverse range of minerals of various commodity types. The ore minerals sector dominated the industry until some decades ago, while industrial minerals, natural stone and construction minerals have gradually gained increasing importance in terms of employment and sales value. By production volume, Norway is among Europe's most important producers of olivine, nepheline, titanium minerals, iron ore, marble, quartz and flake graphite (Geological Survey of Norway, 2016). Furthermore, the country has promising potential for increasing the supply of minerals required for growth in green and high-tech industries such as renewable energy, the manufacturing of electric cars, electronics and aerospace.

Despite its historical presence, the size of the Norwegian minerals industry is quite small compared to other mineral-rich countries or the other domestic natural resource-based industries, such as oil and gas. In 2015, the industry had $\approx$ 6000 employees, distributed over 690 companies operating $\approx$ 1000 mines and quarries. It had a turnover of roughly USD 1.55 billion (NOK 13.3 billion) in 2015, of which $>$ 50% was from export markets. Even though the direct contribution of the minerals industry to Norway's gross domestic product (GDP) is very small ($\approx$0.4% based on data from 2015), a recent analysis showed that the minerals value chain (considering manufacturing of mineral-based products, excluding oil and gas) contributes 12% of total GDP in Norway (The Science Park in Bodø, 2017). In addition, this industry has had a significant development effect in several peripheral regions of Norway, in terms of both direct employment and growth of local supplier industries (Smeds et al., 2016).

According to Siggelkow (2007), empirical settings for single-case research should provide a unique opportunity to obtain first-hand knowledge about the phenomenon under study. We consider that the Norwegian minerals industry, owing to some of its characteristics, makes an attractive case for a study of capability building and an open SOI approach. According to the Norwegian government's strategy for this industry, "efficient, socially responsible and environmentally-friendly operation" should be at the core of development, and that new knowledge, cooperation and technological improvements should play an important role in realizing these intentions (Ministry of Trade and Industry, 2013). The openness of the economy and the relatively high proportion of small and medium-sized enterprises in the minerals industry – with a consequently limited internal knowledge base – will then favor a focus on externally oriented learning.

As shown in Table 1, addressing higher productivity growth and stricter environmental requirements by means of technological developments has led to a continuous improvement in key economic and environmental indicators. Moreover, while measures to ensure that companies act in a socially responsible way have yet to be developed, the government has exerted extra effort through the new Mineral Act to ensure the protection of nature-based activities related to herding and fish farming that are part of the livelihoods of the locals. Concerning market situations, geographical proximity to the European market and

Table 1
Productivity, energy and emission intensities in the Norwegian minerals industry during 2013–16.
Source: Statistics Norway

Indicator	Year			
	2013	2014	2015	2016
Labor productivity (ktonnes/employee)	15.60	16.14	17.59	20.91
Energy intensity (GWh/billion NOK income)	154	133	122	112
Emission intensity (ktonnes of CO_2 equivalent/ billion NOK income)	40.05	39.41	36.88	34.23

access to a long coastline constitute competitive advantages for export-oriented mineral companies in Norway. In innovation terms, this has made knowledge exchange easier, especially in the case of linkages with process and manufacturing industries.

3. Background and theoretical framework

Following the OECD (2011b), sustainability transition denotes moving towards a form of industrial growth where triple-bottom-line objectives (i.e. social, environmental and economic) are taken into account. This multidimensional growth emphasizes the demand for innovative solutions that not only bring economic advantage, but also improve social well-being and decrease detriments to the natural environment (Smith et al., 2010). For the purpose of this paper, we define innovation as "the search for, and the discovery, experimentation, development, imitation and adoption of new products, new production processes and new organizational setups" (Dosi, 1988, p. 222). Accordingly, SOI comprises product, process and social innovations (Klewitz et al., 2014) that may originate either inside or outside a firm's boundary.

The following subsections provide the theoretical groundwork that directed our purpose to explore which internal capabilities the minerals industry should develop in order to pursue an open innovation approach in its SOI activities.

3.1. The broadening scope of external learning linkages for SOI

In recent decades, learning processes and innovations have increasingly become shared activities in industrial settings. Innovation is currently the result of interactions among various actors as components of an innovation system (Fagerberg et al., 2009). According to this open innovation paradigm, a company should be able to manage knowledge inflows and outflows across its boundaries (Chesbrough, 2003), yet the inward flow is more significant in non-high-tech settings such as the minerals industry (Bartos, 2007). In this respect, companies may gain access to external knowledge via two basic mechanisms, namely transactional and collaborative relationships (Greco et al., 2016); whereas the former implies monitoring the outside environment and/or sourcing technologies on a market basis, the latter represents active partnerships to develop new knowledge and innovation.

While companies can generally acquire knowledge from different external sources, a central topic in the literature has been to identify the main sources of knowledge inputs for innovation in different industries. A pioneering idea in this respect is the taxonomy provided by Pavitt (1984), which groups firms into three categories, namely supplier-dominated, production-intensive and science-based. In Pavitt's view, the first category of firms is mainly dependent on the flow of knowledge from suppliers and, to a lesser degree, from large customers and research organizations, whereas engineering service providers and R&D institutions are the essential knowledge providers for the second and third categories, respectively. In a similar vein, Asheim and Gertler (2005) make a distinction between industries with analytical and synthetic knowledge bases and go on to argue that firms in the first category draw substantially from basic science and knowledge produced in research organizations, while those with a synthetic knowledge base mostly interact with their suppliers and customers.

Regardless of different classifications, scholars seem to agree on a dependency between external knowledge sources and the type of knowledge they provide for innovation activities (i.e. technical, scientific, market, etc.). Existing studies suggest that companies rely on their suppliers to obtain technical knowledge related to process innovations, either in the form of knowledge embedded in technologies or by buying engineering services (Robertson et al., 2012). In the minerals industry, collaborative technology development projects could benefit both the mineral company and the equipment supplier by lessening the risk of failure, providing complementary access to financial resources and allowing the possibility of testing prototypes in a real operational setting (Lager et al., 2015). Moreover, managers in this industry are increasingly focusing on outsourcing their non-core activities (Morris et al., 2012), which could result in more flexibility in their linkages with suppliers compared with collaborative arrangements that require deep involvement and shared commitments.

As for knowledge about markets, existing customers and potential markets at large are the main sources of insight that drive innovative product solutions (Bogers and Lhuillery, 2011). Owing to the scarcity of mineral raw materials and their importance in global supply chains, manufacturing industries are reportedly concerned about relationships with their suppliers of raw materials (George et al., 2015). Moreover, interaction with raw-material suppliers is considered a crucial factor for the sustainability of product life cycles and ultimate market success. Pujari (2006) highlights the role of early-stage interaction with suppliers in maintaining a good reputation and increasing eco-efficiency and product quality. Not surprisingly, there is a shortage of research on such interactions from the perspective of the minerals industry. More attention to this shortfall is particularly important when considering the rise in the importance of rare earth and industrial minerals for applications in high-tech and renewable industries (Wang et al., 2017), which calls for an investigation of the dynamics of learning from (potential) customers for these mineral products.

Although not a main focus in non-high-tech sectors, innovation-based development in the minerals industry also requires the establishment of linkages with research organizations (Andersen et al., 2015). Industry–university interactions in such sectors create the applied knowledge required to address specific process- or product-related issues (Asheim et al., 2005). These interactions have proven beneficial for sustainable innovation through learning that happens via both formal collaborations, for example R&D projects, and informal relationships between scientists and industrial personnel (De Marchi, 2012; Grimpe and Fier, 2010). The supply of human capital and engineering services from universities could also contribute to industrial development in mining regions (Figueiredo and Piana, 2016) which, among other positive consequences, would improve both the reputation and social responsibility of the companies concerned.

Beyond technical, market and scientific knowledge, the emerging literature on SOI points to the importance of societal stakeholders for innovation success, particularly those innovative outcomes that target social rather than commercial values. Drawing on several case studies in the UK, Holmes and Smart (2009) demonstrated the value of interacting with non-profit-making organizations as a source of knowledge on societal issues. Successful management of mining projects in the realm of stricter socio-environmental regulations is dependent on interactive communications with local stakeholders (Corder, 2015). This is in accordance with the results of a growing literature which draws on the concept of 'social license to operate' (Prno and Scott Slocombe, 2012) to argue that disregarding the interests and expectations of locals endangers both productivity and efficiency gains in this sector. Suopajärvi et al. (2016) conducted an in-depth empirical study to show that approaches towards social sustainability should go beyond reactive practices (such as the transparency of waste management activities)

and further involve the community in the early stages of planning for mine development.

Nevertheless, the literature on external learning linkages to the minerals industry is rather sparse and is mainly focused on interactions with suppliers in user–producer relationships, which consequently do not reflect the industry's need for a broader approach towards innovation and sustainability. Our perspective in considering various types of knowledge relevant to SOI, including technical, market, scientific and social knowledge, and their respective external sources, could provide some insights into how firms respond to the broadening scope of learning linkages by developing their internal skills and competencies.

3.2. Internal capabilities for absorbing external knowledge

The above discussion suggests that various types of external knowledge sources are conducive to innovation, which may result in an expectation that learning and innovation are automatic results of exposure to an external environment. However, studies have found that these outcomes should not always be taken for granted. Instead, deliberate efforts and adequate amounts of 'internal' knowledge and competence are required to build the capacity for effective learning from these linkages (Zollo and Winter, 2002). This school of thought refers to a firm's absorptive capacity, a concept coined by Cohen and Levinthal (1990) and defined as the capability to utilize knowledge originating outside the firm. The term 'capability' is central to this conceptualization as it points to the 'dynamic' nature of absorptive capacity, which not only captures firms' resources (skills and knowledge competencies) but also their reconfiguration by means of organizational routines in order to comply with changes in the outside environment (Teece, 2007).

Since its introduction, absorptive capacity has undergone significant examinations regarding its definition, measurement and underlying processes. For the purpose of this paper, we follow recent contributions that have specifically advanced this construct by (1) developing a process-based view of it and (2) extending it beyond R&D-based knowledge and commercial innovations. Regarding its definition and construct clarification, it is generally accepted that absorptive capacity is a multidimensional concept comprising three sequential processes: recognizing, assimilating and exploiting the external knowledge (Lane et al., 2006). Accordingly, our theoretical framework (Fig. 1) proposes that firms should develop recognition, assimilation and exploitation capabilities in order to convert external knowledge into different types of SOI, which are driven by various sustainability-related objectives.

Firstly, recognition capability enables a firm to identify and understand external knowledge resources. In the second step, assimilation provides the ability to integrate acquired and internal knowledge, which could result in only a slight change or in an entire transformation of the existing knowledge base (Todorova and Durisin, 2007). Finally, firms should be able to apply the new knowledge in their operations in order to improve performance.

Generally, firms use different routines for accumulation of these three capabilities, which depend to a large degree on the source of knowledge and its R&D intensity. While early investigations relied on the R&D activities of firms to examine their degree of absorptive capacity, there is growing support for the contribution of other types of skills and routines to this capacity (Bogers and Lhuillery, 2011; Vega-Jurado et al., 2008). Nevertheless, for technological changes in products and processes, R&D activities play an important role in developing the scientific knowledge base of a firm and thereby improving the capability to exploit the external knowledge acquired from research-based organizations (Horbach, 2008). Besides R&D, direct involvement in manufacturing processes and engineering activities can also trigger incremental innovations which, in most cases, can be applied to problem-solving strategies regarding specific product or process requirements (Hervas-Oliver et al., 2012). Similarly, Bogers and Lhuillery (2011) adopted a functional perspective to show that, in addition to R&D, marketing- and manufacturing-related practices in a firm also absorb the relevant external knowledge required for product and process innovations.

At an intra-firm level, recognition and assimilation capabilities could also be enhanced by linkages between competitors or firms from different sectors within an industry. In this regard, both informal interactions via employee networks and formal collaborations in the form of strategic alliances have proved to be useful (Dantas and Bell, 2009; Madhok and Osegowitsch, 2000). Therefore, whereas R&D activities lead to the creation of new knowledge, technological innovations also rely on capabilities beyond R&D that are created by combinations of already existing knowledge by means of 'learning by doing and using' (Jensen et al., 2007).

On the other hand, non-commercial innovations in terms of improvements in social practices call for an absorptive capacity that differs in terms of its underlying skills and routines. Murphy et al. (2012) delineate that, in the case of external linkages with societal stakeholders, fundamental differences between the expectations of businesses and locals lead to large learning gaps that should be bridged by effective communications. In another study of the absorptive capacity for social innovations, Veldhuizen et al. (2013) maintained that an open culture, employee involvement and an hierarchical structure drive effective dialogue and knowledge integration for sustainable innovations.

The above review reveals the lack of a thorough, fine-grained understanding of recognition, assimilation and exploitation capabilities for SOI. This informs our objective to explore the skills and routines that shape these capabilities.

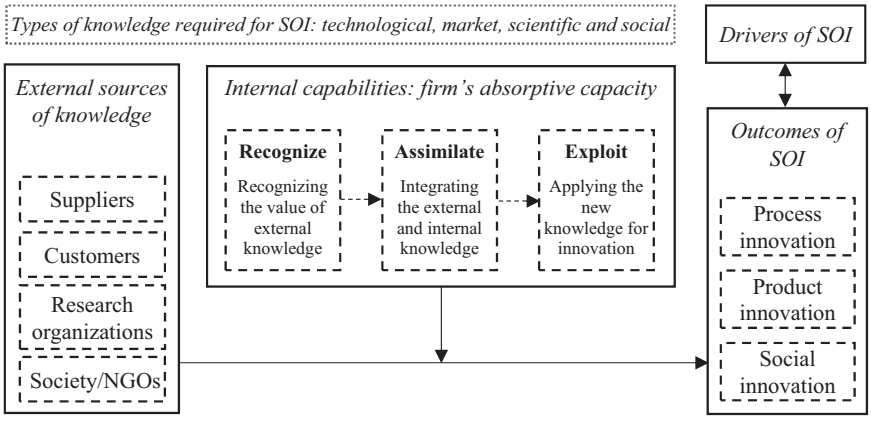


Fig. 1. Theoretical framework. Illustration by the authors according to Lane et al. (2006).

4. Research design and methodology

To answer the research question, we adopted an abductive qualitative approach that is appropriate for elaborating on existing theories where "gaps or oversights need to be filled in" (Pratt, 2009, p. 859). Considering our research question, while the literature argues for the necessity of recognition, assimilation and exploitation capabilities, the mechanisms through which these capabilities unfold in the context of SOI have yet to be thoroughly specified. Thus, our use of abductive reasoning in this paper is that we start from the general theory of absorptive capacity, hence drawing on our empirical insights to re-contextualize this theory in relation to the different capabilities for SOI. Accordingly, an embedded single-case design (Yin, 2009) is used to study various mineral companies as the subunit for our eventual unit of analysis (the industry). This allows the industry to be maintained as the target of the study for exploring the accumulation of capabilities, while at the same time investigating the micro-foundations of these capabilities at firm level by doing a comparative analysis among the companies. Regarding the subunit of analysis (embedded companies), we employed a theoretical sampling strategy (Emmel, 2013) to select cases that could provide in-depth knowledge of the phenomenon under study. Insight derived from reviewing available documents such as industry analyses and annual reports was combined with observations made at the annual meeting of the industry to select companies with certain degrees of internal and external innovation activities. We deliberately took into account a variety of cases in terms of sectors and geographical locations in Norway. Consequently, a list of 22 potential sample cases was prepared, of which 16 companies agreed to participate in our research.

The informants in this study have an executive responsibility for innovation activities in their respective companies. The aim is to capture data via people who are embedded in the phenomenon (Gioia et al., 2013), with the intention that their experience-based interpretations can provide knowledge of the characteristics of capabilities and innovation practices in their companies. None of the authors knew the informants beforehand, and nor did they have any relationships or engagement with the companies. To collect the required data, we prepared a list of questions that revolved around drivers of innovation, various knowledge-exchange mechanisms and internal processes for building innovation capabilities. We deliberately did not use the term 'sustainability' during the interviews to avoid potential social desirability bias. This list of questions, together with a procedural explanation of the data collection, led to the development of an interview protocol (see Appendix A) that supports the reliability (replicability) of our research (Yin, 2009). The first author conducted the interviews via Skype, which enabled a close face-to-face connection with the informants, regardless of their geographic dispersal (Deakin and Wakefield, 2014). The interviews lasted on average one and a half hours, and were conducted during a 6-month period in 2016.

All the interviews were recorded and transcribed, and totaled 220 pages of single-spaced text. We used the NVivo software package to carry out the analysis in three main phases, i.e. coding, classification and cross-tabulation. Based on the principles of inductive thematic analysis (Gioia et al., 2013), we followed a consecutive and recursive process of coding and classification. Firstly, the authors read the data independently and looked for concepts and expressions related to sustainability drivers, different types of SOI, internal capabilities and external sources of knowledge. This first-order analysis led to the identification of 86 distinct concepts. In the second phase, we discussed the similarities and differences between these concepts across the cases in order to classify them under fewer themes, which left us with 27 distinct groups, which we called second-order themes. Then, after several recursive processes of consultation with the existing literature, these themes were reduced to seven ultimate constructs. In the third and final phase of the analysis, the relationship between the emerged constructs was tabulated in a co-occurrence matrix, which indicates pieces of data that receive two specific codes. This matrix has the advantage of providing both qualitative and quantitative (i.e. how many times a co-occurrence is evidenced) insights, allowing us to look for patterns that link SOI types with drivers of sustainability, external linkages and internal capabilities. Appendix B presents an example section of the data structure to illustrate the emergence of ultimate constructs from first-order codes, together with an overview of the second-order themes.

In order to establish the credibility of our findings, we considered two strategies to check for construct and external validity (Yin, 2009). Firstly, the transcripts were sent to the interviewees to obtain their feedback and further reflections. When available, the interview data were triangulated with other information from each company (such as annual reports, news and data from conference presentations and internet documents) to check the consistency of the data. In the case of inconsistencies, we asked the informants for clarifications and comments concerning specific points. Secondly, the multiple cases embedded in our holistic case enabled us to apply replication logic (Yin, 2009, p. 54) by means of looking for similar (literal replication) and contrasting (theoretical replication) results across our cases, thereby increasing the generalizability of our findings to other similar contexts.

5. Findings

5.1. Descriptive case findings

The companies in our study belong to the four main sectors of the minerals industry in Norway, namely construction minerals, metallic ores, industrial minerals and natural/dimension stones. Among these 16 companies, five are large, six are medium-sized, four are small and one is a micro-enterprise.[2] For reasons of confidentiality, the original names of the companies were changed to the letters A–P and are referred to by these letters throughout the paper. Appendix C presents an overview of the case companies and interviewees.

As shown in Appendix B, the outputs from NVivo provide some descriptive statistics of the data, including the number of times that a specific concept or expression appeared in the transcribed interviews. Considering the different types of SOI in the minerals industry, process innovations seem to be more prevalent (being mentioned 70 times by the interviewees), followed by product and social innovations (58 and 37 references, respectively). Our results indicate that suppliers and research organizations are the most frequent external sources of knowledge used in the Norwegian minerals industry, while companies have yet to establish appropriate mechanisms for gaining knowledge from their societal stakeholders and customers. These external linkages represent a diversity of networks in terms of geographical location, ranging from local societal stakeholders to those that cross national boundaries. Interestingly, the results evidence that local and international networks are used equivalently, which in turn points to the fact that the knowledge required for SOI is geographically dispersed.

In the following, the case study results are presented in three sections based on the related sets of final constructs that emerged from the coding process. The first set demonstrates the link between drivers of SOI activities and their outcomes; the second set discusses the characteristics of linkages with external knowledge sources; and the third section synthesizes the findings around processes for developing absorptive capacity.

5.2. What are the drivers and outcomes of SOI activities in the minerals industry?

Norwegian mineral companies are primarily concerned with innovating within their extraction and production operations. These

[2] Micro, small and medium-sized companies are those with fewer than 10, 50 and 250 employees, respectively (European Commission, 2012).

Table 2
Illustrative quotes regarding the characteristics of external linkages.

Knowledge source	Acquisition mechanisms	Geographical breadth	Illustrative quotes
Suppliers	• Transactional (purchase of machinery, contracting out technical services) • Collaborative (technology development projects)	Mostly within Scandinavia/ European Union	"There is a certain supply of equipment from Scandinavian players, I mean both Sweden and Finland, that have a strong supplier sector for the mining industry which are quite front end-oriented and innovative in many ways." (Company N) "Collaboration [with technology suppliers] is not common, with some exceptions for example (…) because they needed data about the metallurgical properties of our raw material to develop their washing equipment." (Company E)
Customers	• Transactional (monitoring the markets, conferences, on-site visits) • Collaborative (product development projects)	Varied, depending on the target market	"I'm actively taking part in international conferences, so we have a general clue about what is happening in our potential markets and their demand." (Company A) "I think the development of our X product fits very well with the definition of a collaborative relationship as we were in close collaboration with the solar cell manufacturers from the start of that project." (Company J)
Universities/research institutes	• Transactional (outsourcing R&D services, personal contacts with researchers) • Collaborative (R&D projects)	Mostly nationally focused	"We initiated mineral exploration in a very unconventional area where we have collaborators from NTNU and a university in Denmark." (Company B) "At the meetings organized by the industry cluster, people from the research organizations share their knowledge about specific issues of interest for the industry." (Company J)
Society/NGOs	• Collaborative (open meetings with the locals, dialogue with NGOs, form expert groups from local businesses)	Local but in some complex cases extending to national scope	"Before making final decisions, we found and involved those people who were more willing to be engaged and then organized them in several groups to take care of some of the development requirements." (Company P) "We are aware that it will not be enough if the knowledge only goes one way, for example only by distributing some reports." (Company I)

process innovations usually occur in the form of utilizing new technologies and making continuous incremental improvements to existing equipment or processes. While such improvements have been important due to the quest for cost-cutting, pressure from environmental regulations made it inevitable that advanced technologies would be employed. According to case L:

> *"(…) so the further development in this industry relies on production processes that are able to increase the yield, decrease the waste materials and pollutants, and make progress in energy efficiency."*

The above quote signifies a trend in the sample that suggests the existence of three main drivers for process innovations in this industry: reducing emissions and waste; increasing productivity; and improving energy efficiency. Productivity enhancement, which includes factors such as labor, resource and capital, has always been at the top of the agenda for managers in this industry. In Norway, the existence of an attractive oil and gas sector that attracts a large share of funding opportunities, as well as high labor costs, intensifies the importance of productivity for economic sustainability. On the other hand, waste/pollution reduction and energy-efficient strategies are mostly directed towards environmental sustainability through either end-of-pipe solutions such as utilizing water treatment equipment or more proactive and strategic practices, including recovery/reuse processes and the employment of clean technologies.

While the industry is mostly concerned with process improvements, the interview data show that two objectives motivate the companies to undertake product innovations: increasing the quality (purity) of their raw-material products; and finding new applications for the minerals. As the chief executive officer (CEO) of company G remarked:

> *"The idea in our company as our survival strategy was to look into the different ore minerals and investigate what kinds of special applications could be developed for those minerals."*

Moreover, the R&D manager of company J explained what forces them to focus not only on process improvements, but also on new-product developments:

> *"(…) there will be then an increased demand for highly purified minerals that are absolutely necessary for production of more sustainable solutions for power production, electric cars, windmills, etc. And to achieve our objectives in product development projects, changes in machinery and enrichment processes are required."*

Tougher competition in the market for raw materials, especially in the metallic ore and industrial minerals sectors, has urged companies to invest in developing specialized products for niche markets. For example, one company in our sample is involved in developing an entirely new product that can assist in removing nuclear pollutants. In this way, the company will be able to bring environmental value to society while ensuring its competitive advantage in a rather saturated market for standard products.

Besides innovative outcomes in processes and products, we found an increasing awareness about societal issues which, in turn, led to the creation of a third innovation path, i.e. social innovation. As stated by the CEO of company D, whereas creating a better social profile could be achieved as a by-product of improvements in areas such as pollution control, the increasing power of interest organizations requires additional efforts with clearer contributions to social well-being:

> *"During several interactions with stakeholders, we have learned that the community around our mine expects us to provide more jobs in the region. This is now one of our highest priorities that can strengthen our tie with them."*

We conclude that there is a necessity to ensure a 'social license to operate' in order to achieve sustainability in this industry, because insufficiency of social practices might result in having to cease or delay operations at the mine. Therefore, social innovations could enable the minerals industry to obtain social approval as an essential component of their long-term economic sustainability strategy.

5.3. What characterizes external-learning linkages for minerals sustainability?

All the firms in our study had some experience of incorporating external sources in their innovation processes, including suppliers, customers, research organizations and local communities/interest organizations. As depicted in our theoretical framework, we distinguish between these linkages in terms of their knowledge content, i.e. technical, scientific, market and social knowledge. The case study shows that such a variation resulted in using different mechanisms for acquiring external knowledge, as well as reconciling the geographical scope of the knowledge search. Table 2 presents some example quotes to illustrate the knowledge acquisition mechanisms and the geographical breadth of external linkages with the four aforementioned knowledge sources.

In Norway, and as far as our sample represents, linkages between the mineral companies and their suppliers occur mostly on a transactional basis, in the form of buying machinery and technical services. Choosing the right suppliers appears to be particularly appropriate as it enables the mineral companies to gain access to the high-quality knowledge embedded in efficient/clean technologies and/or people. To maximize the benefit from such learning, a firm should exhibit a specific level of internal knowledge that is necessary for implementing and customizing the technologies. Indeed, we found that buying ready-to-use technologies is becoming less common as greater interaction between equipment suppliers and mineral companies (users of technologies) is needed during customization of the final solutions:

> *"When we need equipment, we usually refer to our selected suppliers that are located wherever in the EU. So they come back to us with their offers (…) then we enter into a contract to customize the equipment based on our specific requirements."*

When necessary, relationships with suppliers may turn out to be highly collaborative. The main logic behind collaborative arrangements is to ensure the mutual flow of knowledge between the mineral companies and their suppliers, which in turn emanates from the complexity of knowledge required to develop the final process solution. For instance, in the case of company E (see Table 2), the unconventionality of the raw material has made it inevitable for the company to collaborate closely with its washing equipment supplier and to provide them with access to operational data over a relatively long period. The complexity aspect of knowledge also resonates by broadening the geographical scope of linkages with suppliers, as the need for advanced technological solutions and expertise increases the importance of being aware of global actors and their offerings. Although geographical distance may decrease the ease of knowledge flow, the existence of institutional frameworks such as trust-based culture and policies for promoting partnerships could remove some of the obstacles. As remarked by several companies in our study, closely related cultures and the existence of policy initiatives for nurturing collaboration in the Nordic region are decisive factors for the flow of technology and knowledge from Sweden and Finland, which are the homes of strong supplier industries.

> *"I would say that they [our relationships with suppliers] are more often regional, and by region, I'm thinking about Scandinavia. Sometimes we have contacts in other countries (…) but the point with the Scandinavian partners is that we easily trust each other." – Company H*

While doing business in such a globalized industry does not allow for price competition, the majority of our cases showed their increasing interest in monitoring market changes and product innovations. In most cases, the person responsible for the marketing activities of the company was evidenced to be in charge of monitoring the markets, particularly those in high-tech and/or renewable energy industries. In smaller companies, the CEO plays this gatekeeper role, whereas in larger ones the sales manager/market developer is the one who tries to ensure that the relevant market knowledge is transmitted to the company. Nevertheless, developing radical products pushes downstream linkages to be more collaborative, instead of just a one-way knowledge flow to the mineral companies. This radical nature relates to an entirely new application (e.g. the development of a mineral product for remediation of radioactive waste from the sea) or to advanced technical knowledge (e.g. producing crack-free and low-emission concrete). As noted by company C:

> *"We collaborate a lot with concrete producers. Especially with one of them, we are combining our technical expertise and production employees in order to find out the best possible way to make good concrete."*

The findings on the geographical breadth of downstream linkages show notable variance among companies in the minerals industry. On some occasions, especially in the case of industrial minerals, the knowledge-exchange process occurs in a broadly international domain. This is also the case for complex and radical innovation projects. In contrast, in the case of construction minerals, the physical characteristics of which are to a large extent location-dependent, companies look for market knowledge from customers in their vicinity. Moreover, as customers tend to consider the sustainability of a product's life cycle from the very beginning, it is important to involve them in product development projects at an early stage.

Norwegian research organizations have traditionally played a significant role in creating the scientific competencies required for developing the country's resource-based industries (Fagerberg et al., 2009). As expected, little internal R&D activity in the minerals industry is compensated for by outsourcing the production of scientific knowledge to competent institutions and universities. The Norwegian University of Science and Technology (NTNU) and the Foundation for Scientific and Industrial Research (SINTEF) are the most significant players in this regard. In some cases, mineral companies had some experience of being engaged in collaborative and publicly funded research projects led by a big research organization such as SINTEF or NTNU. However, involvement in large projects requires more internal resources (both financial and human) and trust, and hence the lack of any of these factors could result in a preference for dyadic relationships (i.e. those between a single company and a research organization) rather than those that involve other companies and research organizations.

> *"When we collaborate with a research institution, we share proprietary information about our processes or products. When other companies are a part of a project, we are afraid of losing this information to our competitors." – Company O*

The data signify that the minerals industry is mostly nationally oriented when it comes to scientific linkages. Indeed, the presence of a globally competitive process industry (in terms of both cleanliness and productivity) in Norway has led to the development of strong research groups within the universities/R&D institutes that leverage their internal skills and external networks to supply a large share of the required knowledge in the minerals industry. Nevertheless, in a couple of cases where the aim was to develop advanced products or to undertake patent-driven research, mineral companies opted to involve foreign research organizations. Interestingly, even in these cases, a Norwegian research organization was also part of the collaboration, in order to ease the acquisition and further application of the scientific knowledge.

Our case study also sheds some light on the characteristics of linkages with societal stakeholders. Firstly, we found evidence to argue that companies are incrementally moving towards collaborative knowledge exchange, using mechanisms such as dialogue with interest organizations (e.g. environmental non-governmental organizations [NGOs]) about their environmental impact, which could consequently lead to remedial actions within the operations. Secondly, the degree of organizational involvement is increasing as companies are trying to incorporate knowledge about social issues into various organizational levels and functions in order to address the complexity of absorbing this

type of knowledge. Following the CEO of company B:

> *"Obtaining [social] information is expensive. I don't mean monetary value, but the amount of time and engagement that should be spent. When we want to discuss with the communities, a team including managers, consultants and production engineers has to show up."*

Thirdly, social linkages are found to be geographically limited to where the mine or processing plant is located. This is due to the high local impact of the minerals industry, both in a positive (regional development) and negative (socio-environmental impact) manner. Moreover, social knowledge is mostly intuitive (e.g. the expectations of locals) and based on context-specific experience (e.g. nature-based activities such as fishing or reindeer husbandry) that adds to its tacitness and the difficulty of assimilation. Therefore, geographical proximity to the external sources of social knowledge could assist mineral companies in converting the relevant knowledge into innovative outcomes.

5.4. What capabilities underlie the absorptive capacity for SOI?

Considering the findings presented in Sections 5.2 and 5.3, mineral companies exhibit capabilities that absorb various types of external knowledge (technical, scientific, market and social) in order to practice process, product and social innovations. As the process perspective on absorptive capacity illustrates (see Fig. 1), these capabilities can be categorized under recognition, assimilation and exploitation processes. Our data suggest that four types of capabilities underlie these processes: (1) keeping abreast of changes in technologies and markets; (2) increasing awareness about social issues; (3) facilitating internal knowledge dissemination; and (4) piloting new, innovative solutions. While the first two capabilities focus on identifying and understanding external knowledge (recognition), the third and fourth lay the foundations for integrating it with prior knowledge (assimilation) and applying the resultant new knowledge for innovative purposes (exploitation), respectively. Table 3 summarizes the findings regarding these capabilities and their micro-foundations (underlying skills and routines).

With regard to recognition, mineral companies seem to require a specific degree of *prior knowledge* on related technologies and markets to locate and understand the external knowledge. To follow up the continuous changes in what the potential markets for minerals perceive as sustainable solutions, some cases in our study referred to practices such as participation in conferences, which is not only a knowledge source in itself, but also an arena enabling them to identify other sources of knowledge by means of networking. On these occasions, the market knowledge accrued by the company acts as a facilitator for future knowledge acquisition through the existing network. Moreover, keeping abreast of changes in technologies and markets necessitates an ability to *employ the relevant staff* and *train* them on a regular basis. Our case study shows that understanding the knowledge embodied in technologies plays a central role in innovation activities in this industry. The proper operation of equipment requires a substantial level of prior experience at the individual-employee level that is not available based on existing skills or via user manuals/general instructions. Therefore, companies opt to recruit technicians who, through their earlier careers have the practical skills to work with specific equipment. In cases where some prior knowledge exists, training and continuing education seem to be more prevalent due to the high cost of labor in Norway. On-the-job training has been found to be particularly important for familiarizing staff about the incremental technology developments regarding waste reduction and recycling processes. As noted by company I:

> *"The main reason [to educate employees] has been to adjust our production processes according to the environmental regulations since they are sometimes changing overnight."*

The recognition component of absorptive capacity in our case study demonstrates a specific capability for understanding external social knowledge, referred to here as awareness about social issues. In this regard, we found that acquiring social knowledge relies primarily on the *managers' desire to act ethically*. This desire is a decisive factor for establishing a positive reputation in local communities, which consequently makes them willing to share their knowledge with the mineral companies. In contrast, as noted by company H, companies that only respond to coercive forces (e.g. pressure from the government) are often perceived by societal stakeholders as possessing a lack of responsibility, thereby losing the opportunity to build trust-based relationships and gain access to the valuable knowledge required for continuous improvements in social sustainability.

> *"These [environmental] rules are quite strict in Norway and the government forces us to follow the best practices for tailings disposal (…) but here the challenge is to get the locals to trust in us and collaborate with us."*

Table 3
Illustrative quotes about the micro-foundations of capabilities for building absorptive capacity.

Identified capabilities and micro-foundations		Excerpts from the interviews
Recognition	(1) **Keeping abreast of changes in technologies and markets**	"(…) recruited from northern parts of Sweden and Finland since we purchased new equipment from suppliers in those countries" (Company D)
	– *Prior knowledge base*	"Cooperation with technical colleges for training our employees is helping us to secure the need for competence" (Company C)
	– *Recruiting new technicians and university graduates*	"(…) achieving success when the managers had a passion for resolving social conflicts" (Company K)
	– *Employee training and continuing education*	"(…) the corporate social responsibility (CSR) projects were truly small, so we had to be quite realistic about the target and be specific on the required information to meet those targets" (Company I – regional manager)
	(2) **Increasing awareness about social issues**	
	– *Managers' desire to act ethically*	
	– *Setting specific objectives for responding to social issues*	
Assimilation	(3) **Facilitating internal knowledge dissemination**	"(…) promoted communication inside the company in such a way that it became part of the organizational culture" (Company D)
	– *Sharing experiences among co-workers in a specific unit/function*	"To ensure knowledge sharing among more than one plant, we expect the unit managers to arrange meetings to find a solution" (Company F)
	– *Intra-firm communication channels across technical, market and social knowledge bases*	"To modify our product, we should fully understand a customer's desired specifications for the product, (…) and this knowledge is not something that our marketing people have. Then (…) discuss it internally within the production and R&D departments" (Company G)
Exploitation	(4) **Piloting new innovative solutions**	"In these changes [on the machinery], the employees' knowledge about our minerals and processes is essential to experiment [with] what works and what doesn't work" (Company L)
	– *Experimentation and testing process-related changes*	"(…) to decrease the rest materials by implementing a new technique for drilling and blasting (…), but we had to check with one of our customers first to see whether they are satisfied with the new product" (Company M)
	– *Piloting new products and socially related practices on a small scale*	"After publishing our first sustainability report, we recognized through our meetings with environmental activists that caring about the employees' safety is something that might capture their interest. Then we used this insight in our future communications with them" (Company B)
	– *Maintaining external relationships to receive appropriate feedback*	

The desire to act in accordance with social expectations is then combined with the capability to *set specific social objectives*, as the complexity of environmental and social issues might hinder companies for approaching them at the right time (i.e. prioritizing daily operations due to the lack of sufficient time and financial resources). As seen in cases I and O, breaking down complex issues into specific targets and communicating those targets to the societal stakeholders helped the companies to identify experts or interest organizations as potential sources of social knowledge.

Concerning assimilation, the findings suggest that *internal knowledge dissemination, both within and across different units/functions,* is required to integrate external knowledge with existing skills and abilities. To ensure this integration, some cases in our sample have managed to reach such a level of maturity in internal communication that knowledge sharing became part of their organizational culture. Arranging periodic meetings and encouraging peer-to-peer interactions are perceived to be fundamental parts of assimilation, as a great deal of knowledge about technologies, markets and social issues is tacit and cannot flow easily without face-to-face communications. More interestingly, as pointed out by cases B and N, the necessity for involvement of various functions in the assimilation processes is likely to increase across the spectrum from technological to social knowledge. That is, in order to integrate external market knowledge, technical staff from production and R&D functions should also be involved, as well as those responsible for marketing activities, and for social knowledge, in addition to the above, those in charge of communication with societal stakeholders should also be engaged.

> *"Our systematic view to information from locals or voluntary agencies gives us a good way of improving and making more sense from them (…) they speak a different language that is not easy to understand (…) so different people work together in organized teams." – Company N*

In this respect, knowledge-sharing processes that happen between firms are also crucial. For instance, companies that use similar machinery and technical processes – such as those involved in the metallic ore and industrial minerals sectors – noticed a benefit from sharing their experiences, which in turn resulted in assimilation at an inter-firm (industry) level. Nevertheless, coordinating inter-firm knowledge sharing seems to be challenging for individual companies, and this is where intermediary organizations such as the Mineral Cluster Norway[3] and the Association of Norwegian Mineral Industry[4] are crucial in providing such opportunities.

> *"We are a member of a technical committee in the industry association (…) once we talked about our problems with equipment. This is a problem for the whole industry (…) so our aggregates were used as a case and we get good ideas from other companies." – Company E*

Finally, insights into how companies exploit knowledge resulting from assimilation processes support the existence of three interrelated capabilities: *experimentation*, *small-scale testing* and the *maintenance of external relationships*. As reflected in the quote from case L in Table 3, experimentation represents utilizing a combination of knowledge, particularly on technical solutions, for the purpose of trial and error and incremental changes. In such cases, knowledge gained from elsewhere (training, co-workers, etc.) is combined with prior experiences for further 'learning by doing' and the achievement of innovative outcomes. Similarly, we evidenced that successful product and social innovations need to be tested by users and stakeholders on a small scale, before implementation in larger projects and markets. As noted by the companies themselves, addressing sustainability often entails some trade-off between its different aspects, which in turn necessitates testing an innovative solution before final development and implementation. For instance, achieving a lower environmental footprint may come at the expense of lower product quality (e.g. the durability of a natural stone) and challenges with regard to satisfying customers. Therefore, as the third capability for exploitation depicts, successful exploitation requires the ability to retain external linkages up to the point that the desired commercial or non-commercial (e.g. social) value is created. This capability serves as a feedback loop from the exploitation step to the acquisition of new knowledge from external sources.

6. Discussions

6.1. Discussion of findings

This qualitative study adopted a process view of absorptive capacity to explore the capabilities for recognition, assimilation and exploitation of external knowledge in order to undertake SOI activities. More specifically, attention was directed towards capabilities for pursuing a broad innovation approach, where learning from various external knowledge sources is necessary for economic, environmental and social sustainability. To this end, we demonstrated the knowledge characteristics that condition the use of knowledge-acquisition mechanisms, and revealed a set of skills and routines that contribute to the development of certain capabilities for absorbing the acquired knowledge.

Regarding the mechanisms for knowledge acquisition, we followed the open-innovation literature and differentiated between transactional and collaborative types of relationships with external knowledge sources (Greco et al., 2016). Our findings suggested that, while mineral companies generally take advantage of both of these mechanisms, choosing one or the other depends on the complexity and tacitness of the knowledge, so that high complexity and/or high tacitness are conducive to the use of more collaborative mechanisms. As proposed by Lane et al. (2006), these two knowledge characteristics are important factors as they explain the ease of gaining access to the external knowledge bases. In this regard, while tacitness depicts the extent to which the knowledge can be codified and transferred, complexity refers to how unknown (in terms of a technology or market) a form of knowledge is for a company.

In the case of technical knowledge where suppliers are the major source, the knowledge flow seems to be primarily one-way (towards the mineral companies), unless the suppliers' existing technical solutions and services do not meet the process requirements. In these complex (technological) situations, mineral companies contribute to the production of new knowledge (e.g. washing equipment) by means of providing information and the opportunity to test the equipment in a real operating environment (Lager et al., 2015). Similarly, with regard to scientific and market knowledge, transactional mechanisms have been found to be more prevalent, as collaborations designed to develop these types of knowledge – which are often far beyond a mineral company's knowledge base – could disperse internal resources and have a detrimental effect on the innovation outcomes (Greco et al., 2016). With respect to social knowledge, tacitness plays an important role in motivating the mineral companies to collaborate with their societal stakeholders. Knowledge about social issues and the expectations of locals could not be codified as it involves individuals' perceptions about the impacts of a company (Hall et al., 2003; Suopajärvi et al., 2016). Thus, mutual interactions are necessary for building trust-based relationships, which in turn result in shared understandings about social issues and the expectations of local communities regarding the minerals industry.

For recognizing (understanding) the external knowledge, our data corroborate the importance of prior knowledge within a company for building absorptive capacity (Cohen and Levinthal, 1990). Contrary to the traditional approaches to innovation, SOI necessitates a broader range of prior knowledge regarding technical, scientific and market aspects, as well as a desire by managers to participate in knowledge-exchange processes with societal stakeholders (Sharma, 2005). Moreover, while prior knowledge and a desire by managers to act ethically

[3] http://www.mineralklyngenorge.no.

[4] https://www.norskbergindustri.no/about-us—info-in-english/.

represent static capabilities (i.e. resources), we argue that successful recognition requires dynamic capabilities, such as new recruitment and training, that assist mineral companies to keep abreast of changes in technologies and markets. In his seminal paper, Teece (2007) suggests that rapid changes in the business environment call for continuous modifications to a company's knowledge base. Accordingly, in line with Lozano (2015), our findings indicate that sustainability transition implies rapid changes in technologies, market demands, environmental regulations and social expectations, thereby highlighting the importance of continuous learning through organizational routines such as employee training that consequently increase a company's ability to understand the external knowledge.

Our case study provides supporting evidence for the importance of internal knowledge dissemination as a capability for the assimilation (integration) of external knowledge. The existing literature on absorptive capacity argues that formal and informal mechanisms of knowledge exchange within a company facilitate knowledge dissemination by means of closing the cognitive gap among the employees (Vega-Jurado et al., 2008; Zahra and George, 2002). As formal mechanisms such as using knowledge-exchange coordinators and job rotation have yet to be developed in the Norwegian minerals industry, internal knowledge dissemination hinges on informal peer-to-peer interactions. We further contributed to the existing literature by demonstrating the interrelatedness between the assimilation of different knowledge types in sustainability contexts. While successful integration of technical and scientific knowledge entails interactions between a relatively limited number of employees (mostly those involved in production), combining external market knowledge involves a knowledge exchange between those in charge of production and marketing activities. These cross-functional interactions become even broader in the case of social knowledge (Murphy et al., 2012) which, according to our findings, is of a different 'language' and its further application in innovative activities demands the contribution of several functions within a firm.

Finally, this paper proposes that the exploitation of external knowledge in sustainability contexts rests on appropriate capabilities for testing and piloting innovative, new solutions, regardless of their type (product, process or socially oriented practices). This finding contributes to the debate on the importance of considering commercial and non-commercial interests in SOI processes (Amui et al., 2017; Watson et al., 2017) by showing that long-lasting external linkages with societal stakeholders and customers can create mutual value for both the focal company and its collaborators. As a fundamental capability in such linkages, piloting innovative solutions provides significant feedback to a mineral company, enabling it to align its ultimate solution with the needs of customers and/or societal stakeholders (Murphy et al., 2012).

6.2. Implications for managers and policymakers

Considering the three outcomes of SOI, policymakers and managers should get involved in efforts that go beyond the frequent focus of the minerals industry on process improvements and economic sustainability. Specifically, pursuing a social innovation path to tackle broader sustainability issues calls for policy interventions that aim to increase awareness about social issues (van der Have and Rubalcaba, 2016). Taking a capability perspective, these policies should be directed towards establishing a range of mechanisms for public engagement, from formal acts such as regulations concerning the involvement of minority groups to informal forums for dialogue between the companies, locals and interest organizations. In this regard, the existence of performance evaluation frameworks such as Towards Sustainable Mining in Canada or Finland is crucial in providing key indicators for measuring the effect of social linkages.

Owing to the financial and human resource limitations of individual mineral companies, strengthening industrial clusters and professional associations should be placed at the core of policy support tools to bring together various companies and external knowledge sources. Although the role of innovation intermediaries has rarely been discussed in the context of non-high-tech industries, recent research suggests that these organizations could help companies in the implementation of open innovation by reducing misunderstandings between managers and creating an arena for discussions among the industrial actors, governmental agencies and societal stakeholders (Radnejad et al., 2017). While the intermediary organizations in the Norwegian minerals industry are primarily focusing on forging external links with suppliers and universities, engaging governmental agencies such as Innovation Norway[5] could offer funding and network opportunities to promote links with potential markets for raw materials. Moreover, industrial clusters and associations could act as neutral organizations between the mineral companies and societal stakeholders (e.g. NGOs) by involving the latter in knowledge-exchange arenas regarding social issues.

As for building the absorptive capacity for SOI, managers should extend their organizational capabilities beyond the recognition component, in order to take full advantage of external knowledge. In this regard, firstly, more effort is required to assimilate technical, market and social knowledge that often resides in various functions or individuals within a firm, and which consequently hinders its application in addressing broader sustainability issues via innovative activities (Watson et al., 2017). Accordingly, companies need to combine informal and formal mechanisms for internal knowledge dissemination to respond to the challenge of integrating various types of knowledge into their existing knowledge bases. Secondly, our findings signify the necessity of ongoing external linkages even in the knowledge-application step, in the sense that the new products or practices (as outcomes of the exploitation of new knowledge for innovation) meet the expectations of both the company and its stakeholders. As proposed by Watson et al. (2017), this mutual understanding is particularly important for accommodating varying expectations when economic sustainability runs counter to environmental and social sustainability.

We reiterate that addressing sustainability objectives via innovation is a demanding goal that implies the accumulation of a broad range of capabilities and the efficient functioning of various external linkages. Therefore, policymakers and managers should maintain a balance between policies and strategies for building the four types of capabilities by taking into account the types of innovation outcome and the different components of absorptive capacity.

6.3. Conclusion and future research

To conclude, we believe that this study sheds some light on the determinants of absorptive capacity for innovations aimed at sustainability. By building on the extant literature and a rich empirical insight from the Norwegian minerals industry, we demonstrated how mineral companies can build appropriate capabilities concerning the different components of absorptive capacity, i.e. recognition, assimilation and exploitation. While some skills and routines for building these capabilities exist, more effort is needed to increase understanding about the various types of knowledge relevant to sustainability contexts. More importantly, company-level strategies and national policies should address the issue of strengthening the ability of firms to integrate and apply external knowledge, with the aim of fulfilling different sustainability objectives.

Nevertheless, this study has some limitations. The first concerns the generalizability of the findings to other industrial settings that differ in character from Norway's minerals industry. Therefore, we call for future studies in other resource-intensive industries and national contexts, possibly in countries with dissimilar market and innovation characteristics. In doing so, taking a longitudinal approach is highly preferential as it will allow researchers to examine how these

[5] http://www.innovasjonnorge.no/en/start-page.

capabilities and their underlying routines change over a period of time when firms/industries move through different SOI paths. Second, our approach using qualitative data does not allow for an objective measure of innovation outcomes and of how our interviewees differentiated between incremental and radical innovations. To extend the theoretical understanding, research could employ a quantitative design and use survey-based data to test our arguments. Despite these limitations, we believe that our work makes theoretical and practical contributions to the topic of sustainability in the minerals industry, and could serve as a springboard for future investigations.

Appendix A. Interview protocol for the study

Interviewee: ……..
Company and Position: …….
Date and time: ……...
Duration: ……
Pre-interview comments: …….

Introduction

To facilitate our note-taking, I would like to record our conversation. For your information, only researchers on the project will be privy to the recorded interviews, which will be eventually deleted after they are transcribed.

We have planned this interview to last no longer than one hour. During this time, we have several questions that we would like to cover. If time begins to run short, it may be necessary to interrupt you in order to push ahead and complete this line of questioning. Besides these questions, our line of discussion might raise some extra questions and comments.

You have been invited to participate in this research because you have been identified as someone who has a great deal to share about innovation, knowledge exchange and capability building in the minerals industry. This PhD research project as a whole focuses on the improvement of innovation performance in the industry, with particular interest in understanding how the flow of knowledge and relevant capabilities contribute to that performance. Our study does not aim to evaluate your company's activities or your own experiences. Rather, we are trying to learn more about innovation process, and internal and external practices that are important in this regard.

Interview questions

1. Could you please tell me about the main challenges of your company regarding innovation?
2. How do you deal with these challenges?
3. What are the main opportunities in your business?
4. How can these opportunities be maximized and result in value creation?
5. How does innovation help your company to deal with the challenges and opportunities?
6. Please describe the innovation process in your company.
7. Who are mostly involved in the innovation activities of your company? Both in terms of business units and organizational levels.
8. Please briefly describe how you look for knowledge outside your company.
9. What kinds of practices do you use for bringing in the external knowledge?
10. For which purposes do you use external knowledge in your activities?
11. Could you give me an example of a successful collaboration and a failure example?
12. In your company, what are the internal resources and skills required to do innovation?
13. What motives or purposes are pivotal when you want to choose an external knowledge source?
14. Are there any particular characteristics regarding the type of knowledge you use in your different innovation activities?
15. What are the main knowledge exchange arenas in this industry in Norway?
16. Please briefly describe how knowledge flow happens in those arenas.

Post-interview comments: …….

Appendix B. From second-order themes to ultimate constructs

Drivers of SOI
- Developing specialty products (36)*
- Improving energy efficiency (49)
- Improving employment attractiveness (19)
- Increasing productivity (45)
- Supplying the best quality of raw materials (21)
- Reducing emission and waste (53)
- Obtaining social approval (22)

Capabilities for absorptive capacity
- Recognition – technology/market changes (73)
- Recognition – awareness about social issues (23)
- Assimilation (64)
- Exploitation (31)

Outcomes of SOI
- Process innovation (70)
- Product innovation (58)
- Social innovation (37)

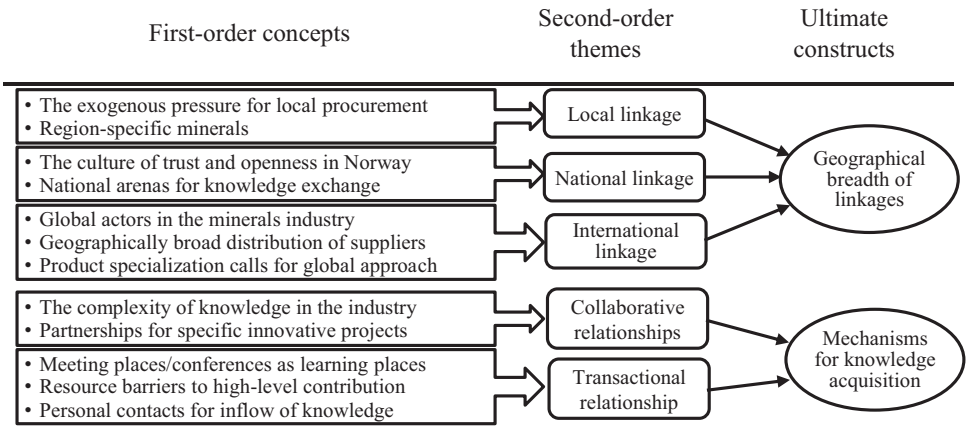
External sources of knowledge
- Suppliers (105)
- Research organizations (92)
- Society/NGOs (47)
- Customers (59)

Knowledge acquisition mechanisms
- Collaborative relationship (57)
- Transactional relationship (54)

Type of knowledge required for SOI
- Technical know-how (65)
- Market knowledge (37)
- Scientific knowledge (52)
- Social knowledge (35)

Geographical breadth of linkage
- Local linkage (40)
- National linkage (35)
- International linkage (42)

*The numbers show how many times the second-order themes were mentioned by the interviewees.



Appendix C. Demographic overview of the interviewees

Company	Sector	Interviewee's position	Date of interview
A	Natural and dimension stone	Sales manager	15.12.2015
B	Metallic ores	CEO	18.12.2015
C	Construction minerals	CEO	21.12.2015
D	Metallic ores	CEO	11.01.2016
E	Construction minerals	Production manager	19.01.2016
F	Construction minerals	CEO	16.02.2016
G	Industrial minerals	CEO	18.02.2016
H	Industrial minerals	CEO	09.03.2016
I	Construction minerals	Regional manager	10.03.2016
J	Industrial minerals	R&D manager	06.04.2016
K	Construction minerals	Production manager	07.04.2016
L	Natural and dimension stone	CEO	08.04.2016
M	Natural and dimension stone	Business development manager	21.04.2016
N	Metallic ores	Chief commercial officer	03.05.2016
O	Industrial minerals	Process development manager	06.05.2016
P	Industrial minerals	CEO	11.05.2016

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Paper 2

sustainability

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Article

Sustainability-Oriented Innovation in the Minerals Industry: An Empirical Study on the Effect of Non-Geographical Proximity Dimensions

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Abstract: Minerals mining and processing companies (hereinafter referred to as "minerals industry") face the increasing demand for a comprehensive approach towards innovations aimed at sustainability. While the ability to learn from external sources of knowledge is at the core of this process, lack of geographical proximity and multiplicity of external sources impose challenges for mineral companies in this respect. The present study proposes that organizational, institutional and cognitive proximities could provide a platform for this industry to overcome those challenges, thereby achieving a superior innovation performance across various sustainability dimensions. Results of an analysis based on a sample of 101 mineral companies in Norway reveal that these dimensions of proximity are conducive to process, product and social innovation in different ways. More specifically, organizational proximity (diversity of non-local collaborations) and informal institutional proximity (shared cultural norms and values) spur social innovation. Furthermore, formal institutional proximity (similarity of rules and laws) and cognitive proximity (familiarity of knowledge base) support both process and product innovations. This paper provides some insights on the determinants of innovation in sustainability contexts, and contributes to the recent debate on the role of non-spatial proximity dimensions for innovation in the peripheral regions.

Keywords: proximity; innovation; sustainability; minerals industry; peripheral region

1. Introduction

While there is a wide opposition to further development of the minerals industry due to its negative social and environmental impacts, pursuing a comprehensive sustainability strategy may help the industry to reduce those impacts while maximizing the financial benefits [1]. Accordingly, mineral companies are embracing the value of innovation to tackle the diverse sustainability challenges concerning economic, environmental and social aspects of their business [2]. A sustainability-oriented innovation (SOI) approach could thereby result in new or significantly improved technological processes, products or organizational practices [3] that ultimately facilitate the transition towards a more profitable, socially acceptable and cleaner minerals industry.

Considering the extensiveness of SOI that necessitates a variety of competencies beyond the internal firm-level innovation capabilities [4], research has shown that companies have to open up their innovation process in order to spur the inflow of knowledge from outside [5]. As such, companies may engage and benefit from various external sources such as suppliers, consultants, customers, universities, NGOs and local communities [6]. There are several examples of mineral companies that benefited from such as "open innovation" [7] approach. Anglo American initiated an open collaboration forum, FutureSmart™, including different stakeholders such as suppliers,

research groups and companies from other industries in order to find more efficient and more sustainable ways to create and capture value [8]. LKAB, the large Swedish mining company, followed this approach by undertaking collaborative technology development with equipment suppliers [9]. Erzurumlu and Erzurumlu [10] report the insights from a gold mine in Central America where communities were involved in the decision-making processes towards developing social innovations.

However, mineral companies encounter a twofold obstacle in pursuing such an open SOI approach. First, they are typically located in peripheral regions characterized by under-developed innovation systems and limited local knowledge spillover [11]. Indeed, their geographical remoteness might be a barrier for obtaining the required knowledge from the relevant external sources, especially in the case of highly uncodified knowledge when geographical proximity and face-to-face interaction play an important role in the absorption of new knowledge [12,13]. Second, the diversity of external sources in terms of knowledge backgrounds and perceptions about sustainability goals poses significant challenges for acquisition and exploitation of knowledge in sustainability contexts [6,14]. Here, the focal company may lack the requisite internal competencies to search for and absorb new technical and market knowledge, and is not able to establish a common interest among the internal and external stakeholders regarding the ultimate economic, societal or environmental value expected from SOI activities [15].

By building on the concept of proximity dimensions, the author of this paper argues that various types of proximities can support the mineral companies to overcome the described obstacles. More specifically, organizational, institutional and cognitive proximities [16] are considered as determinants of SOI in peripheral regions. In this sense, proximity expands learning from the external linkages by bridging technical or market knowledge gaps [17] and managing institutional conflicts of interest [18]. Empirical studies assessing the link between these proximities and innovation outcomes in peripheral regions have focused primarily on a single type of proximity, for instance organizational [19] or institutional proximity [20]. As a result, we know little about the combined effect of various non-spatial dimensions of proximity on innovation in peripheral regions. This question is particularly significant by considering the complexity of knowledge exchange processes in the context of sustainability, and that such circumstances call for proximity in more than just a single dimension [21]. Thus, I propose the following question: What proximity dimensions, i.e., institutional, cognitive and organizational proximities, or any combinations of them, explain SOI performance of the companies in the minerals industry?

This paper contributes to the theory and practice in two main ways. First, it addresses the call for more empirical research on investigating firm-level determinants of superior SOI performance [5,22]. This has been done by means of a survey-based study in Norway's minerals industry, which is challenged by sustainability issues to the greatest extent. Moreover, the Norwegian context is characterized by relatively small companies and established cultural norms such as trust, that in turn encourage firms to embrace an open approach to innovation. Second, by including social innovation in the outcome variable, the paper goes beyond the prevalent focus of the regional sustainability literature on technological innovations (product and/or process). This will shed some light on the different innovation pathways of companies located in the periphery, and therefore assists in developing more informed policies to nurture innovation and development in these regions [23].

The remaining part of the paper is structured as follows: Section 2 presents the theoretical background and hypotheses that will be tested empirically. Section 3 deals with the research design and data collection process; Section 4 presents the results of descriptive statistics and regression analysis, and Section 5 discusses the findings and implications of this study.

2. Background and Hypotheses

2.1. Various Innovation Pathways towards Sustainability

Recent decades have evidenced a growing interest for studies on the linkage between innovation and sustainability, leading to the introduction of various notions such as green innovation [24],

sustainable innovation [25], eco-innovation [26] and cleaner technologies [27]. Although it is not an easy task to differentiate between these notions, it has been argued that the inconsistency in using these notions stems from the variance in terms of emphasis on different aspects of sustainability [25]. For instance, whereas eco-innovation seeks to integrate environmental and economic improvements [26], sustainable innovation broadens this scope by incorporating social considerations to the aforementioned aspects [28]. Indeed, using the term "sustainable" reflects the idea that all the three pillars of sustainability in business contexts, known as triple bottom-line [29], are considered: economic prosperity, environmental protection and social justice.

This paper adopts a broad conceptualization of sustainability, as it better reflects the diverse range of challenges in industrial settings, particularly in the case of mineral companies that should balance the economic, environmental and social aspects of their business [1]. In this regard, innovation for sustainability goes beyond ad-hoc activities with short-term benefits, and is conceived as a strategic orientation for transition towards more profitable, socially acceptable and cleaner business practices, referred to as sustainability-oriented innovation [3]. Adams et al. [5] define SOI as "making intentional changes to an organization's philosophy and values, as well as to its products, processes or practices to serve the specific purpose of creating and realizing social and environmental value in addition to economic returns". By building on this definition, the current study assumes three general pathways for innovation in sustainability contexts: process, product and social innovations. While I follow the same logic as Schiederig et al. [30] in differentiating between technological and non-technological innovations, dedicating a separate category to social innovations brings about a valuable chance to study the idiosyncrasies of this type of SOI.

There is general agreement that process and product innovations in sustainability contexts primarily aim to improve the firms' eco-efficiency [31,32]. Eco-efficiency as an overarching concept has been put forward by the World Council for Sustainable Business Development and is known as creating more economic value whilst reducing resource use and environmental impact [33]. Following this definition, Bocken et al. [34] systematically reviewed the literature and developed three generic archetypes through which eco-efficient processes and products may create sustainability-related values: maximizing resource and energy efficiency, minimizing pollution and creating value from waste, and promoting the use of renewable resources. While these drivers are directly related to economic and environmental aspects of sustainability, Suh et al. [35] posit that the spillover effects of eco-efficiency measures may also improve the firms' social performance. For example, environmental considerations such as reduction of emission could assist a firm to gain a good reputation among the locals and societal stakeholders.

On the other hand, the social innovation category of SOI points toward organizational practices that aim to improve corporate social responsibility (CSR). Research has shown that the nature of these practices are increasingly changing from a reactive and conflict resolution perspective to those with long-term considerations and broader engagement of stakeholders, in order to enable the firm to create social and economic value [36]. The importance of linking social and economic value creation in sustainability practices has led to the emergence of the concept of "social license to operate" that is widely used by researchers and practitioners. This concept implies that CSR in the context of resource-extractive industries, particularly minerals industry, goes beyond the good being of the firm and may have significant influence on the further continuation of operations and the economic sustainability of firms [37]. In this regard, leveraging on innovative routines to communicate with societal stakeholders and integrate that knowledge in introducing new CSR initiatives will help firms to act in a sustainable manner [6]. Based on this conceptualization, Suopajärvi et al. [38] argued that social sustainability in the minerals industry should incorporate organizational practices in three different aspects: communicating on environmental issues, involving societal stakeholders in relevant decision-making processes, and providing economic benefit (employment, paying tax, etc.) to the local communities.

Despite the valuable insights of the growing literature on SOI, studies on the antecedents of building innovation capability in sustainability contexts are relatively scarce. Indeed, a great deal of

research has studied the outcome of sustainability practices, and left us with limited understanding about the firm-level determinants of SOI [5,39]. Just recently, some scholars such as Ketata et al. [25] have tried to fill in this gap, but they considered the firm's absorptive capacity as the sole explanatory factor for increased degree of SOI. Whereas the above discussion showed the importance of social aspect and the need for knowledge exchange across sectors (industry–university–NGOs), the absorptive capacity construct, which is usually a scale for internal technological knowledge, is not capable of explaining all the innovation activities of firms regarding SOI. Thus, this paper aims to shed some light on those determinants using the theoretical insights from proximity literature and provides possible explanations for variation concerning SOI performance.

2.2. Non-Spatial Dimensions of Proximity for Learning and Innovation

As described above, increasing the capability of firms for conducting SOI activities requires effective learning from a diverse range of external sources that represent different knowledge backgrounds and institutional logics. This, in turn, makes SOI a demanding and extensive process for firms [4]. Moreover, peripheral localization adds to this complexity since co-location might be beneficial for firms by providing access to local knowledge spillovers, as well as assisting them in overcoming barriers such as coordination issues and uncertainty [13]. Thus, the question is what other dimensions of proximity exist and how they can contribute to learning and innovation in sustainability contexts? I will address this question in the following and Section 2.3.

Due to the growing importance of external knowledge sources for innovation, attention has risen among scholars to study the underlying factors that could affect the inter-organizational relationships. Proximity, which refers to relational closeness in inter-organizational relationships, is one of these underlying factors that could be beneficial for facilitating the knowledge exchange and hence improve the innovation performance [40]. While the literature has traditionally focused on geographical (spatial) aspect of proximity, it has been showed that proximity has other dimensions that could help firms to overcome the complexities of learning from external knowledge sources by providing coordination mechanisms and reducing the uncertainty [13,16]. In a similar vein, Mattes [41] maintains that organizational, institutional and cognitive dimensions are the three main types of non-spatial proximities.

Organizational proximity is defined as "the extent to which relations are shared in an organizational arrangement" [16]. It explains the degree of coordination between entities where a high proximity implies that those entities follow similar organizational logics [41]. Moreover, this dimension of proximity assists firms to reduce the level of uncertainty and opportunism in interactive learning. For institutional proximity, Boschma [16] differentiate between "formal" and "informal" institutions, and further describe that while the former signifies similarity in "rules and laws", the latter implies sharing the same "cultural norms and habits" that enable interaction and knowledge transfer. Whereas this dimension of proximity is primarily reflected at macro levels (such as countries), Knoben and Oerlemans [42] argued that institutions at national level could also affect rules and norms at the level of organizations. Cognitive proximity, according to Boschma [16], points toward the situations when organizations share the same knowledge base and expertise. It is an essential factor in interactive learning since it denotes whether the focal firm is able to understand and absorb the external knowledge [43]. Firms that accumulate this ability are thereby cognitively closer to their external knowledge sources, and are expected to achieve a higher degree of learning and innovation by means of increasing the effectivity of communication channels.

The logic behind the importance of non-spatial proximities is that co-location is neither a prescription for all issues arisen from different types of "distance", nor is essential when other dimensions of proximity (but not necessarily all of them) are existent [16]. For instance, a high degree of cognitive distance among actors might hinder the effective exchange of knowledge, even though these actors are geographically proximate [44]. On the other hand, Pond et al. [45] found that the existence of common incentives and constraints (high institutional proximity) between similar

organizations (for example two universities) positively affect the degree of collaborations despite of long (geographical) distance.

2.3. The Proposed Relationships between Proximity Dimensions and SOI Performance

According to the above discussion, peripheral localizations represent situations in which firms are far from their external sources of knowledge in one aspect (spatial), but can rely on other dimensions of proximity to compensate for the shortage of local knowledge spillovers and access to innovation actors in their vicinity [20]. I follow this theoretical stance and posit that firms in peripheral regions could leverage on organizational, institutional and cognitive proximity in order to acquire and absorb the knowledge from various external sources, and consequently improve their SOI performance. The theoretical framework of this study is outlined in Figure 1.

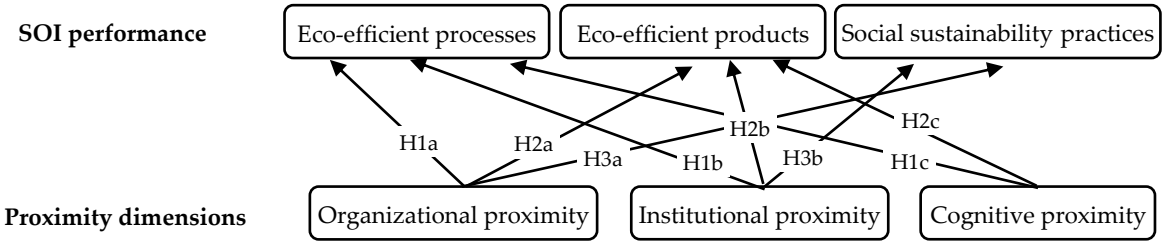

Figure 1. Non-spatial proximity dimensions as determinants of (SOI) performance.

By means of a study in a peripheral region of Sweden, Bjerke and Johansson [46] revealed that collaborations with different sources of knowledge outside their respective region have helped the firms to achieve a higher innovation performance. Lagendijk and Lorentzen [17] predict a similar outcome by arguing that collaborations provide a shared organizational setting (organizational proximity) that ease the exchange of knowledge regardless of being peripherally located. Formal institutions such as regulatory frameworks could drive eco-innovations (a subset of SOI) by means of aligning interests in supplier-end user relationships [47]. Moreover, informal institutions are essential for building trust among actors in innovation systems, and that there seems to be a strong relationship between trust and CSR-related practices such as sustainability reporting in resource-extractive industries [48]. A similar positive effect is also expected for the cognitive dimension of proximity, since it bridges the knowledge gap between the actors in innovation contexts. Ketata et al. [25] suggested that developing the technological knowledge base results in a twofold advantage due to the increase in the capacity to understand the external knowledge and also facilitate a better access to those knowledge resources. However, this type of proximity is related to technological innovations, and is expected to only affect process and product innovations in sustainability contexts. Thus, I hypothesize that:

H1a. Organizational proximity is positively related to eco-efficient process innovations.

H1b. Institutional proximity is positively related to eco-efficient process innovations.

H1c. Cognitive proximity is positively related to eco-efficient process innovations.

H2a. Organizational proximity is positively related to eco-efficient product innovations.

H2b. Institutional proximity is positively related to eco-efficient product innovations.

H2c. Cognitive proximity is positively related to eco-efficient product innovations.

H3a. Organizational proximity is positively related to new social sustainability practices.

H3b. Institutional proximity is positively related to new social sustainability practices.

3. Materials and Methods

3.1. The Empirical Setting

According to the Geological Survey of Norway, the minerals industry includes businesses that are involved in extracting and primary processing of minerals, and could be categorized into five main sectors: industrial minerals, natural and dimension stone, metallic ores, energy minerals (except oil and natural gas) and construction minerals [49]. The ore minerals sector dominated the industry until some decades ago, while industrial minerals, natural stone and construction minerals have gradually gained an increasing importance in terms of employment and sales value. By production volume, Norway is among Europe's most important producer of olivine, nepheline, titanium minerals, iron ore, marble, quartz and flake graphite. Furthermore, the country is considered for potential deposits of Critical Raw Materials (an initiative at the EU level) [50]. Besides the current mines that are in operation, there is also a high potential for significant increase in production of particular minerals, especially metallic ores and industrial minerals. Several mines that are currently in the developing or exploration phase have a promising potential for production of the so-called "green minerals" with an increasing demand in sectors such as renewable energy, manufacturing of electric cars, electronics and aerospace.

Despite its historical presence, the size of industry is quite small compared to other minerals-rich countries or the other domestic natural resource-based industries such as oil and gas. Even though the direct contribution of the minerals industry to Norway's GDP is scarce (around 0.4% based on the data from 2015), an analysis by the Geological Survey of Norway [50] shows that the GDP share of minerals value-chain (considering manufacturing of mineral-based products and metals) is just over 18%. In addition, the minerals industry in Norway has had a great significance in several peripheral districts, in terms of both direct employment and the ripple effects on local supplier industries [51]. Accordingly, it could be argued that the industry is significant for Norway's regional development and national economy.

Besides the fact that mineral companies are generally located outside the so-called urban regions due to the physical constraints of natural resources, some characteristics of Norway's minerals industry make it particularly attractive for a study on sustainability and proximity dimensions. First, the high level of labor cost in Norway puts "process efficiency" and "specialty product development" at the forefront of firms' strategies to achieve economic sustainability. Second, the strict environmental and HSE regulations in Norway constitute a severe challenge for this industry, and the firms are continuously looking for improvements concerning environmental sustainability. The social sustainability of the minerals industry in Norway is also an ongoing debate, and the government has put an extra effort through the new Mineral Act to ensure the protection of nature-based activities related to herding and fish farming that are part of locals' livelihoods. Third, openness of economy and the relatively high share of SMEs in the minerals industry (with consequently limited internal innovation base) lead to more focus on collaboration and getting access to external knowledge. Finally, Nordic countries are well known by the high level of trust among people, which again creates a milieu that facilitates the exchange of knowledge within national and Nordic territories.

3.2. Sample and Data Collection

The empirical analysis draws on the primary data collected by means of a survey concerning innovation activities in Norway's minerals industry covering the years 2013–2015 [52]. The survey was designed and administered by the author. In doing so, Dillman et al.'s [53] tailored survey design method was adopted and carefully implemented, particularly by following their guidelines concerning phrasing, testing the questionnaire, configuring the online survey instrument and contacting the target population. To increase the awareness about this research and maximize the responses, the author made initial contacts with several firms during the annual gathering of Norwegian Mineral Industry (the industry's trade association). To collect the data, a personalized

email invitation was sent to each CEO, with a link to the online instrument (Questback). The email included a cover letter that provided a brief description of the research's background and motivation. The email package and the questionnaire was administered in Norwegian to ease the communication with the firms.

In accordance with the relevant surveys regarding innovation collaboration in Norway such as Community Innovation Survey (CIS) and survey of business managers (for examples of researches that used the two mentioned surveys, see [20,54]), I opted to leave out those firms that had less than five employees at the end of 2015. Based on this exclusion criterion, a total of 193 companies were identified through the Norwegian registry of business enterprises. Following the advice of Johnnie [55], the survey took a census of the entire population of 193 companies since this research needs to include very small categories of population in some specific sectors of the minerals industry in Norway. Accordingly, the research population had 5053 employees and an aggregated income of roughly USD 1.42 billion (NOK 12.2 billion) in 2015. A pilot test was conducted in October 2016 by sending a draft of the questionnaire to six CEOs from the sample firms and two industry informants, enquiring them about the understandability of the items and concepts in the questionnaire. This resulted in some minor adaptations and reformulations of questionnaire items, and the informants approved that the companies were able to provide the required data over the questionnaire.

During the survey period from February to April 2017, a total of 101 companies provided complete responses, representing a response rate of 52%. In addition to a reminder email, I made follow-up contacts by phone in order to fill in the missing data. The non-responders were also contacted by phone and in the cases I managed to talk with the CEO, he refused to participate in the research because of time limitation or fear of information leakage. However, the respondents cover a relatively high share of firms in the target population, both in terms of total employee number (3936, that is 78% of the total employees in the population) and aggregated income (USD 1184 million, that is 83% of the income in the population).

3.3. Measurement of the Constructs

The survey builds on the existing literature to measure the theoretical constructs used in this research, i.e., the proximity dimensions as the independent and SOI performance as the dependent variables. Moreover, the econometric model includes several controls to rule out the potential effects of variables that are not of primary interest in this research. Table 1 presents the variables and their measurement scales based on the adopted definitions.

As described in Section 2.1, I differentiate among three types of SOI pathways: First, eco-efficient process innovations that concern both technological and organizational (such as supply chain management and environmental management systems) improvements at the level of production or administrative processes. Second, eco-efficient product innovations capture the introduction of mineral products that either serve as an input for development of renewable energy technologies or feature improved purity and recyclability. Third, the implementation of social innovations as practices for improving the social sustainability. Hence, the SOI construct comprises of three variables: PROCINN, PRODINN and SOCINN. The paper further measure these variables by asking the firm managers whether they have had introduced new/significantly improved processes, products, and organizational practices, respectively.

To measure the proximity constructs, the paper adopts the original definitions of proximity dimensions from Boschma [16] as described in Section 2.2. Organizational proximity (ORGPROX) implies the degree of formal arrangements used for external interactions. Following Lagendijk and Lorentzen [17], local collaborations are not included in measuring this variable since geographical proximity could also forge interactions and innovation. I included five types of external knowledge sources that could potentially act as collaborators in innovation activities: suppliers of equipment, customers, universities or research institutes, competitors or other firms in the minerals industry, and NGOs or public authorities. Therefore, a firm scored 0 if it had no collaborations with these actors and 5 when it had collaborated with all of them during 2013–2015.

Table 1. Overview of variables.

Variable	Definition	Measurement
ORGPROX	Number of non-local external sources of knowledge that were involved in the firm's collaborative innovation activities	0 to 5 (discrete)
INSTPROXF	The level of agreement ("strongly disagree" to "fully agree") with the statement: "We and our external knowledge sources follow similar rules and laws."	0, 1, 2, 3, 4 (ordinal)
INSTPROXI	The level of agreement ("strongly disagree" to "fully agree") with the statement: "We and our external knowledge sources have similar norms and values."	0, 1, 2, 3, 4 (ordinal)
COGSCI	Share of personnel with a master degree or above	% (continuous)
COGENG	Share of personnel with a bachelor degree/technical certificate	% (continuous)
PROCINN	Whether the company has introduced eco-efficient process innovation	1 = yes; 0 = otherwise
PRODINN	Whether the company has introduced eco-efficient product innovations	1 = yes; 0 = otherwise
SOCINN	Whether the company has introduced social sustainability practices	1 = yes; 0 = otherwise
SIZE	Number of employees at the end of 2015	(Continuous)
SECTOR	The 4 categories of minerals, adopted from Geological Survey of Norway	4 dummy variables
FOREIGN	Whether the company is part of a foreign conglomerate	1 = yes; 0 = otherwise
ECOREG	The seven economic regions within Norway according to NUTS 2	7 dummy variables

The institutional proximity is gauged by two variables: formal institutional proximity (INSTPROXF) and informal institutional proximity (INSTPROXI). To isolate this construct from organizational proximity, knowledge exchange through informal mechanisms and personal contacts such as meeting arenas (as opposed to formal arrangements such as contracts) are also included. I asked the firms to indicate their level of agreement with two statements concerning similarity of their "rules and laws" and "norms and values" with those of their external knowledge sources, to account for formal and informal institutional proximity, respectively. These variables are measured along a five-point Likert scale from "strongly disagree" to "fully agree", thus taking a value from 0 to 4.

For cognitive proximity, researchers argued that having university graduates among the employees increase the likelihood of mutual understanding and learning in inter-sectoral contexts such as university–industry relationships [56]. This operationalization has been widely used for measuring the absorptive capacity [43] of firms, as the prior knowledge that enable firms to assimilate and exploit the external knowledge, and seems to comply with Boschma's [16] description that "the cognitive base of organizations define their absorptive capacity for learning and innovation". Thus, this paper considers the cognitive proximity of a firm to an external source of knowledge as equivalent to the firm's capacity (prior knowledge) to absorb the knowledge from that specific external source. Since the minerals industry is of synthetic knowledge base where both engineering and scientific knowledge are relevant [57], the cognitive proximity construct in this paper comprises of two variables: engineering-related cognitive proximity (COGENG) and science-related cognitive proximity (COGSCI), measured by the share of personnel with a "bachelor degree/technical certificate" and "master degree or above", respectively.

In addition to the main variables described above, the proposed econometric model will control for four variables that may offer probable explanations for the performance of firms in terms of SOI. First, firm size may influence both the capacity to pursue sustainability practices [58] and general innovativeness [59]. Therefore, the variable SIZE is defined as the number of full-time equivalent (FTE) employees a firm had at the end of the year 2015. Second, following Greco et al. [60] and Fitjar and Rodríguez-Pose [20], I expect that foreign-owned companies by having a better access to external resources, may be more prone to introduce various innovations. Thus, the paper introduced the

binary variable FOREIGN to control for firms' ownership type. Third, inter-sectorial variance may also influence the likelihood of innovation activities, due to the relatively different market characteristics such as the competitive environment and features of the raw material. To control for this variance, the paper included the variable SECTOR, by four dummies representing four different types of minerals: industrial minerals, natural and dimension stone, metallic ores and construction minerals. The energy minerals sector is not included in the sample due to its extremely low activity in Norway (only one company was active at the end of 2015). Finally, the fourth control variable accounts for the location of firms. The reason is that the driver for pursuing a specific SOI path, such as social innovation, may be stronger in regions with a higher density of nature-based activities, such as Northern Norway. The variable ECOREG is defined based on the NUTS level 2 classification for Norway [61], including seven regions: "Oslo and Akershus", "Hedmark and Oppland", "Southeast Norway", "Agder and Rogaland", "Western Norway", "Trøndelag" and "Northern Norway". To measure this variable, I included seven dummies in all the models used for testing the hypotheses.

4. Results

4.1. Descriptive Statistics

This study included 101 Norwegian firms that are active in four different sectors within the minerals industry. As shown in Table 2, the construction minerals sector is highly represented in the sample in terms of number of firms (58% of total sample), which corresponds to the overall representation of this sector in the Norway. On the other hand, the metallic ore sector in Norway comprises of only a few firms, though their size (number of employees) is relatively higher than other sectors, specially the construction minerals sector. Small and micro enterprises (with less than 50 FTEs) constitute 80% of the firms in this study, which is again in accordance with the dominance of small companies in Norway's minerals industry. The mean value for the firm size is 38.97 (SD = 61.5) FTEs, with the largest firm having 315 full-time employees.

Table 2. Number of sample firms and their distribution in terms of size and minerals sector.

Company Size (FTEs) / Minerals Sector	Micro (between 5 and 9)	Small (between 10 and 49)	Medium (between 50 and 249)	Large (over 250)	Number of Firms	Number of Employees	Aggregated Income (MUSD)
Construction minerals	21	30	8	0	59	1680	502
Natural/dimension stone	11	9	3	0	23	604	130
Industrial minerals	2	6	6	1	15	1024	411
Metallic ore	2	0	0	2	4	628	141
Total	36	45	17	3	101	3936	1184

Table 3 provides the descriptive statistics and correlation coefficients for the variables. The dependent variables are the firms' innovation performance in three different sustainability-related paths. A total of 42 firms (41.6%) declared that they have introduced either a new or significantly improved eco-efficient process, 16 firms (15.8%) developed new or significantly improved eco-efficient products, and 35 firms (34.7%) implemented new or significantly developed social sustainability practices during 2013–2015. Further investigation into the SOI construct shows that 45 firms (44.6%) introduced no innovation during the years covered by the survey, while 9 firms (8.9%) conducted simultaneously all the three types of innovations.

Table 3. Descriptive statistics and coefficients for Spearman's correlations.

	Variable	Mean	SD	Min.	Max.	1	2	3	4	5	6	7	8	9
1	ORGPROX	0.78	1.39	0	4									
2	INSTPROXF	2.13	0.97	0	4	0.09								
3	INSTPROXI	1.97	1.09	0	4	0.32 **	0.24 *							
4	COGSCI	0.03	0.06	0	0.40	0.00	0.27 **	0.05						
5	COGENG	0.14	0.10	0	0.52	0.03	0.63 **	0.26 **	0.22 *					
6	PROCINN	0.42	0.50	0	1	0.09	0.72 **	0.28 **	0.29 **	0.65 **				
7	PRODINN	0.16	0.37	0	1	0.22 *	0.42 **	0.34 **	0.36 **	0.34 **	0.29 **			
8	SOCINN	0.35	0.48	0	1	0.35 **	0.28 **	0.76 **	0.13	0.32 **	0.31 **	0.36 **		
9	SIZE	38.97	61.50	5	315	0.15	0.39 **	0.11	0.42 **	0.19	0.49 **	0.26 **	0.30 **	
10	FOREIGN	0.16	0.37	0	1	0.09	0.03	0.00	0.24 *	–0.06	0.18	0.03	0.14	0.45 **

Note: $n = 101$; ** indicates significance at $p < 0.01$ and * indicates significance at $p < 0.05$.

The variable ORGPROX that measures a firm's organizational proximity has a mean value of 0.78, which indicates that during 2013–2015, mineral companies in Norway collaborated on average with less than one non-local organization. While 72 firms (71.3%) have had no collaborations beyond their local area, 10 firms (9.9%) had collaborations with four different types of non-local knowledge sources, and no firm had collaborations with all the five potential sources. The mean values for INSTPROXF and INSTPROXI show that firms on average have declared a moderate degree of similarity (value around 2 that is equivalent to the middle value in a five-point Likert scale from 0 to 4) of their "rules and laws" and "norms and values" to their external sources of knowledge. Although, the mean value for the formal dimension is slightly higher than informal institutional proximity. Finally, the values for the variables COGSCI and COGENG proves that the amount of employees with master degree or above is quite scarce in Norway's minerals industry (mean share of personnel equals 3%), and the value for those with formal engineering education is also very low (mean share of personnel equals 14%). Of the total 101 firms in the sample, 59 firms (58.4%) have had no employees with master degree or above and 18 firms (17.8%) have had no employees with bachelor degree/technical certificate.

4.2. Robustness Checks

Late-response and non-response biases were assessed by comparing the answers to some particular questions and demographic examinations. For this purpose, the answers to the questions about introducing various types of SOI have been compared across responders after the first email invitation, after the reminder email, and after follow-up phone calls. To address non-response bias, I examined the demographics of responders and non-responders in terms of size, their location in Norway, sector and income. None of the above investigations revealed a significant difference between responders, late-responders and non-responders.

To examine the issue of multicollinearity, I first assessed the correlations between all the dependent and independent variables. As shown in Table 3, the Spearman's coefficient for only one of the correlations between independent variables, i.e., the correlation between COGENG and INSTPROXF, is above the threshold of 0.5 and significant, which raise the concern of multicollinearity. This issue was further examined by means of variance inflation factor (VIF) test and running linear regression models for all dependent and control variables. The result showed VIF values ranged from 1.07 to 1.73, which is long below the rule of thumb of 10. Therefore, no potential collinearity problem is indicated.

4.3. Regression Results

In order to examine which proximity dimensions contribute to SOI performance of the firms in Norway's minerals industry, logit regression models were run with SPSS 24 software. The general model takes the following form:

$$\mathrm{SOI}_i = \ \mathrm{Constant} \ + \alpha_1 \mathrm{PROX}_i + \ \gamma_1 \mathrm{Controls}_i + \varepsilon_i$$

where SOI represents the three different dependent variables as described in Section 3.3: (1) PROCINN, (2) PRODINN and (3) SOCINN. The term PROX covers the five explanatory variables concerning various proximities, i.e., ORGPROX, INSTPROXF, INSTPROXI, COGSCI and COGENG. The model also includes the term Controls that refers to four control variables, namely SIZE, SECTOR, FOREIGN and ECOREG. Finally, ε represents the error term.

Table 4 shows the results of the logit regression models in three columns. As shown in column A that belongs to the dependent variable PROCINN, model 1 introduces the effect of ORGPROX. As a result, the coefficient is positive but not significant, which rejects H1a. Model 2 adds INSTPROXF and INSTPROXI into the previous model, and shows significant and positive effect of the former on PROCINN. In model 3, the coefficient for COGENG is positive and significant, hence verifies the proposed relation between engineering-related cognitive proximity and PROCINN. Therefore, H1b

and H1c are partly supported. The overall results for the outcome variable PROCINN show that while formal institutional proximity and engineering-related cognitive proximity are important factors in explaining the introduction of eco-efficient process innovations, the effect of other proximity dimensions is not significant for this outcome variable.

Table 4. The regression results on the relationship between proximity dimensions and SOI performance.

	Column A: PROCINN			**Column B: PRODINN**			**Column C: SOCINN**	
	Model 1	**Model 2**	**Model 3**	**Model 4**	**Model 5**	**Model 6**	**Model 7**	**Model 8**
ORGPROX	0.134 (0.158)	–0.002 (0.258)	–0.425 (0.293)	0.255 (0.182)	0.151 (0.231)	0.084 (0.287)	0.47 ** (0.157)	0.422 * (0.167)
INSTPROXF	-	2.852 ** (0.597)	1.97 * (0.636)	-	1.539 ** (0.528)	1.212 * (0.601)	-	0.441 (0.406)
INSTPROXI	-	0.198 (0.33)	–0.283 (0.51)	-	0.559 (0.353)	0.62 (0.414)	-	3.784 *** (0.823)
COGSCI	-	-	–10.594 (12.635)	-	-	13.319 * (5.228)	-	-
COGENG	-	-	59.209 ** (19.776)	-	-	12.283 (5.716)	-	-
SIZE	0.036 ** (0.011)	0.025 * (0.013)	0.095 * (0.019)	0.012 * (0.012)	0.007 * (0.005)	0.017 * (0.008)	0.01 * (0.005)	0.01 * (0.008)
FOREIGN	0.373 * (0.732)	0.57 * (1.015)	1.459 * (1.067)	–1.129 (1.284)	–0.471 (1.016)	–0.986 (1.358)	–0.004 (0.688)	1.553 (0.742)
SECTOR dummies included	yes	yes	yes	Yes *	Yes *	Yes *	yes	yes
ECOREG dummies included	yes	yes	yes	yes	yes	yes	yes	yes
Nagelkerke R^2	0.113	0.291	0.378	0.16	0.347	0.573	0.125	0.308
Hosmer and Lemeshow Test	$p = 0.455$	$p = 0.668$	$p = 0.334$	$p = 0.055$	$p = 0.791$	$p = 0.973$	$p = 0.441$	$p = 0.582$

Note: Standard errors in parenthesis; *** indicates significance at $p < 0.001$, ** indicates significance at $p < 0.01$ and * indicates $p < 0.05$.

Column B shows the results of regression models concerning the dependent variable PRODINN. Model 4 indicates that the effect ORGPROX is not significant for PRODINN. This finding rejects H2a. In model 5, I included INSTPROXF and INSTPROXI, and the result shows that there is a positive relation between the formal dimension of institutional proximity and PRODINN, which partly supports H2b. Finally, introducing the terms for COGSCI and COGENG in model 6 results in a positive and significant coefficient for the former variable, thereby H2c is partly supported. The overall results for the outcome variable PRODINN show that formal institutional proximity, together with the science-related cognitive proximity, may be important determinants for the introduction of eco-efficient product innovation in Norway's minerals industry.

Lastly, column C presents the regression results for SOCINN. According to model 7, the regression coefficient for ORGPROX is positive and significant, which provides support for H3a. The outcome of adding INSTPROXF and INSTPROXI to model 8 is a positive and significant coefficient for the latter variable, thus H3b is partly accepted. The combined result for the outcome variable SOCINN specify that collaboration with non-local external sources and shared norms and values are likely to increase the probability of implementing new or significantly improved social sustainability practices.

With regard to the control variables, firm size influences the likelihood of introducing all types of innovations aimed at sustainability. However, foreign-ownership is only significant for PROCINN. A possible explanation for this result is that implementation of eco-efficient processes requires a certain degree of financial capital that may be provided via foreign investment. The results for the

variable SECTOR only shows significance for the introduction of eco-efficient products, which could be explained by the higher market possibilities for new product development in some specific sectors such as the industrial minerals. Lastly, I have not found any evidence for the relationship between the economic region in which a company is located and its innovativeness.

5. Discussion

By using evidence from the minerals industry in Norway, this paper aims to contribute to our understanding about the determinants of SOI performance in peripheral regions through investigating the individual and cumulative effects of three non-spatial types of proximities: organizational, institutional and cognitive proximity. Table 5 summarizes the findings concerning the research question.

Table 5. Summary of the research findings.

SOI Performance / Proximity Dimensions	Eco-Efficient Processes	Eco-Efficient Products	Social Sustainability Practices
Organizational proximity	X	X	√
Formal institutional proximity	√	√	X
Informal institutional proximity	X	X	√
Engineering-related cognitive proximity	√	X	-
Science-related cognitive proximity	X	√	-

Note: √, relationship supported; X, relationship not supported.

Therefore, the theoretical framework of this study is revised based on the confirmed relationships between proximity dimensions and SOI (Figure 2).

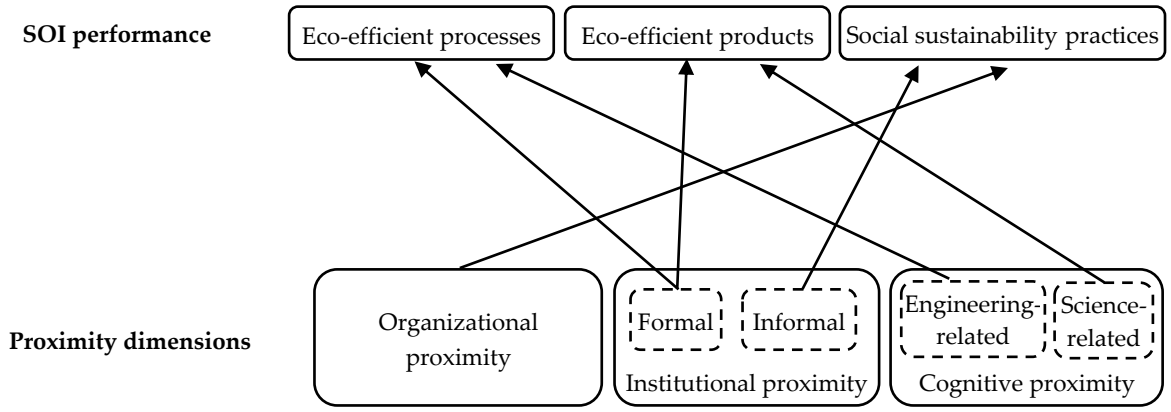

Figure 2. The confirmed relationships between proximity dimensions and SOI performance

The result shows that the degree of collaborations beyond the local region (as a measure for organizational proximity) is only significant for the implementation of social innovations. On the one hand, this finding corroborate the results of previous studies that engaging stakeholders through appropriate communication channels is a necessary precondition for generating innovations aimed at delivering social values [6]. One the other hand, the rejection of proposed relationship between broadness of collaborations and process/product innovation would seem in contradiction to the earlier studies in low-and-medium-tech industries [59]. A possible explanation for this result is the relatively longer period required for collaborative development of processes or products in the minerals industry, which may cause that the outcome of innovation activities does not appear simultaneously with the development stage. Future studies could investigate this effect by including lagged dependent variables.

As for the institutional proximity, the result of regression analysis indicates that similarity of governing rules and regulations, i.e., the existence of shared formal institutions, predicts the probability of introducing eco-efficient processes and products. Researchers have shown that in addition to lowering the uncertainty of interactions in the context of technological innovations at large, for instance by regulating the intellectual property rights [62], rules and laws can also act as underlying mechanisms to align the economic and environmental objectives in the quest for eco-efficiency [26,47,63]. Contrary to the formal dimension, informal institutional proximity has observed to be only (positively) related to social innovations. This finding could be explained by bearing in mind that informal institutions, which are related to cultural norms and values, are more region-specific [18] and their impacts on innovation outcomes with more regional orientations (such as social innovations) are expected to be more than other types of SOI.

Cognitive proximity, as hypothesized, is related to both process and product innovations in Norway's minerals industry. More specifically, a higher share of personnel educated from technical schools or universities helps the focal company to bridge the gap between its knowledge base and those of its external knowledge sources, thereby increasing the odds of learning and innovation. In this sense, the existence of educated employees not only augments a firm's capacity to understand and apply the external knowledge, but also provides a better access to external knowledge sources through the employees' relationships with skilled technicians and researchers [25]. The novel approach of this paper to distinguish between the personnel with a master degree or above and those with a bachelor degree/technical certificate contributed to a better understanding about the relationship between different types of cognitive proximity and innovation pathways. As stated by Huber [44], cognitive proximity is a complex and broad concept that requires further clarification about its sub-dimensions, for which I in this study took a step forward.

The findings presented above could have implications for policymakers and managers, specifically concerning how strategies and policy actions should address three different types of "distance", namely organizational, cognitive and institutional, between the mineral companies and their external sources of knowledge. Closing this distance could in turn augment the ability of mineral companies to learn from those knowledge sources in their quest for innovations aimed at sustainability issues. In formulating policies, specific attention should be paid to the relatively different dimensions of proximity that affect a specific innovation pathway. In this regard, while regulative frameworks at national or European level might increase the ability of firms in achieving eco-efficiency objectives, it does not necessarily bring the same result in the context of social sustainability. Instead, cultural norms and values of conduct play a more important role than formal institutions in achieving superior social sustainability. For instance, the growing political attention towards green growth [64] could facilitate the introduction of incentives that consequently encourage the minerals industry to invest on developing processes or products with less environmental footprints. On the other hand, strategic focus on establishing appropriate dialogue and improving the quality of sustainability reporting could close the normative gap between the minerals industry and societal stakeholders.

Policy interventions should also consider the progressive effect of promoting more than one proximity dimension to increase the SOI performance. Indeed, whereas the existence of one type of non-spatial proximity might increase the odds of innovation, augmenting the inter-organizational relationship by means of combining the existing proximity with another dimension(s) of proximity could exhibit a better innovation performance. As in the case of eco-efficient products in the minerals industry, the evidence suggests that the outcome from innovation activities could be significantly increased by combining policies and strategies that address the establishment of shared regulative frameworks and development of employees' scientific knowledge beyond bachelor degree. In addition to nurturing cultural values such as trust, minerals policy initiatives are suggested to promote collaborations beyond local regions. These relationships could not only increase the likelihood of learning about the concerns of the broader community, but can also spur the inflow of new knowledge about the CSR solutions from other companies or industries.

This study certainly has some limitations that motivate future research. There is an increasing empirical evidence for curvilinear (inverted U-shape) relationships between various proximities and the innovation outcome [40]. While this could be also the case for the positive relationships in this study, testing for a curvilinear effect requires larger samples that could then lower the sensitivity of logistic regression to interaction effects between the linear and quadratic terms for explanatory variables. Therefore, it is highly recommended to apply the theoretical framework of this study in larger samples in order to examine the proposed detrimental effect of excessive proximity for learning and innovation. Future research could also use a multi-level perspective for a detailed investigation of the interplay between proximity dimensions and the ultimate SOI performance. A possible research question will then be whether informal institutional proximity at the individual level triggers organizational proximity at firm and inter-firm levels. Finally yet importantly, adopting longitudinal research design to study the evolution of proximity dimensions over time will extend our understandings about their microfoundations and the likely changes in importance of one type of proximity for a specific type of innovation during various stages of sustainability transitions.

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Abbreviations

The following abbreviations are used in this manuscript:

NGO	Non-governmental organization
GDP	Gross domestic product
SME	Small and medium-sized enterprise
HSE	Health, safety and environment
CEO	Chief executive officer
MUSD (also USD)	Million United States Dollars
NOK	Norwegian Krone (currency)

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Paper 3

Linking stakeholder engagement to profitability through sustainability-oriented innovation: a quantitative study in the minerals industry

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Abstract

Firms' capability to develop sustainability-oriented innovation (SOI) can be enhanced by stakeholder engagement (SE) to acquire a wide range of external knowledge in support of those innovations. While we understand some of the transactional and relational attributes at stake for firms to leverage engagement with external stakeholders, we do not yet fully understand all the underlying mechanisms that are conducive to greater SOI outputs (through new or improved products, processes and organizational practices). At the same time, stakeholder theory emphasizes the importance of such engagements for firms' financial performance (FP), even though these findings are far from conclusive. Therefore, this paper suggests and tests a mediation model to establish an empirical basis for the associations between SE, SOI and FP. The results based on data collected from 101 mineral companies in Norway show that both the transactional and relational interactions matter for improving SOI outputs. Interestingly, SOI is a full mediator in the association between SE and FP, measured by profitability. This suggests that external engagement activities do not directly link to FP, and that the (financial) benefit begins to appear once a firm is able to transform the acquired knowledge from external stakeholders to innovative outputs.

Keywords: stakeholder engagement; innovative output; sustainability; profitability; mediator

1. Introduction

The increase in both the size and significance of social and environmental challenges has made it inevitable for firms to integrate these aspects of sustainability with their prevalent strategic focus on profit seeking (Hall & Vredenburg, 2003). This has led to emergence of corporate sustainability perspective, outlining economic, environmental and social sustainability as pathways to gain competitive advantage (Amini & Bienstock, 2014; Hart, 1995). Here, practicing socio-environmental sustainability follows a 'business case for sustainability' logic (Schaltegger et al., 2012), where managers seek economic success while performing better in social and environmental aspects, by means of for instance improving their corporate image and getting social legitimacy.

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The role of innovation in the quest for sustainability has received considerable attention from academics and businesses. It has been argued that firms have no choice but making sustainability-oriented 'changes' to the status quo of value-chain, product/service offerings and business model, in order to remain competitive (Nidumolu et al., 2009). More specifically, sustainability-oriented innovation (SOI) acts as a strategic approach through which firms innovate on different areas of products, processes and organizational practices to realize the various objectives of sustainability (Klewitz & Hansen, 2014). While recent studies in this domain call for transitions from focusing on a single area of innovation to a broader approach where product, process and organizational changes are pursued concurrently (Adams et al., 2016), we consider that such shifts also add to the complexity and uncertainty associated with SOI (Sharma, 2005) as a demanding innovation approach.

Previous research suggests that engaging stakeholders is a prerequisite for overcoming the complexity and uncertainty of SOI as it enable firms to incorporate external knowledge in their innovation processes (Rodriguez et al., 2002; Segarra-Oña et al., 2017). They further evidence the necessity of going beyond engaging primary stakeholders (those within the supply-chain), and consider secondary stakeholders (e.g. environmental activists, universities and local communities) even more important in the context of SOI (Hall & Martin, 2005). What we already know from the emerging literature on SE and SOI is centralized around either the characteristics and various roles of stakeholders (Goodman et al., 2017), or the organizational capabilities required for effective learning to happen (Kazadi et al., 2016). However, the conceptual argument of this literature that engaging more stakeholder groups is beneficial for firms' capability to achieve innovative outputs, has yet to be examined empirically.

Moreover, SE is usually perceived as costly and outside the core business activity (Nidumolu et al., 2009; Sharma, 2005), hence lack of knowledge about its significance might impede managers' ability to fully recognize the value of such engagements in terms of financial returns. While examining the performance outcomes of SE has been a major theme in the previous research, mixed findings make it difficult to understand the exact association between firms' SE practices and their performance (Laplume et al., 2008). Rather than a straightforward association, organizational resources and capabilities might mediate the effect of firms' activities regarding stakeholders and socio-environmental management on their performance (Dixon-Fowler et al., 2013; Martinez-Conesa et al., 2017). Considering that innovation capability is among the most important determinants of firm performance (Mone et al., 1998), it could be considered as a mediating factor that enable firms to transform external stakeholders' knowledge to financial benefits.

Therefore, this study addresses three research questions: (1) To what extent does SE affect a firm's SOI outputs, and (2) Does increasing engagement and SOI outputs relate to higher profitability? (3) Is SOI a mediator in SE-FP association? To address the first question, we follow Jones (1995) in distinguishing between transactional and relational interactions with external stakeholders, hence defining 'high SE' as being considerable in quality and quantity of those types of interactions (Greenwood, 2007). This will also help us to address the call for research that goes beyond the prevalent focus on characteristics of organizations or their

stakeholders (Hörisch et al., 2014) by shedding some light on the characteristics of the 'relationships' between organizations and stakeholders.

Then, by building on the natural resource-based view (NRBV) of the firm, we argue that SOI outputs in terms of processes, products and organizational practices, act as a capability through which firms continuously respond to sustainability challenges, thereby improving their competitiveness (Hart & Dowell, 2011), here measured as profitability. Finally, our theoretical model tests if SOI is a mediating factor in the link between SE and profitability, hence extends the recent contributions (Martinez-Conesa et al., 2017) that consider innovation to explain the link between social and financial performance. To test our hypotheses, we opted to study the minerals industry in Norway for two main reasons; firstly, the Scandinavian firms are characterized by a long tradition of engaging stakeholders in their business activities (Strand & Freeman, 2015). Second, resource extractive industries suit to corporate sustainability perspective (Sharma, 2005) as they faces the environmental and social challenges to the greatest extent.

This paper also makes two empirical contributions. First, our quantitative approach could add to the prevalent qualitative stance of the literature in this domain, hence providing empirical insight on the link between engagement practices and firm-level outcomes that has not been sufficiently examined before (Watson et al., 2017). Second, we draw on the recent literature that view SOI as an evolving capability (Adams et al., 2016), and bring a fresh perspective to the research on innovations in sustainability contexts by operationalizing SOI along a range, rather than a dichotomy (succeeded to innovate or not).

The remaining parts of the paper is structured as follows; in section 2, we review the state-of-the art on the intersection between SE, corporate sustainability and innovation, and presents our research hypotheses. Section 3 introduces our empirical setting and the measures, and section 4 presents the results of statistical analysis. Section 5 concludes the paper with discussions around the findings and implications for research and practice.

2. Literature review and hypotheses

2.1. Theoretical background

Sustainable development, as an overarching concept, proposes a mindset for growth that "meets the needs of the present without compromising the ability of future generations to meet their own needs" (WECD, 1987, p. 8). Subsequently, Elkington (1999) has extended this concept to the business-level through his 'Triple Bottom Line (TBL)' approach by arguing that businesses should satisfy three criteria in order to ensure success in long-term: economic prosperity, environmental protection and social equity. By building on the TBL approach, Wilson (2003) further elaborates that 'corporate sustainability' is a management paradigm that recognizes the significance of environmental and social performance, in addition to profitability. Important here is that economic, environmental and social aspects of corporate sustainability are interrelated (Amini et al., 2014) in a sense that despite of potential contradictions, they should be pursued simultaneously by adopting combinations of different strategies at the firm-level (Hahn et al., 2015).

Similar to the competitive landscape, firms' innovation practices has also undergone changes driven by the broad corporate sustainability perspective (Nidumolu et al., 2009). This has led to the emergence of several concepts at the intersection of innovation with different aspects of sustainability, such as green innovation, CSR-innovation, eco-efficiency and sustainability-oriented innovation (SOI), among the others. However, the latter seems to be more aligned with the holistic approach to sustainability, as it denotes a strategic orientation towards sustainability by deliberate improvement (incrementally or radically) in existing processes, products, technologies and business models (Klewitz et al., 2014).

While adopting an innovative approach to improve individual aspects of sustainability is neither new in research nor for practice, what differentiates SOI from the traditional approaches to innovation is the multiplicity of purposes, impacts and focus areas that adds to the complexity and uncertainty associated with innovation activities (Jay & Gerard, 2015). Complexity arises as a result of socio-technical diversity inherent in sustainability contexts (Clarke & Roome, 1999), where incorporating environmental and social considerations require knowledge about technologies, regulative standards and societal expectations.

Uncertainty, on the other hand, points to the risks and costs associated with SOI. Social and environmental improvements might be achieved at the expense of increasing the cost of processes and products, which could result in market and system failures of innovations (Foxon & Pearson, 2008). SOI, with its potential impact on wider groups of stakeholders, may create conflict situations due to the opposing interests between the focal firm and its stakeholders, for instance local communities (Hall et al., 2005; Watson et al., 2017). Because of these uncertainties, the desired outcome from SOI (e.g. market success of green products) is likely to be unknown. In below, we will discuss in what ways SE may enable firms to overcome the complexity and uncertainty of SOI.

2.1. Leveraging on stakeholders' knowledge for SOI

Before moving on, it is necessary to get a better understanding of the terms 'stakeholder' and 'stakeholder engagement'. A stakeholder "is any group or individual who can affect, or is affected by, the achievement of a corporation's purpose" (Freeman, 2010, p. 9), which in this paper, is improving SOI outputs and FP. For SE, although a single definition doesn't exist, we follow Greenwood (2007, pp. 317-318) who defines it as "practices that the organization undertakes to involve stakeholders in a positive manner in organizational activities." He separates SE from corporate responsibility as a purely moral attitude, and considers it as strategic processes through which "an organization responds to the needs of stakeholders with the aim of furthering the goals of the organization" (Greenwood, 2007, p. 324). This implies creating mutual value for the firms and their wider groups of stakeholders, as one of the tenets of corporate sustainability (Hörisch et al., 2014). By means of addressing socio-environmental sustainability through their interactions with stakeholders, firms strive to maximize the value accrued to their shareholders and other economic stakeholders.

In Hall et al.'s opinion (2003), complexity and uncertainty of SOI at the firm-level boil down to the lack of internal knowledge about technological and social aspects of sustainability, which

in turn impedes effective decisions. In this regard, engaging stakeholders in innovation processes provides access to their needs and expectations (Luyet et al., 2012), improves the firms' internal capacity to understand their stakeholders' language (Veldhuizen et al., 2013), and nurtures trust-based dialog between the firm and its societal stakeholders that infer increased knowledge for all parties (Herremans et al., 2016). Therefore, SE is not only beneficial for 'obtaining' the external knowledge, but also for 'commercializing' it (West & Bogers, 2014), i.e. to create and capture values that are of interest to both the focal firm and its stakeholders.

A deeper look into the attributes of SE directs us to what stakeholder theorists refer to as transactional vs. relational interactions (Hillman & Keim, 2001; Jones, 1995). In transactional or one-way interaction process, the primary intention of the firm is to learn about the needs and expectations of the stakeholder(s) without their direct involvement in the learning processes (Herremans et al., 2016). This inbound knowledge flow entails utilizing pecuniary (contract-based) and non-pecuniary (information search) mechanisms to supplement the internal knowledge base (Chesbrough & Crowther, 2006; Dahlander & Gann, 2010). For example, in the case of environmental management, Roome and Wijen (2006) discuss the adoption of available sustainable solutions from other companies as a means of providing the basis for change processes and innovation.

In a study of Canadian extractive industries, Bansal (2005) evidenced a positive association between pursuing an active mimicking strategy and corporate sustainability performance. She explains that firms who continuously adopt existing ideas and solutions from other companies or organizations such as industry associations decrease the uncertainty of their social and environmental sustainability practices. Holmes and Smart (2009) indicate the importance of spotting 'weak signals' for building an appropriate capability to respond to the societal stakeholders' demands. Here, powerful search mechanisms such as employing boundary spanners increases the frequency of transactions and provides timely access to ideas and opportunities, which in turn results in innovative outcomes. High quality transactional interactions go beyond ad-hoc and market-based transactions, thus involve a time dimension that adds to the depth of these relationships and converts them to resources that are not easy to duplicate by competitors (Hillman et al., 2001). A recent literature review by Dangelico (2016) on green product innovations reveals strong proof for the positive effect of firms' ability to establish and manage 'intense' knowledge flows from a variety of stakeholders such as customers, suppliers and special interest groups.

H1a. *Transactional SE is positively associated with SOI outputs*

On the other hand, relational or two-way interactions entail knowledge exchange processes between a firm and its stakeholders (Onkila, 2011). Known as coupled knowledge flow in the innovation literature, they occur mainly via formal mechanisms such as alliances and socially constructed relationships such as personal networks (Faems et al., 2008; West et al., 2014). Others maintain that relational interactions with external stakeholders are grounded on mutual trust and honesty, hence require the focal firm to disclose and share its internal information (e.g. issues, solutions, requirements) in order to establish an effective dialogue with its stakeholders

(Gould, 2012; Herremans et al., 2016). Consequently, the probability of creating shared value through SOI depends on the ability of the firm to effectively manage its networks of relationships with multiple stakeholders (Kazadi et al., 2016). This could provide a learning milieu for the firm and its stakeholders for reaching a common understanding about the specific purpose(s) of a sustainable product, process or organizational practice.

Compared to the transactional interactions, their relational counterpart has received more attention from the researchers who linked SE to SOI. Nevertheless, the focus has been mainly on exploring the capabilities required to learn from different types of stakeholders. By emphasizing the necessity of actively involving multiple stakeholders in innovation processes, Kazadi et al. (2016) illustrate that 'stakeholder co-creation capabilities' are highly crucial in the context of SOI since the inability of firms to attract specific groups of stakeholders can even result in the stop of innovation projects. Similarly, Hall et al. (2005) report on the case of Monsanto, a biotechnology corporation, that had to deal with a variety of economic, environmental and social risks associated to its new herbicide product. To this end, the company established new communication channels with their secondary stakeholders to hear and address their concerns about the product.

Recent studies also suggest that secondary stakeholders are even more important that those within the typical supply-chain of a company, and use this insight to propose that two-way interactions with a diverse range of stakeholders is beneficiary in different stages of SOI (Goodman et al., 2017). In the context of new product development, firms who integrate issues and demands that are important to both primary and secondary stakeholders could earn the social approval as a success factor for commercialization of their products (Driessen & Hillebrand, 2013). This line of reasoning allows us to hypothesize that:

H1b. *Relational SE is positively associated with SOI outputs*

To the best of our knowledge, only two studies has quantitatively examined the effect of SE on outcomes related to SOI. Ayuso et al. (2011) argued for a positive link between diversity of engagement and tendency of firms to undertake SOI, but did not find support for this hypothesis when controlling for the firms' knowledge management practices. On the contrary, Ketata et al. (2015) found empirical support for their propositions that both the quantity and quality of SE increase the degree of sustainability achieved through a firm's innovations. However, common in both of the above studies is the limitation regarding the dependent variable, i.e. SOI. While in the first study, the dependent variable is tendency of firms but not the actual innovative outputs in terms of products, processes or practices, the second study only include innovative firms in the analysis, hence missing the baseline (firms with no reported activities of SOI). Another caveat of Ketata et al.'s (2015) measure of SOI lies in the fact that it doesn't represent sustainability-oriented practices but also allowing the intrusion of actions such as greenwashing, since it assesses the sustainability-related effects of 'all innovations' a firm has developed. Coincidental practices such as greenwashing does not conform to the definition of SOI (Baumgartner & Ebner, 2010) that implies deliberate improvements as an integrated part of a firm's strategy and routines.

2.2. Linking SOI to FP

Organization scholars maintain that innovation capability is an important source of superior business performance (Mone et al., 1998). They encourage researchers to establish empirical links between determinants of this capability, innovation outcomes, and FP, in order to elucidate the likely value of innovation to firm managers (Crossan & Apaydin, 2010). In the domain of corporate sustainability, Bocken et al. (2014) developed a conceptual framework to explain how different types of SOI, including technological, social and organizational outcomes, could provide firms with financial benefits whilst helping them to create social values for their communities. Their proposed business model archetypes range from 'efficiency maximization' aiming at reducing environmental and financial costs to 'adopting stewardship roles' towards the society with the purpose of generating positive reputation in their communities.

Our point of departure for linking SOI to FP is the natural resource-based view (NRBV) of the firm, as a theory that concerns competitive advantage to be increasingly dependent on capabilities driven by corporate sustainability (Hart, 1995). By extending the resource-based view (RBV) and in close connection with the dynamic capabilities approach (Teece et al., 1997), NRBV introduces pollution prevention, product stewardship and sustainable development, as the three main strategic approaches for continuous reconfiguration of firm-level resources and capabilities in sustainability contexts (Hart et al., 2011). While the complexity and uncertainty of sustainability objectives exhibit rapidly changing business environments, dynamic capabilities rooted in these strategies will help firms to address environmental and social issues as an integrated part of their overall business strategy, thereby gaining advantage against their competitors.

As Rodriguez et al. (2002) explain, innovations that target corporate sustainability are typical examples of valuable, rare and inimitable assets, which reflects their competitive potential as depicted by RBV theorists (Barney, 1991). SOI is difficult to imitate concerning the participation of several groups of stakeholders in their development (Hillman et al., 2001). Moreover, interactions with stakeholders often involve the exchange of tacit social and environmental knowledge that are hard to be copied by competitors (Zollo et al., 2013). Accordingly, we argue that SOI is likely to provide sustained FP. In one of the first empirical studies that draws on NRBV, Sharma and Vredenburg (1998) examined if the capability for continuous innovation, triggered by proactive environmental strategies, predicts the competitive advantage of firms in different aspects. Their findings corroborated this link, hence supporting the assumption that SOI capability is positively related to cost reduction and process optimization, among the other benefits.

From a narrower approach to SOI, researchers has so far provided convincing empirical evidence to highlight the effect of environmental, and more generally, green innovations, on different aspects of firms' performance. By examining the link between green product/process innovations and new product success in China, Wong (2013) found that product innovation capability predicts higher product success compared to process innovation capability. In a similar vein, Aguilera-Caracuel and Ortiz-de-Mandojana (2013) showed that the intensity of green innovation, measured by the share of registered green patents, is positively related to FP

expressed in return on assets (ROA). However, they did not find any significant performance difference between green innovators and non-green innovators that based on their opinion emanates from the fact that the financial benefit from such innovations appears in long-term.

While the existing research contributed to our understanding about the link between different types of SOI and performance, we have yet to know whether undertaking various SOI activities at the same time could also provide firms with better FP. The need for such insight stems from the growing necessity for a holistic approach to SOI, that is, developing innovation capabilities at different levels of process, product and organizational practices (Adams et al., 2016). This could be also perceived in NRBV, where sustainability-related strategies are supposed to be interconnected, in a sense that achieving a certain output (for instance, product stewardship) might depend on the existence of others (for instance, pollution prevention) (Hart, 1995). Therefore, considering different types of SOI in isolation might limit our understanding about their interrelation, and the likely positive effect of a broader SOI approach on FP. Accordingly, we hypothesize that:

H2. *A firm's SOI outputs positively contribute to its FP*

2.3. SOI as a mediator of SE-FP association

Considering hypotheses H1a and H1b that propose a positive association between SE and SOI, and H2 that considers the latter as being positively related to FP, one could also assume that SE might conduce to FP regardless of SOI outputs. This alternative explanation is indeed rooted in the stakeholder theory, particularly the instrumental approach to stakeholder relationships, which basically proposes that firms practicing SE could outperform their competitors on various long term financial indicators (Donaldson & Preston, 1995; Jones, 1995). However, the empirical studies have shown mixed results (Laplume et al., 2008), implying that the likely effect of SE on FP is contingent upon other variables that should be taken into account.

Whereas the contingency of SE-FP association has yet to be studied thoroughly, a similar perspective could be found in the literature examining the association between firms' socio-environmental activities (and/or performance) and their FP. In an effort to address this debate, Dixon-Fowler et al.'s (2013) meta-analysis underpins that firms with better environmental performance exhibit more focus on continuous innovation as an strong organizational capability, hence increase their efficiency by lowering costs. Indeed, environmental management does not directly contribute to financial benefits, but rather, cultivates innovation as an organizational capability that generate competitive advantage (Sharma et al., 1998). In the context of SMEs, Martinez-Conesa et al. (2017) found that firms with proactive CSR strategies achieve better financial performance, and this association could be augmented through an increase in innovation performance relative to others in their industry.

By applying the contingency perspective to SE-FP association, we argue that SE may not lead to financial benefit for all firms under all conditions. Unlike to the previous studies that identify SE as an organizational capability (Ayuso et al., 2006; Watson et al., 2017), this argument posits that even though relationships with stakeholders provide firms with new knowledge resources, they may not result in superior performance if the knowledge is not converted to innovative

outputs. Unique innovation capabilities with potential for competitive advantage could be developed through combinations of external stakeholders' knowledge, as one type of necessary resource, with other resources (e.g. firms' internal knowledge), in order to bring benefits to the firm and its stakeholders (Cohen & Levinthal, 1990; Teece et al., 1997). For instance, Driessen et al. (2013) suggest that while addressing the interests of stakeholders is not directly related to indicators of competitive advantage such as FP, it may result in valuable, rare and inimitable organizational capabilities that eventually improve the performance. Therefore, it is likely that tapping to external knowledge might not per se be related to firm performance, but instead conduce to the development of a capability that in turn improves FP. This discussion implies a fully mediating role for SOI, leading us hypothesize that:

H3. *SOI fully mediates the association between SE and FP*

Figure 1 illustrates our theoretical framework as described above. It consists of three core elements: SE, SOI outputs and FP. First, we test the association between SE, featured by transactional and relational interactions, and firms' SOI outputs. As for the second hypothesis, the effect of SOI on FP is examined. Finally, the indirect effect of SE on FP is investigated in H3, by introducing SOI as a mediating variable.

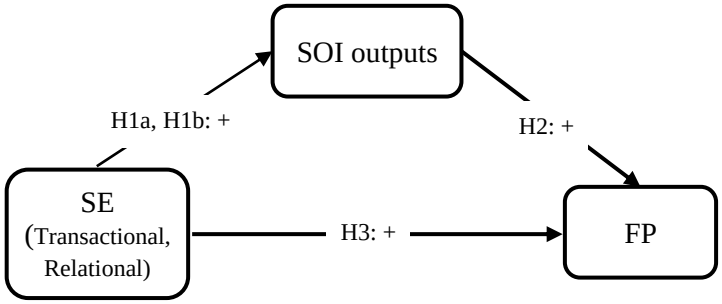

Figure 1: Theoretical framework

3. Methods

3.1. Sample and data

The Norwegian minerals industry serves as the empirical setting for our study. By definition, this industry comprises of firms that are involved in extracting and primary processing of minerals in five main categories: industrial minerals, natural and dimension stone, metallic ores, energy minerals (except oil and natural gas) and construction minerals (Geological Survey of Norway, 2016). We refer to two main criteria that guided us to choose this empirical setting, that is, urgency of corporate sustainability perspective in the minerals industry, and the cooperative culture in the Scandinavian context. First, the minerals industry is generally characterized by a high degree of environmental and social pressure, as well as economic difficulty due to the fluctuations in the commodity markets (Laurence, 2011). The situation is even more challenging in a country such as Norway that commits to strict environmental and social regulations. For instance, a considerable number of existing mines and proved reserves in Norway are located in peripheral districts with nature-based activities such as herding and fish farming, which in turn makes it crucial for firms to integrate environmental and social

sustainability into their business practices. In addition, previous studies in organization and management literature argue that institutionalized cultural norms such as trust, welcoming critical voices and long-term approach towards value-creation nurture company-stakeholder cooperation in the Scandinavian business context (Strand et al., 2015). We therefore consider that our empirical setting is an interesting context as it marries the features of SE and corporate sustainability.

Data regarding SE and innovation activities was gathered by means of an author-designed survey that asked firms to specify their innovation outcomes, relationships with external stakeholders and internal routines for knowledge sharing in the period 2013-2015 (Ghassim, 2018). Dillman et al.'s (2014) tailored survey approach was carefully followed in testing the questionnaire, configuring the online survey instrument and contacting the target population. Following relevant surveys such as the Community Innovation Survey (CIS), we did not include firms that had less than five employees in the end of 2015. Accordingly, 193 companies were identified through the Norwegian registry of business enterprises. The questionnaire was directed to company managers as their perceptions about stakeholders are central in stakeholder relationships (Mitchell et al., 1997). Prior to the survey, we made initial contacts with several firms during the annual gathering of Norwegian Minerals Industry (the industry's trade association) to increase the awareness about this study. However, we deliberately avoided to use the term 'sustainability' both in our preliminary discussions and in the questionnaire in order to reduce social desirability bias.

A pilot test was conducted in October 2016 to establish the construct validity of the survey instrument. Six managers from the sample firms and two industry informants received a draft of the questionnaire and then were interviewed over phone. This resulted in some minor adaptations and reformulations of questionnaire items. A personalized email invitation was thus sent to the chief executive managers of 193 companies, including a cover letter and the link to online questionnaire. Finally, and after two rounds of follow-up contacts, 101 companies (response rate: 52%) provided complete responses during the period from February to April 2017. The respondent firms account for 78% of the total employees and 83% of the total annual sales value in the overall population of the Norwegian minerals industry.

For firms' FP, we draw on the openly accessible database of accounting data in Norway, called Proff®. The majority of Norwegian firms are legally required to submit their annual accounts to the governmental authorities, which is also used as a reliable open source of information for instance in B-to-B partnerships. We particularly matched respondents from the survey with the financial database in order to collect their gross sales value and operational profits in the years 2012 and 2016.

To assess late-response bias, we compared the three groups of respondents, late-respondents (including two subgroups of respondents after the reminder email and those after the follow-up phone call) and non-respondents in terms of size, sales value and innovation outcome. The result revealed no significant difference between these groups. To reduce common method bias, we adopted both procedural and statistical approaches following the suggestions of Podsakoff et al. (2003). First, two different sources of information (survey and financial database) were

used so that the data for all predictor and outcome variables were not obtained from the same respondents. We also used different response types such as Likert scales, yes/no answers, indications of percentages and questions requiring absolute numbers in the questionnaire. Moreover, the respondents were assured full anonymity in order to reduce evaluation apprehension and obtain reliable answers. As for the statistical remedies, we employed Harman's single-factor test by loading all of the variables in an exploratory factor analysis. The unrotated factor solution (the principal component factor analysis) revealed the presence of four distinct factors with eigenvalue greater than 1.0, rather than a single factor. The four factors together accounted for 71% of the total variance; the first (largest) factor did not account for a majority of the variance (22%). Thus, no general factor is apparent, suggesting that common method bias is not a substantial validity threat to this study.

3.2. Measures

For FP, we follow the extant literature on the performance effects of innovation (Faems et al., 2010; Piening & Salge, 2015), and use *return on sale (ROS)* defined as the extent of total revenues that is actually converted into profits. As using contemporary data for dependent and independent variables might raise the issue of endogeneity (Fiske et al., 2010), we used time-lagged operational profit and sales value in year 2016. Again, following the earlier studies, we include firms' ROS in the year prior to the survey period, i.e. 2012, to control for the likely effect of past performance on future performance.

As described in section 2, SOI is generally categorized into processes, products and organizational practices (Klewitz et al., 2014). In each of these categories, the questionnaire provided various areas for innovation, and asked managers to specify their innovative outputs in the period 2013-2015. For process innovations, we took into account the following improvements: maximizing resource and energy efficiency, minimizing pollution and creating value from waste, and promoting the use of renewable resources. Product innovations capture development of mineral products that either serve as an input for new markets such as renewable energy technologies or feature improved purity and recyclability. Lastly, the organizational dimension of SOI in our study pertains to new practices aimed at obtaining social approval, including three different aspects (Suopajärvi et al., 2016): communication about environmental and social impacts, involvement in the development of a mine, contributing to the socio-economic welfare of the local community (e.g. creating jobs). For simplicity, we refer to the last category as social innovations. *SOI* is then measured along a 4-point scale (0 to 3), when 0 indicates no innovations in the three categories described above and 3 specifies at least one type of innovation in each of the categories. Between these extremes, two other levels represents firms that declared one and two types of innovative output in the survey period.

Regarding SE, we included six different groups of external stakeholders in the questionnaire: customers, suppliers, NGOs/interest organizations, public authorities, competitors/peer companies and universities. Greenwood (2007, p. 322) defines 'high SE' as "where these activities [transactional and relational interactions] are numerous and/or these activities are of

high quality"[†]. In other words, high SE is related to both the quantity (variety) and quality (strength) of relationships with external stakeholders. Whereas relational mode of SE is inherently intense, transactional interactions denote weak connections between a firm and its stakeholders (Herremans et al., 2016). Accordingly, for transactional interactions (*TRA*), firms were asked to state how often they searched for knowledge from each of the above stakeholder groups, based on a 5-point scale from never (=1) to very often (=5). We then calculated the number of stakeholder groups that a firm declared to search 'often' (=4) and 'very often' (=5), hence considering frequent interactions as those that are of high quality. Regarding relational interactions (*REL*), firms indicated their collaboration activities during the survey period, enabling us to measure the number of stakeholder groups that were engaged in this type of interactions. For instance, a firm scores 6 in TRA if it engaged all the six stakeholder groups often or very often, and 0 if all of them were engaged at medium (=3) or lower levels. On the other hand, a score of 6 in REL shows that the company collaborated with all the stakeholder groups, and 0 if with none of them.

Next to firms' ROS in 2012, we also control for several other variables. R&D activities and employees' education level may influence the ability of firms to pursue SOI (Ketata et al., 2015). The dummy variable *INRD* captures whether a firm performed internal R&D activities during 2013-2015. For education level (*EDN*), we calculated the share of personnel with university degree. Furthermore, earlier studies suggest that the amount of benefit from SE depends on a firm's internal capacity to share and integrate the acquired knowledge (Ayuso et al., 2011; Wong, 2013). Accordingly, we included the variable 'knowledge assimilation capacity' (*ASSIM*) as a firm's ability to analyze, interpret and understand knowledge. It was then measured by averaging the scores from a five-point Likert scale (low = 1 to high = 5) for four questionnaire items adopted from Flatten et al. (2011). Firm size could influence its capacity to pursue sustainability practices and also FP (Hörisch et al., 2015). The variable *SIZE* is loaded to all our models gauged as the natural logarithm of number of full-time equivalent employees at the end of 2015. To account for inter-sectorial variety in the minerals industry, the variable *SECTOR* is introduced as four dummies representing four different types of minerals sector in our final sample. Finally, it is argued that family firms have a higher tendency to seek corporate sustainability due to the relatively longer-term view in their management team (Laplume et al., 2008). To this end, the binary variable *FAMILY* is added to our model.

4. Analysis and results

Data analysis was performed by following different procedures in SPSS. In a preliminary stage, it was required to identify different clusters of firms in terms of their SOI outputs. In this regard, we performed a combined cluster analysis (hierarchical and non-hierarchical procedures) that increase the validity of final cluster solutions (Ketchen & Shook, 1996). First, firms' reported process, product and social innovations (if any) were used for a hierarchical cluster analysis (Ward's method and the squared Euclidian distance measure), which is particularly appropriate for identification of number of clusters (Ketchen et al., 1996). By inspecting the dendrogram, a

[†] emphasis in the brackets by the authors

'seven clusters' solution was to be apparent. However, the theoretical discussion favors a 'four-cluster' solution where firms with similar number(s) of SOI output (0-3) are homogenous. Consequently, in the second step of our cluster analysis, k-means method was employed to examine the results for four- and seven-cluster solutions. While the results seemed to be appropriate for both solutions, we followed Ketchen et al.'s (1996) recommendation and re-examined the results analysis for splitted (halved) sub-samples. The findings showed that the four-cluster solution is more consistent; hence, we chose to proceed our hypotheses tests with four levels of SOI. As shown in the Appendix, the homogeneity of these four clusters could be also confirmed by highly significant F-values in the subsequent ANOVA analysis.

4.1. Descriptive statistics

Table 1 presents the descriptive statistics and correlation coefficients for the dependent, independent and control variables. Our sample covers a range from micro-companies (5 to 9 employees) to large ones (over 250 employees), with the smallest and largest having 5 and 315 full-time equivalent employees, respectively. As for the sector, the construction mineral companies are highly represented in the sample, compared to the other three categories[‡]. However, this over-representation is in accordance with the overall structure of the minerals industry in Norway and could not be an issue for generalizing the findings. On average, ROS in 2016 has increased compared to 2012. A deeper look into this variable shows that while some companies are struggling with making profit and even experience negative profitability (cost exceed sales), some companies assured sustained profitability growth over time.

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Insert Table 1 about here
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Similarly, firms in our sample demonstrate different levels of SOI output, which on average appears to be on one SOI type. More specifically, non-innovators account for 44%, focused innovators (one type of SOI) for 26%, strong innovators (two types of SOI) for 21%, and finally, all-round innovators (three types of SOI) constitute 9% of firms in the sample. According to the mean values for TRA and REL, Norwegian mineral companies engaged between one and two external stakeholders in their innovation processes in the survey period. Based on the fairly strong and significant correlation between these variables and SOI, we believe that the low mean values for TRA and REL is due to the extremely low SE of non-innovators. We further examine this argument in testing the hypotheses.

The correlation coefficients between independent and control variables, specifically those above 0.5 and significant, suggest that multicollinearity might be an issue. We therefore ran variance inflation factor (VIF) test for all the independent and control variables, which resulted in VIF values ranged from 1.13 to 1.47. Since these values are well below the rules of thumb

[‡] Although per definition the industry includes a fifth category, i.e. energy minerals, there was only one active company in this category in the survey period and we decided not to include it due to the likely problems in making the data subject unidentifiable.

of 10 or 4 (O'brien, 2007), we can conclude that multicollinearity is not a serious concern in our analysis.

4.2. Test of hypotheses

The first question we examine is to what extent external SE affects SOI outputs. To this end, we developed hypotheses H1a and H1b, respectively addressing the effects of transactional and relational SE. We test these hypotheses by employing an ordinal logit regression, as the dependent variable is measured on an ordinal scale[§]. The results is shown in Table 2.

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Insert Table 2 about here
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A fundamental assumption of ordinal regression is that the effect of independent (including control) variables are the same for each level of the dependent variable. In SPSS, this assumption could be examined by a test of parallel lines (Norušis, 2006), which rejects the similarity of effects (the null-hypothesis in this test) when the result is significant. Thus, for each of the models testing H1a and H1b, the results for the test of parallel lines is also presented (see Table 2). Overall, our results indicate a non-significant result for this test in all the three models (p-values are greater than 0.1); hence, we assume that the predicting variables have identical effects on the various levels of SOI output.

Model 1 is the baseline model that includes the effect of control variables: ROS2012, INRD, EDN, ASSIM, FAMILY, SIZE and SECTOR. In model 2, we introduce the effect of TRA to the previous model in order to test H1a. As shown in Table 2, the coefficient is positive and highly significant, in agreement to H1a. Model 3, on the other hand, adds the effect of REL to model 1. The regression coefficient is again positive and highly significant, as hypothesized in H1b. Model 4 loads the effects of both independent variables, and corroborates the positive and significant coefficients for the independent variables obtained in the previous models. Model 4, as the final model in the ordinal regression, is highly significant ($\lambda^2(11) = 94.775$, $p = .000$) with a McFadden pseudo R-square of .375 that shows the overall goodness-of-fit for the model. The results described above indicate that both the transactional and relational SE are positively associated to SOI. Ceteris paribus, the odds of achieving higher SOI outputs improves by 99.4% and 78.9% with a unit rise in transactional and relational SE, respectively. As for the control variables, EDN, ASSIM and SIZE are positive and significant in all the models. The coefficients for inter-sectorial variance show that only the metallic ore firms differ in terms of SOI outputs.

Our second hypothesis suggests that firm's SOI outputs positively contribute to their FP. Linear regression and multiple OLS method was performed to test this hypothesis. As shown in Table 3, we first loaded the effect of controls to model 5. Subsequently, SOI is added to create model 6. Concerning the control variables, the regression coefficient for ROS2012 shows that prior

[§] An alternative might be to treat SOI capability as a nominal variable, meaning that different levels of SOI output have not a natural ordering. Therefore, we also ran the analysis using multinomial logit model and found similar results as the one obtained from ordinal logit regression. The results are available from the authors upon request.

FP is an important predictor of subsequent performance. Interestingly, we found that firm size is not significant for FP, whereas non-family firms seems to outperform their counterparts.

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Insert Table 3 about here
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For the theoretical argument suggested in this study, model 6 provides information about the positive impact of SOI on firm's FP. More specifically, a single unit increase in SOI (e.g. from one to two types of innovative output) could then increase the profitability by 3.186%, a highly significant effect at $p<0.001$. Comparing the standardized coefficients for ROS2012 and SOI in model 6, we see that the effect of prior FP on the subsequent performance is just over two times the effect of SOI on the latter. The goodness-of-fit statistics for model 6 indicate that adding SOI results in a significant improvement compared to model 5 that only include controls (F change = 13,572, $p<0.001$).

The last hypothesis of this study (H3) goes beyond straightforward relationships tested before, and suggests if SOI fully mediates the SE-FP association. While the traditional practice in mediation analysis was to require the existence of a significant direct path from predictor to outcome variable, recent advancements in this area argues for unnecessity of such a link (Aguinis et al., 2017). This argument draws on the fact that mediation is established through two paths: (1) from the predictor to the mediator and (2) from the mediator to the outcome variable. As we already investigated these two paths in our ordinal and linear regressions (H1 and H2), test of H3 deals particularly with examining the size and significance of the indirect link between the predictor (SE) and outcome variable (FP).

Accordingly, we followed Zhao et al.'s (2010) instruction for doing mediation analysis in SPSS that is built upon Preacher-Hayes bootstrapping script. As we have two predictor variables (TRA and REL), the analysis is done separately for each of them while controlling for the other. Including in both models are our controls, as described above. The results reveal that SOI fully mediates the effect of both TRA and REL on ROS2016, which supports H3. More specifically, for TRA, the mean indirect effect from the bootstrap analysis is positive and significant (effect size = .741), with a 95% confidence interval excluding zero (.1991 to 1.6625). Concerning REL, the mean indirect effect is positive and significant (effect size = .6485), with a 95% confidence interval excluding zero (.1191 to 1.5758). The ratios of indirect to total effect indicate that SOI accounts for 56% and 50% of total effects of TRA and REL on ROS2016, respectively.

5. Discussion

As firms are increasingly pressured to leverage innovation in the quest for balancing social, environmental and economic sustainability (Klewitz et al., 2014; Nidumolu et al., 2009), a central question would then concerns the antecedents and consequences of accomplishing SOI. In light of the growing literature emphasizing the utmost importance of SE in tackling sustainability challenges (Hall et al., 2005; Segarra-Oña et al., 2017), this paper sets out to examine the mechanisms through which externally acquired knowledge could contribute to firms' SOI outputs and financial performance. By drawing on the stakeholder theory, we

focused on two specific modes of SE, i.e. transactional and relational, and adopted a nuanced approach to quantitatively test the association between SE, SOI outputs and FP. This has enabled us to reveal the mediating effect of SOI in SE-FP association, hence suggesting SOI as a mechanism that conditions the financial benefit from engaging highly with external stakeholders.

Concerning the association between SE and SOI, both transactional and relational modes of SE are conducive to broader range of SOI outputs, covering process, product and social innovations. Given the complexity and uncertainty of adopting such a holistic approach to SOI, SE enable firms to access a diverse range of knowledge resources that in turn increase their ability in understanding socio-technical requirements and mitigating conflicting interests (Clarke et al., 1999; Watson et al., 2017). Our findings extend this insight by showing that not only the variety of stakeholders engaged in innovation processes matter for SOI, but also engagement practices should be frequent enough to result in strong relationships that spur effective learning. Therefore, we respond to Hörisch et al.'s (2014) call for more attention to the intricacies of the relationships with external stakeholders, as it does not anymore suffice to answer "What types of stakeholder groups should be engaged", but rather "How to engage dissimilar stakeholders?" in order to fulfill various sustainability objectives.

More specifically, regarding transactional SE, firms need to implement ongoing knowledge acquisition activities that compensate for the low direct involvement of stakeholders in these one-way relationships. Assuming external stakeholders as mere information sources, rather than co-creators of knowledge, may hinder mutual understanding required for closing the gap between conflicting goals (Kazadi et al., 2016). Others also understate transactional SE from a 'competitive advantage' point of view by arguing that they are easily duplicable by competitors due to the dearth of socially complex resources (e.g. knowledge assets and trust) embedded in them (Hillman et al., 2001). However, our study allows to conclude that repeating transactional processes such as actively mimicking the established technical solutions in the market (Bansal, 2005) or employing boundary spanners to spot weak signals from societal stakeholders (Holmes et al., 2009) could provide firms with timely access to external knowledge, and consequently increase the probability of innovation.

Relational SE differs from the transactional one in the sense that it requires relatively long-term commitments together with the desire of the focal firm in sharing the internal knowledge with external stakeholders. This trust-based relationship, in turn, increases the exchange of complex technical and social knowledge (Hillman et al., 2001), especially in the case of highly uncertain innovations that entail a variety of economic, environmental and social risks (Hall et al., 2005). Our results corroborate earlier findings about the importance of engaging a diverse set of stakeholders in SOI practices (Goodman et al., 2017; Kazadi et al., 2016; Sharma, 2005), and furthermore provide empirical insights that move beyond the small case samples used in the extant literature.

As for the association between SOI and FP, we found convincing evidence to support the hypothesis that adopting a holistic SOI approach and broadening the scope of innovations into different areas of process, product and organizational practices explain superior profitability.

While a positive association between narrower approaches to SOI (e.g. technological advances in products and processes) and FP has been identified in the previous studies (Aguilera-Caracuel et al., 2013; Martinez-Conesa et al., 2017; Sharma et al., 1998), our finding sheds more light on SOI as a multi-dimensional capability that enable firms to simultaneously address various sustainability objectives. A firm that focuses on innovations with limited sustainability approaches, for instance environmental process innovations, might not be necessarily more profitable than its counterparts (Aguilera-Caracuel et al., 2013). Instead, combining advancements in technological processes with improvements in product quality and effective communication with societal stakeholders could assist a firm in reaping the financial benefits of environmental management by differentiating its product in the respective markets (Bansal, 2005).

The competitive value of SOI as a unique capability directs us to describe the results about the fully mediated hypothesis. Our results show that the direct association between SE (both transactional and relational) and FP does not exist, as the mere access to external knowledge may hardly denote valuable, rare and inimitable assets required for superior FP (Barney, 1991). This is in contradiction with other studies that identify SE as an organizational capability by arguing that relationships with external stakeholders provide firms with access to complementary resources (Ayuso et al., 2006; Watson et al., 2017). While we do not reject the benefit of SE in terms of complementary resources, our data let us to believe that firms accumulate valuable capabilities when they are able to combine external inputs, as one type of resource, with other resources such as their internal knowledge (Cohen et al., 1990; Teece et al., 1997). Hence, the only-indirect SE-FP association is fully mediated by SOI outputs that translate the benefits of SE to financial outcomes.

Based on these findings, we can formulate some implications for practice. Firm managers should recognize the benefits and limitations of SE as regarding innovative and financial outcomes. Whereas both transactional and relational relationships may enhance firms' capability in carrying out innovations, the manner in which these mechanisms of SE conduce to innovative outputs differ. Besides considering the need for engaging a wide set of external stakeholders, specific attention should be devoted to make the engagement practices strong enough (e.g. by increasing the frequency of transactions) such that timely access to knowledge resources and effective learning are secured. However, managers should also be aware of their internal capacity limitations, and the extent their human and financial resources ought to be allocated to external engagement activities. In this regard, transactional SE are advantageous over its relational counterpart as the latter entails mutual commitments and greater pressure to sacrificing own interests.

Another lesson from this study is the positive financial effect that broadening the scope of SOI might have. Indeed, focusing on either process, product or organizational innovations may hinder firms to address one or another aspect of sustainability, thereby missing their profitability in the long run. For instance, the 'green growth movement' has found its way in to the policy discourse in Norway and is increasingly changing the strategic orientation of firms in the minerals industry. Thus, it is expected that firms that lag behind this movement and fail to move

beyond the prevalent focus on process innovations might then face the risk of sudden changes in customers' product specifications. In addition, building appropriate capabilities for continuously innovating processes, products and organizational practices not only has a direct impact on FP, but also is a mechanism through which the (financial) benefit from engagement activities unfolds.

This study certainly has some limitations that motivate future research. Since firms usually do not have enough internal resources to engage intensely with all the external stakeholders, there might exist a trade-off point where performance is optimized. A particular attention should be paid to the marginal returns (in terms of both innovation and financial outputs) from transactional and relational SE, as they are usually used in combination. Accordingly, a potential avenue for SOI research would be to investigate the role of internal factors such as absorptive capacity in moderating the complementary/substitution effect of SE on SOI and FP. Another limitation of this study is inherent in our empirical setting. While examining the associations between SE, SOI and FP in a single industry provides deep insights on how firms in a particular sector respond to sustainability concerns, we encourage future research to test our model in other sectors and country contexts. Finally, SOI is one out of possibly several factors that serve to clarify the nature of the SE-FP association. As this complex association is still under-researched, examining other contingency factors will help us to better understand under what conditions firms' efforts invested in engaging stakeholders and addressing broader sustainability concerns would pay off in economic terms.

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Appendix

Table A1: Results from the hierarchical cluster analysis

Preliminary clusters in terms of SOI output			i	ii	iii	iv	v	vi	vii
			No innovation	All	Only social	Product & social	Only Process	Process & product	Process & social
process innovation	No	Count	45	0	9	4	0	0	0
	Yes	Count	0	9	0	0	17	4	13
product innovation	No	Count	45	0	9	0	17	0	13
	Yes	Count	0	9	0	4	0	4	0
social innovation	No	Count	45	0	0	0	17	4	0
	Yes	Count	0	9	9	4	0	0	13
Total		Count	45	9	9	4	17	4	13
		% of all	44%	9%	9%	4%	17%	4%	13%

Table A2: Results of ANOVA between clusters in terms of different SOI output

		Sum of Squares	df	Mean Square	F	Sig.
whether the company has introduced a process innovation	Between Groups	57.115	1	57.115	126.982	.000
	Within Groups	44.529	99	.450		
	Total	101.644	100			
whether the company has introduced a product innovation	Between Groups	51.599	1	51.599	102.074	.000
	Within Groups	50.045	99	.506		
	Total	101.644	100			
whether the company has introduced a social innovation	Between Groups	60.113	1	60.113	143.298	.000
	Within Groups	41.530	99	.419		
	Total	101.644	100			

Table 1: Descriptive statistics and correlation coefficients

	Variable	Mean	SD	Min.	Max.	1	2	3	4	5	6	7	8	9
1	ROS2016	9.8	8.848	-5.45	45.63									
2	SOI	.94	1.01	0	3	.36**								
3	TRA	1.46	1.06	0	4	.19	.56**							
4	REL	1.2	1.2	0	5	.39**	.62**	.59**						
5	ROS2012	8.72	9.23	-20.56	48.52	.71**	.11	.04	.24*					
6	INRD	.12	.33	0	1	.07	.52**	.44**	.4**	-.11				
7	EDN	.17	.13	.00	.63	.14	.41**	.25*	.36**	.12	.15			
8	ASSIM	3.12	.86	1.5	4.75	.23*	.54**	.34**	.38**	.01	.44**	.2*		
9	FAMILY	.63	.48	0	1	-.13	.07	.07	-.06	-.05	-.04	.24*	.03	
10	SIZE	2.94	1.13	1.61	5.75	.18	.51**	.34**	.39**	.07	.47**	.2*	.29**	.04

Note: n = 101;
** indicates significance at $p < 0.01$ and * indicates significance at $p < 0.05$.

Table 2: Regression results for the effect of SE on SOI

	Model 1	Model 2	Model 3	Model 4
Threshold				
SOI = 0	3.182† (1.744)	5.197** (1.948)	4.069* (1.811)	5.336** (1.983)
SOI = 1	5.138** (1.835)	7.365*** (2.07)	6.276** (1.932)	7.626*** (2.114)
SOI = 2	7.866*** (1.831)	10.172*** (2.09)	9.079*** (1.959)	10.462*** (2.144)
ROS2012	.011 (.024)	.011 (.026)	-.006 (.027)	-.001 (.028)
INRD	-2.42 (.946)	-1.249 (.992)	-1.666 (.959)	-.986 (1.008)
EDN	7.895*** (1.973)	7.662*** (2.011)	6.194** (2.077)	6.581** (2.133)
ASSIM	.875*** (.287)	.795** (.304)	.767* (.301)	.722* (.311)
FAMILY	-.15 (.464)	-.131 (.484)	-.446 (.49)	-.317 (.505)
SIZE	.691** (.231)	.646** (.242)	.645** (.241)	.624* (.246)
SECTOR categories				
Metallic ores	1.336 (1.062)	2.421 (1.134)	1.718† (1.116)	2.417* (1.163)
Industrial minerals	-1.041 (.686)	-.574 (.7)	-.511 (.725)	-.297 (.735)
Natural stone	-.242 (.536)	-.487 (.563)	.179 (.555)	-.119 (.581)
Construction minerals		Reference category		
TRA		.923** (.266)		.690* (.287)
REL			.804*** (.235)	.582* (.253)
Goodness-of-fit				
Chi-Square	76.726***	89.535***	88.864***	94.775***
McFadden pseudo R^2	.303	.354	.351	.375
Test of parallel lines				
Chi-Square	15.304	18.045	11.156	9.097

Note: Standard errors in parenthesis;
*** indicates significance at p<0.001, ** at p<0.01, * at p<0.05 and † at p<0.1

Table 3: Regression results for SOI-FP association

	Model 5	Model 6
constant	.823 (3.245)	4.534 (3.208)
ROS2012	.696*** (.07)	.669*** (.066)
INRD	-.042 (2.552)	-.143 (2.509)
EDN	.127 (5.215)	.019 (5.277)
ASSIM	.118 (.838)	.026 (.828)
FAMILY	-.157* (1.367)	-.158* (1.283)
SIZE	.063 (0.669)	-.029 (.658)
SECTOR dummies	included	included
SOI		.363*** (.865)
Adjusted R^2	.49	.551
F-value *for* ΔR^2	14.728***	13.572***

Note 1: standardized coefficients (β) are reported (except for constant).
Note 2: Standard errors in parenthesis.
*** indicates significance at p<0.001, ** at p<0.01 and † at p<0.1

6 Discussion and implications

Having presented the three papers, the main findings of the thesis will now be presented in response to the overall RQ and sub-questions. The theoretical contributions of the work will then be summarized and potential future directions for research in the field of open SOI outlined. After presenting the limitations of the thesis, the findings in terms of implications for firm managers and policymakers will be discussed.

6.1 Findings

As guided by the overall RQ, the thesis developed three main objectives relating to the conditions under, and the extent to which, engaging external stakeholders can result in superior SOI outputs and financial performance. In this section, the empirical findings from the appended papers are drawn upon and the answers that the thesis has provided with respect to the three research objectives will be synthesized. A summary of these findings with respect to the overall RQ and the three research objectives is presented in Table 8.

Under which conditions can engaging external stakeholders result in superior SOI outputs?

The systematic literature review in chapter 2 revealed that existing studies in the field of open SOI have paid insufficient attention to the factors that can provide better conditions for firms to convert external knowledge into innovative outputs. The empirical analysis conducted in papers 1 and 2 found that two sets of conditional factors are of utmost importance in a firm's quest for developing sustainable process, products and organizational practices; namely, its internal capabilities and the proximity to external stakeholders. With the aim of providing a synthesis of the findings regarding these factors, Figure 12 illustrates capabilities and proximity dimensions in two levels of hierarchy, respectively referred to as first-order and second-order conditions under which engaging external stakeholders can result in superior SOI outputs.

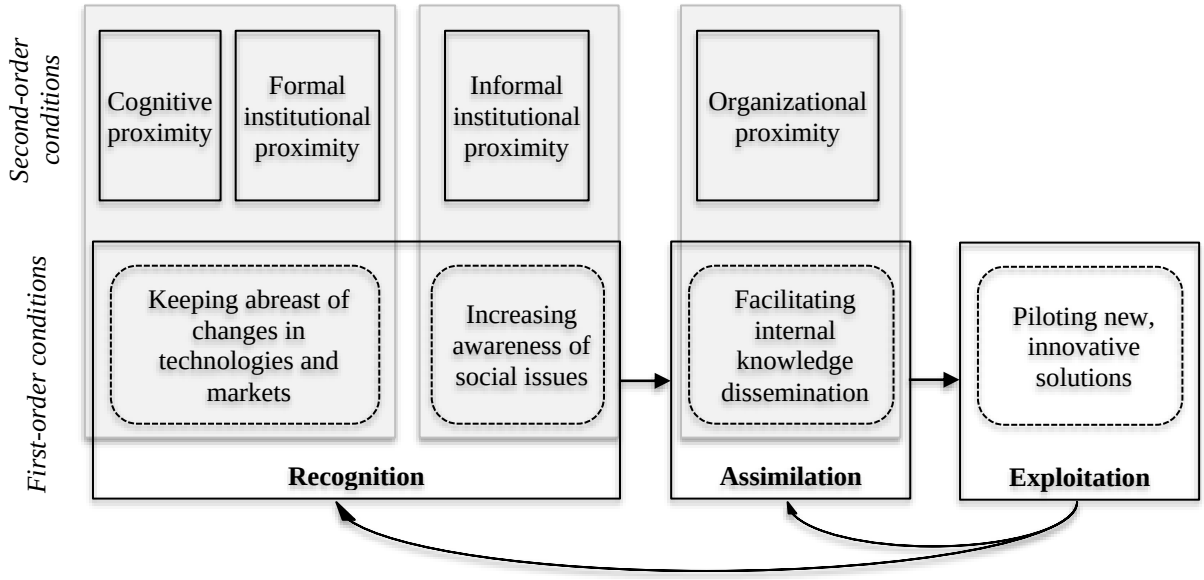

Figure 12: First- and second-order conditions for converting external knowledge into SOI outputs

Table 8: Summary of the findings from the empirical papers

Research objective	Papers	Empirical findings
Under which conditions can engaging external stakeholders result in superior SOI outputs?	Paper 1 and Paper 2	• Two sets of different but interdependent conditional factors are of utmost importance: firms' internal capabilities and their proximity to external stakeholders. • To identify and understand external knowledge, firms need to keep abreast of changes in technologies and markets. This capability can develop the cognitive and formal institutional proximities between firms and external stakeholders. • Next, firms need to increase their awareness of social issues, which in turn operates the informal dimension of institutional proximity and closes the normative gap in firm-stakeholder relationships. • In order to integrate external knowledge internally, firms should combine informal mechanisms such as peer-to-peer interactions, with formal arrangements such as using knowledge exchange coordinators to increase cross-functional collaborations. This capability is important for establishing an optimum degree of organizational proximity. • Exploiting the new knowledge rests on the capabilities to retain stakeholder relationships in the latter stages of innovation, together with experimentation and small-scale testing of new products and social practices.
To what extent can engaging external stakeholders result in superior SOI?	Paper 2 and Paper 3	• Engineering- and science-related education backgrounds (cognitive proximity) are positively related to process and product innovations respectively. • The similarity between rules and regulations (formal institutions) is positively related to both process and product innovations. On the contrary, the similarity between cultural norms and moral values (informal institutions) is positively related to the social type of SOI. • A diversity of collaborations beyond the local region (organizational proximity) is positively related to social (but not process nor product) innovations. However, a diversity of collaborations regardless of their geographical loci triggers the relational aspect of stakeholder engagement and allows a firm to achieve broader SOI outputs (all three types of SOI). • Not only the diversity, but also the intensity (frequency), of transactional relationships are important for achieving broader SOI outputs.
Under which condition can engaging external stakeholders result in better financial performance?	Paper 3	• The effect of stakeholder engagement on financial performance (measured by profitability) appears to be conditioned on the achievement of SOI outputs. In other words, there exists no direct link between engaging external stakeholders in innovation processes and profitability, and SOI fully mediates the association between stakeholder engagement (both transactional and relational) and financial performance.

The logic of this conceptual framework is that different dimensions of proximity (second-order conditions) effectuate various capabilities (first-order conditions) for SOI. Regarding the latter, a firm's internal capabilities are reflected in a sequential process of recognizing, assimilating and exploiting external stakeholders' knowledge, in which each of these building blocks emerges from a set of organizational skills and routines. Moreover, the exploitation capability is not only related to the first two capabilities from a linear perspective, but also initiates a feedback loop that enables a firm to reconfigure its skills and routines in order to recognize and assimilate the external knowledge. These two capabilities can in turn trigger the proximity dimensions in the upper level of the illustrated hierarchy. Based on the findings from papers 1 and 2, the remaining part of this section give a more detailed account of capabilities, proximity dimensions, and the relationship between them, with respect to their role in stakeholder engagement and SOI.

As concerns capabilities, and in line with recent conceptual works (Amui et al., 2017; Watson et al., 2017), this study found two main reasons why SOI capabilities are specific and different from what a firm might already possess regarding its general innovations: first, the fact that sustainability spans different areas of technology, markets and society; and second, the imperative for engaging with stakeholders who are more concerned with environmental and social sustainability than economic impacts of innovations. This situation makes it inevitable for a firm to understand knowledge areas that might be far from its existing knowledge base, as well as to ensure ongoing feedback from external stakeholders regarding its products and processes, so that environmental and social expectations can be fulfilled. Therefore, firms draw on a diverse range of organizational skills and routines to develop their capabilities in recognizing, assimilating and exploiting external stakeholders' knowledge.

In the first step, successfully identifying and understanding external knowledge (recognition) in SOI contexts requires a priori knowledge of different areas of technology, markets and society. This is reflected in the development of two distinct capabilities for recognition: 1) keeping abreast of changes in technologies and markets; and 2) increasing awareness of social issues. With respect to the first capability, not only can internal R&D assist firms in overcoming the greater complexity of SOI, for example in the case of cleaner technologies, but employee training and new recruitment are also important mechanisms for improving technical and market knowledge bases. In the latter group of mechanisms, capabilities emerge by means of dynamic processes of learning and the development of existing knowledge in order to address rapid changes in technologies, market demands, environmental regulations and social expectations, which is a specific characteristic of sustainability contexts (Lozano, 2015).

From a proximity perspective, this thesis demonstrates that keeping abreast of changes in technologies and markets allows firms to activate two second-order conditions for achieving a higher degree of learning and innovation, namely cognitive and formal institutional mechanisms. Considering cognitive proximity, this finding is in accordance with what Ketata et al. (2015) refer to as the twofold advantage of developing a technological knowledge base, as it not only increases a firm's capacity to understand knowledge coming from different sources, but also eases their assessment of how to choose the most relevant knowledge for a

specific innovation purpose. Similarly, paper 2 conceptualizes that improved knowledge of regulative frameworks (as a result of a capability to follow up the changes in this respect) can close the formal institutional gap in firm-stakeholder relationships. Closing this gap is particularly important for aligning various sustainability objectives; for example, through reducing tensions between economic and environmental improvements, which in turn plays a significant role in facilitating the flow of knowledge from external stakeholders.

Alongside the capability to follow up the latest developments in a multiplicity of areas related to sustainability, successful recognition in SOI contexts is also dependent on the way managers interpret and act upon environmental and social issues. This capability relies primarily on managers' desire to act ethically, and can result in a positive reputation among socially/environmentally concerned stakeholders, hence making them willing to share their knowledge and expectations due to trust-related factors (Eccles et al., 2014; Sharma, 2005). Indeed, as shown in Figure 12, increasing awareness of social issues is the type of capability in the recognition phase that can operate the informal dimension of institutional proximity; that is, to close the normative gap in firm-stakeholder relationships. Accordingly, this thesis emphasizes that managers show their desire to engage in broader sustainability issues by providing transparent information on firms' performance with respect to social and environmental impacts (Herremans et al., 2016). Such a desire should then be combined with organizational routines to set specific sustainability objectives regarding social and environmental issues, as the complexity of such issues might hinder a firm from approaching them at the right time.

Regarding assimilation as the second step in the capability building process, the explorative study in this thesis highlights the presence of organizational routines that facilitate internal knowledge dissemination, either within a specific function or organization wide. In agreement with previous works (Ayuso et al., 2006; Dangelico et al., 2017), the findings indicate that informal mechanisms such as periodic meetings and peer-to-peer interactions are a prerequisite for nurturing an open culture within a firm, yet formal arrangements such as using knowledge exchange coordinators are required to increase cross-functional collaborations. Consequently, combining these mechanisms can assist a firm to achieve a balance between flexibility and control regarding transactions of knowledge, which is in turn an important factor in establishing an optimum degree of organizational proximity to external stakeholders (Boschma, 2005). To this end, formal mechanisms mitigate the uncertainty about ownership rights by controlling knowledge exchange through hierarchical frameworks (as in the case of the knowledge coordinators discussed above), while informal ones establish weak ties and thereby allow better access to novel information.

Finally, firms rely on their capability in piloting innovative solutions in order to exploit the new knowledge that results from integrating external knowledge internally. Exploring this capability in more detail revealed that beyond retaining stakeholder relationships in the latter stages of innovation, which is similarly demonstrated by recent studies on SOI projects (Behnam et al., 2018; Kazadi et al., 2016), successful exploitation is also dependent on experimentation and small-scale testing of new products and social practices. Long-lasting engagement practices

bring about more commitment (from both firms and external stakeholders) to shared goals, which is as an important factor in achieving corporate sustainability objectives. Moreover, by ensuring engagement in the long-term, firms can test whether an innovative output fulfills the requirements of external stakeholders, irrespective of the economic, social or environmental nature of these requirements.

Therefore, this thesis suggests that the exploitation phase of the capability building process and its underlying mechanisms do not relate directly to proximity dimensions, but actuate them by means of the feedback loops to recognition and assimilation capabilities (see Figure 12). As an example, to respond to environmental pressures, a firm studied in paper 1 employed a new blasting technique to reduce the waste materials, but this environmental improvement has caused an increase in the price, which according to the firm displeased an important customer. Subsequently, the feedback from this customer in the piloting of the product was used to engage another relevant stakeholder, an NGO, to set environmental objectives that allowed an improvement process in a stepwise manner, in such a way that the economic aspect was not compromised. Therefore, engaging the new stakeholder and setting specific objectives (rather than idealistic ones) allowed the firm to close the normative gap (with societal stakeholders) created by the lack of trust in its commitment to broader sustainability objectives.

To what extent can engaging external stakeholders result in superior SOI?

Having explored the conditions under which stakeholder engagement can result in better SOI outputs, the next task was to explain the extent of possible associations between these two constructs. To this end, papers 2 and 3 employed different perspectives on stakeholder engagement, and addressed the gap identified in the literature review by providing quantitative evidence for external stakeholders' contribution to SOI outputs. More specifically, paper 2 found that various dimensions of proximity in firm-stakeholder relationships were associated with individual types of SOI (process, product and social practices) in different ways. To complement the results obtained on the determinants of SOI, paper 3 operationalized it as an aggregated and evolving outcome, in which transactional and relational types of stakeholder engagement were demonstrated to be conducive to higher levels of SOI. Figure 13 provides a summary of the nature of the associations found between different aspects of stakeholder engagement (proximity dimensions and types of engagement) and SOI outputs.

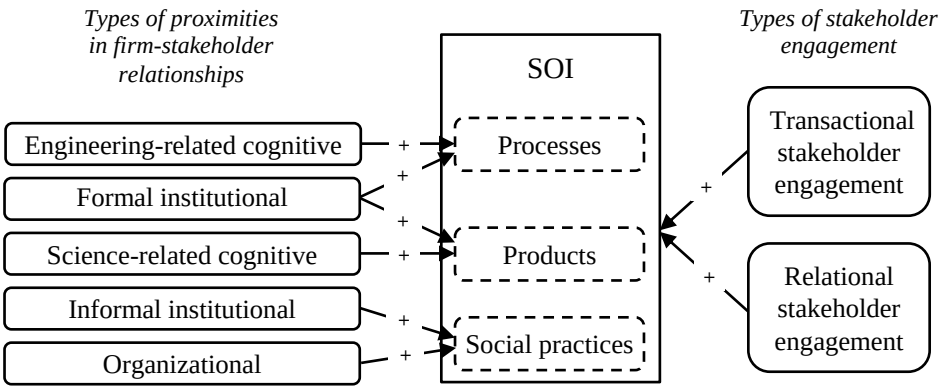

Figure 13: Positive associations between aspects of stakeholder engagement and SOI outputs

Concerning proximity dimensions, it was argued in the previous section that firms draw on a range of capabilities in an attempt to get closer to the 'worldviews' of their external stakeholders, which comprise cognitive, institutional and organizational foundations. Regarding the first dimension, the thesis determines that keeping abreast of developments in technological and market areas makes a firm cognitively closer to external stakeholders, particularly value chain partners and universities, which are more relevant sources for technical and market knowledge (Fitjar et al., 2013; Robertson et al., 2012). Nonetheless, cognitive proximity in industrial settings with synthetic knowledge bases is seen as similarities in two different types of knowledge, i.e. engineering and scientific ones, which are measured by means of employees' educational background. As shown in Figure 13, engineering-related and science-related cognitive proximities are positively associated with process and product types of SOI respectively, which provides support for the claim that specific innovative outputs are driven by somewhat different knowledge bases.

Process innovations are characterized by how well engineering staff are able to combine different facets of existing knowledge regarding implementation and improvement of technical operations and managerial systems. However, this is not to ignore the importance of developing completely new knowledge in the form of, for instance, cleaner production technologies or environmental management systems, but as discussed in section 2.4, it should be emphasized that SOI can be also achieved through incremental improvements and without conducting R&D activities.

Despite the observed difference between the cognitive dimensions of process and product innovations, it was found that a similar type of institutional proximity (the formal dimension) explains both these SOI outputs. In other words, a significant effect of informal institutions on product and process innovations was not observed, and this dimension of proximity seems to be only related to the third type of SOI, i.e. social practices. To explain this finding, one can refer to the fact that formal and informal institutions deal with two diverse mechanisms of uncertainty reduction; while the former regulates the governing rules and laws in inter-organizational relations, the latter entails the set of cultural norms and moral values surrounding stakeholder engagement (Boschma, 2005; Rodriguez-Pose, 2013). Additionally, we already know that value chain partners and universities are likely to hold back their knowledge due to insecure intellectual property rights and/or rewards for investing in environmental/social improvements (Bstieler et al., 2015; Yuan et al., 2017). A similar situation might occur in a firm's relations with NGOs and governmental authorities when these stakeholders do not trust in or commit to the environmental/social contribution of the firm (Brunner et al., 2013; Suopajärvi et al., 2016). Therefore, the positive effect of formal institutions accrues more to process and product innovations, as they are primarily dependent on the flow of knowledge from value chain partners and universities, whereas informal institutions affect social practices due to their strong reliance on engaging secondary stakeholders.

Finally, the thesis investigated the extent to which outside-in and coupled processes of open innovation affect SOI outputs in the minerals industry. For the latter process, two different but interrelated mechanisms upon which collaborations with external stakeholders can influence

SOI were considered and tested, which resulted in interesting insights into the attributes of coupled open SOI. First, paper 2 used collaborations as an indicator for organizational proximity, but only focused on collaborations beyond a firm's local region to rule out the potential effect of geographical proximity on the extent of interactions and innovative outputs. The regression analysis then revealed that the diversity of non-local collaborations was significantly related to SOI, but only to its social type. On the other hand, paper 3 hypothesized that collaborations (regardless of their geographical loci) trigger the relational aspect of stakeholder engagement, and thereby allow a firm to evolve towards broader SOI, in which all three types of innovation outputs can be realized. The paper then found that the odds of achieving higher SOI outputs improved by 78.9% with a unit increase in the number of stakeholders engaged through collaborative mechanisms.

At first glance, this result would seem to contradict the lack of support in paper 2 for the association between collaborations and two other types of SOI, i.e. process and product innovations. However, the insights from the interviews in paper 1 signify that mineral firms employ non-local collaborations for the specific purposes of process and product innovations when they need advanced technological solutions and expertise. Consequently, as discussed in paper 2, the outcome of such innovation activities is less likely to appear simultaneously or within a few years (less than the 3 years that is covered by the survey).

Moreover, the thesis suggests that the outside-in process of open innovation operates on the transactional aspect of stakeholder engagement, and similar to the coupled process, leads to higher levels of SOI outputs. Nonetheless, the positive association between transactional stakeholder engagement and SOI outputs is not evident, because ad-hoc and pure market-based transactions lack the time dimension required to deepen the firm-stakeholder relationships that consequently facilitate the outside-in flow of knowledge. From a competitive point of view, such weak relationships do not describe valuable resources for innovation, as they could be easily duplicated by competitors (Hillman et al., 2001). However, an extended proxy for transactional stakeholder engagement has been created by means of including (besides diversity) the intensity of such firm-stakeholder relationships. Accordingly, it confirms and extends previous works (see for example Mothe et al., 2017 that focuses on environmental innovations) by demonstrating that persistent transactions assist firms to routinize their search activities in the external environment and to ensure timely access to valuable knowledge.

Under which condition can engaging external stakeholders result in better financial performance?

To rephrase this question, "does stakeholder engagement lead to financial benefit for all firms under all conditions?" To approach the question, the thesis has argued that SOI acts a mediating condition through which firms will be able to reap the financial benefits of stakeholder engagement. In addition to the association between stakeholder engagement and SOI that was investigated in answering the previous question, establishing such a mediating effect has two interesting facets: first, that SOI affects a firm's financial performance; and second, that there exists a direct link between stakeholder engagement and financial performance.

As discussed in section 2.4, the double externality problem that accompanies SOI can discourage firms even more from pursuing such innovation practices, as they generate social and environmental benefits (primarily for society) that are hard to be reaped in financial terms. This situation points to the failure of creating a business case for sustainability, as not all three pillars of corporate sustainability are realized. However, the results in paper 3 support a positive effect of SOI outputs on financial performance, hence suggesting that these innovations can also enable a firm to achieve a higher financial performance, in addition to environmental and/or social improvements.

The second interesting insight from the mediating model is that SOI fully mediates the association between stakeholder engagement (both transactional and relational) and financial performance. In other words, there exists no direct link between engaging external stakeholders in innovation processes and profitability. This leads us to theorize that external knowledge is, by itself, only part of the whole picture in achieving broader purposes such as financial performance, and that firms need to be able to apply this knowledge internally and convert it (by the use of other resources such as their internal expertise) into innovative outputs in order to maintain their profitability.

6.2 Theoretical contributions and directions for future research

In order to derive the main theoretical contributions of the thesis, this concluding section ties the presented findings back to the current literature and the theoretical framework presented in Figure 9. In doing so, the section starts with a discussion of the specific contributions to the research field of open SOI and will then proceed to briefly argue how these contributions extend our understanding of the three underlying concepts of open SOI, i.e. corporate sustainability, SOI and open innovation (see Figure 1).

6.2.1 Contributions to and future directions for research on open SOI

As for its specific theoretical contributions, the findings from the thesis help to answer the "what", "how", "why" and "when" (Whetten, 1989) of open SOI as a social phenomenon (Figure 14). First, the study identifies *what* internal, inter-organizational and external factors should be considered to explain the innovative outputs of firms as far as external stakeholders' knowledge is concerned. While previous studies have focused on either internal factors such as capabilities (e.g. Ayuso et al., 2006; Behnam et al., 2018; Kazadi et al., 2016) or external ones such as open innovation processes (e.g. Cainelli et al., 2015; Segarra-Ona et al., 2017), inter-organizational factors including the proximity between firms and external stakeholders are ignored. Portraying a more complete picture of SOI allows both academics and practitioners to recognize some of the unique characteristics of this type of innovation compared to general innovations. Hence, the theoretical framework presented in this thesis seeks to be a relatively parsimonious framework for explaining a complicated phenomenon, which in turn may make it more effective for developing appropriate policies and strategies. That said, future studies in the field of open SOI could help to identify other factors that may be at play in determining SOI outputs.

Next, the thesis provides insights about *how* the internal, inter-organizational and external factors are related by means of describing and empirically testing some of the associations between them, as well as with SOI outputs. Concerning the associations between these factors and SOI outputs, the results from papers 2 and 3 indicate that proximity dimensions and open innovation processes are positively related to with various types of innovative outputs. In this regard, a notable contribution of the thesis is the inclusion of multiple external stakeholders and innovative outputs, thereby providing empirical evidence for the conceptual argument of Adams et al. (2016) that the extensiveness of SOI (compared to its subsets such as environmental innovation) necessitates tapping into a more diverse set of knowledge. Nonetheless, it was not possible to reveal the causal link between stakeholder engagement and SOI outputs, mainly due to the nature of cross-sectional data. Therefore, a possible research avenue is to draw on longitudinal data and repeated surveys that have more power than cross-sectional data in observing the temporal order of events (whether stakeholder engagement increases innovation, or whether innovation enables firms to tap into external stakeholders' knowledge).

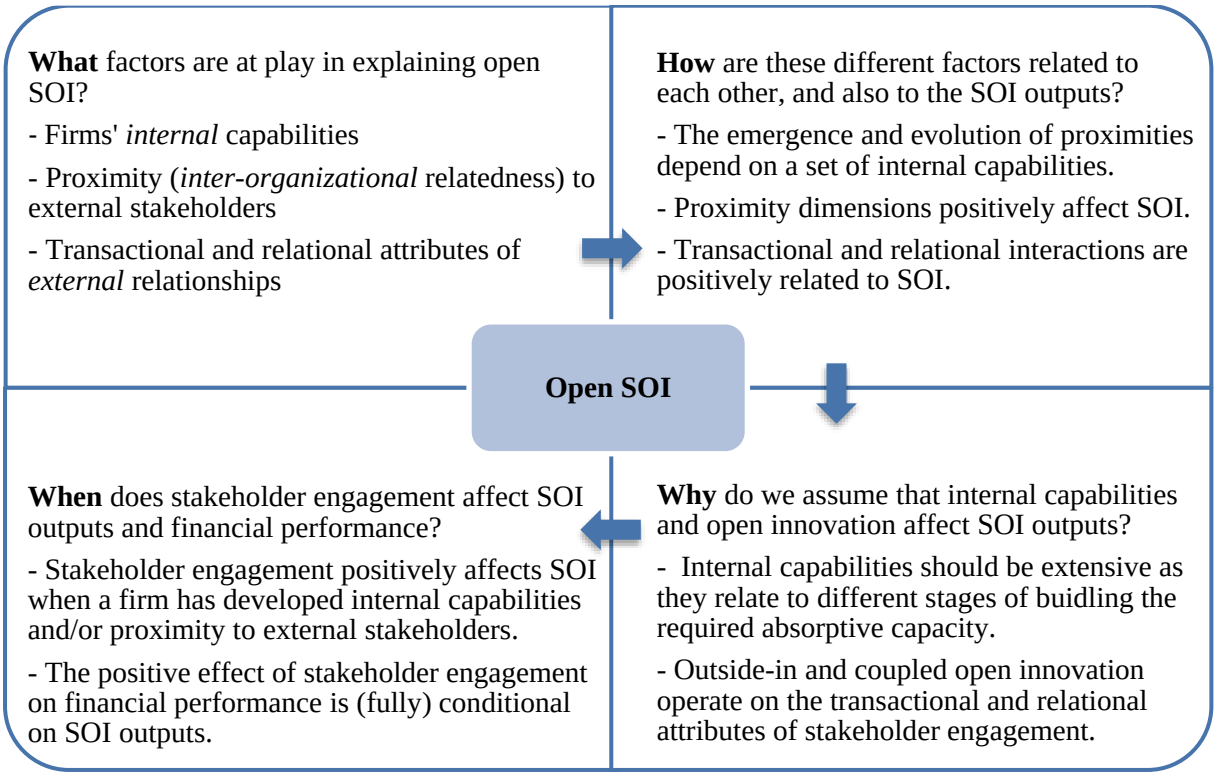

Figure 14: Theoretical contributions of the thesis to the research field on open SOI

Considering the input side of SOI, the model in Figure 12 illustrates that internal capabilities and proximity dimensions are also related, in the sense that capabilities can have both direct and indirect effects (by triggering proximity dimensions) on SOI outputs. As a preliminary step towards addressing the call for more research on the dynamics of proximity dimensions (Balland et al., 2014), this finding suggests that the emergence and evolution of cognitive, institutional and organizational proximities depend on a set of organizational skills and routines developed over time. For example, the ability of managers to appropriately interpret and act on

environmental and social issues can result in the long run in a positive reputation among socially/environmentally concerned stakeholders, which in turn close the normative gap (enhance informal institutional proximity) in firm-stakeholder relationships. Future research on SOI may offer further clarifications to the model in Figure 12 by empirically testing the association between internal capabilities and proximity dimensions (the connected boxes).

Having established the *what* and *how* of open SOI, the third contribution of the thesis lies in addressing the *why* question; that is, the logics behind the proposed associations between the input (internal and external) and output sides of open SOI. Considering the role of internal capabilities in pursuing open SOI, previous research has failed to provide comprehensive understanding of how different capabilities should be combined in different stages of open innovation, from obtaining external knowledge to making use of it (see Table 6). From their fragmented results, this thesis has built on the theory of absorptive capacity, and particularly on recognition, assimilation and exploitation processes, as the basis for arguing why a comprehensive set of internal capabilities are required for innovation in sustainability contexts. This has then resulted in identifying the underlying skills and routines that form specific capabilities for open SOI in each of the aforementioned processes. As such, the thesis also echoes the call of two recent literature reviews (Amui et al., 2017; Watson et al., 2017) for the characterization of firm-level capabilities in SOI contexts, as they are likely to be different from what a firm might already possess regarding its general innovations. More specifically, additional studies are needed to prove the importance of the capabilities identified in this work by applying them to different industrial contexts; for instance, by conducting comparative case studies between different industries with various levels of pressure for social and environmental sustainability.

In the same vein, the thesis also contributes to our understanding of why we can expect SOI outputs to also be positively affected by different mechanisms of open innovation; that is, the outside-in and coupled processes. As discussed in section 2.7.3.3, the only two notable exceptions in the research field of open SOI that have investigated both of these processes are the works of Cainelli et al. (2015) and Dangelico et al. (2013), which obtained contradictory results regarding the significance of outside-in open innovation for SOI outputs. This inconsistency might partly be because of the different measurements used for operationalizing SOI (which will be discussed later in this section). However, why it is important to address this contradiction is the fact that none of these studies (nor most of those that focus on a single open innovation process) present any convincing logic (theory) behind the supported and non-supported hypothesized associations between open innovation processes and SOI outputs.

Accordingly, this thesis borrowed from stakeholder theory and has argued that the outside-in and coupled processes of open innovation in sustainability contexts operate respectively on the transactional and relational attributes of stakeholder engagement, and thereby exert a positive effect on a firm's innovative outputs. In light of such framing, the thesis is thus able to provide convincing logic for why outside-in open innovation can be significant (or insignificant) for SOI outputs: transactional stakeholder engagement may not always result in an inflow of valuable knowledge because of its likely inability to transfer tacit and complex knowledge

(whether of technologies or social expectations). However, frequent transactions involve a time dimension that adds to the depth of these relationships (Hillman et al., 2001) and provide a firm with timely access to novel knowledge and solutions that might not even be accessible through relational stakeholder engagement. Examples of such transactional engagement are active mimicking strategies to continuously adopt established solutions from competitors (Bansal, 2005) and boundary spanners that attend weak signals related to social and environmental issues (Holmes et al., 2009). Future research could further follow the advice of Ghisetti et al. (2015) and Muscio et al. (2017) and investigate whether the marginal returns (in terms of SOI outputs) from transactional and relational stakeholder engagement diminish at some point when the number of stakeholder groups and/or the frequency of relationships exceed a certain level.

Finally, the thesis answers some of the *when* questions surrounding the phenomenon of open SOI by revealing some of the conditions under which the innovative and financial benefits from stakeholder engagement begin to appear. The primary implication of setting these conditions is that stakeholder engagement may not result in superior innovative and financial performance for all firms and all the time. To this end, the findings from the analysis in papers 1 and 2 has highlighted the role of internal capabilities and proximity dimensions for transforming external stakeholders' knowledge to innovative outputs. Therefore, it is expected, but yet to be studied, that stakeholder engagement may not necessarily result in augmented SOI outputs when a firm lacks certain capabilities and/or has too little proximity to its external stakeholders. Furthermore, the thesis has found that the (positive) effect of stakeholder engagement on financial performance is (fully) conditional on firms' SOI outputs. As such, it confirms and extends the findings from a multiple case study conducted by Driessen et al. (2013), which proposes that addressing the environmental and social interests of external stakeholders enables a firm to continuously change the nature of its new product development processes, consequently allowing it to achieve better profitability compared to its competitors. In this regard, it has been demonstrated that the proposed mediation effect of SOI does also hold true when considering various types of stakeholders and innovative outputs. Nonetheless, the thesis does not by any means claim or aim to provide a complete list of boundary constraints that are at play in determining the conditions under which the relationships between stakeholder engagement, SOI outputs and financial performance hold. One could even speculate that the proposed capabilities and proximity dimensions may not be relevant in all industries, countries or across time periods. These are all possible avenues for future research in the field of open SOI which will help achieve better understanding of the limitations of the factors that antecede or result from SOI, before generalizing them to other contexts.

6.2.2 Contributions to the broader literature underlying open SOI

According to Figure 1, which set the stage for conceptualizing open SOI, the specific contributions of the thesis to the literature on open SOI (as discussed above) could also touch upon the three generic concepts underlying this notion, i.e. corporate sustainability, SOI and open innovation.

The concept of corporate sustainability, as far as it is used in management and organization fields, denotes an integrated approach towards sustainability in which the economic, environmental and social aspects are taken into account. However, scholars often tend to use simplified versions of this concept, which consequently results in overlooking either economic sustainability as the primary emphasis of firms, or the social and environmental issues that are of interest to various groups of external stakeholders. This has subsequently left a cognitive gap in the literature on corporate sustainability as to how a win-win situation can be achieved in which the interests of both parties are secured (Hörisch et al., 2014). To take a step towards solving this issue, this thesis postulates and conceptualizes SOI as a basis that assists firms to fulfill their social and environmental responsibilities, and simultaneously to seek maximal profits. Although the extent to which SOI is able to alleviate social and environmental issues in the minerals industry was not explicitly tested, it is maintained that the range of innovative outputs that was used to measure SOI encompasses all three aspects of corporate sustainability. Moreover, the findings regarding the positive association between external stakeholders' knowledge and SOI outputs, and that of the latter with financial performance, lead us to conclude that stakeholder engagement goes beyond controlling stakeholders' negative influences, and portrays how they can (also) improve financial-centric indicators.

Concerning SOI, the thesis tackles the inconsistency in the literature regarding the conceptualization and application of this construct by providing an operationalization that is informed by both theory and practice. In doing so, the point of departure was the classical definition of innovation by Dosi (1988), which introduces three general categories for innovation: products, production processes and organizational practices. This conceptualization is also in accordance with two recent literature reviews on SOI (Adams et al., 2016; Klewitz et al., 2014). This theoretical approach was then combined with the insights gained through the interviews with representatives from the mineral firms to develop a parsimonious list of innovative outputs. Indeed, the aim was not to provide a comprehensive list of all possible innovations in the context of SOI, but instead to prepare a context-dependent measure that could also be effective in capturing firms' innovation activities.

Apart from the majority of studies that only consider specific subsets of SOI (e.g. environmental innovation), a caveat also applies to the few broader studies, in that they measure the effect of all reported innovations on social and environmental issues by asking firm managers to rate the importance of these effects. As a result, their SOI variables are possibly 'contaminated' by coincidental practices and subjective appraisal, leading to serious problems such as social bias. Despite being somewhat context-specific to the minerals industry, it is believed that the SOI measure used in this thesis is a reliable one, and that future research could increase its generalizability by applying it to and proving it in other industrial contexts.

Finally, but importantly, the thesis has brought a fresh perspective to the literature on open innovation by making, as far as can be ascertained, the first empirical attempt to apply stakeholder theory to theorize the different processes of open innovation. Using this theoretical anchor has been useful in two specific ways: first, and as discussed in the previous section, it allowed the study to provide convincing logic for why we can expect outside-in and coupled

open innovation to be positively related to SOI outputs. An important and notable contribution in this regard is the explanation of the potential value of the outside-in process for those outputs, where frequent search activates the timeliness of transactional stakeholder engagement.

Furthermore, stakeholder theory recognizes the importance of a wide range of stakeholder groups who can affect (and are also affected by) a firm's operation and achievements, which is in accordance with the necessity of securing access to different types of knowledge for SOI. Reflected in the deliberate use of the term 'stakeholder', instead of the more general ones such as 'external knowledge sources' that are used in the open innovation literature, the thesis thus goes beyond the prevalent focus of this literature on value chain partners and research organizations. More specifically, and as a response to the call by Bogers et al. (2017), the thesis extends the literature on open innovation by introducing and testing the effect of both primary and secondary stakeholders on SOI outputs, and thereby provides a more comprehensive picture of how open innovation works when firms pursue broad objectives (instead of being restricted to profit seeking). It is also believed that not only can the open innovation literature benefit from applying stakeholder theory, but the open innovation literature can also enhance our understanding of the stakeholder engagement mechanisms by providing a practical context to test the effect of these mechanisms on innovation and overall firm performance.

6.3 Limitations

It is essential to acknowledge the limitations of this thesis that should be taken into consideration in the interpretation of its findings. As the specific limitations of the three studies are presented in the appended papers, in this section the general issues in studying the phenomenon of open SOI in Norway's minerals industry will be discussed.

First, the thesis, in line with the emerging literature in the field of open SOI, assumes that SOI generates economic, environmental and social improvements. However, measuring the actual impact of innovative outputs on the three aspects of sustainability is prone to inconsistent results for a number of reasons: the varied perceptions of firms and external stakeholders of social and environmental sustainability; the context-dependency of sustainability measures; and the difficulty in aggregating the impacts across the three sustainability aspects. To create a measurable construct of SOI, firms were therefore asked to report their various innovative outputs with the expected (but not necessarily actual) improvements at the crossroads of economic, environmental and social sustainability. Therefore, the thesis does not claim that SOI is a definite solution for firms to overcome economic, environmental and social problems, but that it does provide a basis for their actions towards corporate sustainability, and allows us as researchers to understand sustainability from a business case perspective.

This point about measuring corporate sustainability and SOI leads to the second limitation, which is the fact that stakeholder engagement is studied only from the firms' perspective. Indeed, using self-reported measures of innovation and stakeholder engagement poses limitations on the extent to which firms' responses match stakeholders' points of view. In this regard, it could have been more insightful to obtain external stakeholders' views, specifically in paper 1, and in the cases where stakeholders were actively involved in capability

development and innovation processes. While this simplification was due to the limited capacity of the thesis in interviewing a broad range of stakeholders in paper 1, the large-scale data required in the two quantitative studies made it inevitable to rely on the firms' responses. However, as shown in Table 7, the three papers took several steps to increase the validity of the data and to mitigate different biases. In particular, concerning the focus on the firms' perspective, use of the term 'sustainability' was deliberately avoided throughout the interviews and the questionnaire in order to reduce the social desirability bias that might have arisen from the firms' desire to be viewed favorably.

Third, despite its advantages in ruling out the effect of sectorial and country-level variations, the focus on a single industry as the empirical setting limits the generalizability of the findings. Thus, the results should be applied cautiously to other contexts, especially firms operating in industries or countries likely to face lower pressure for environmental and social sustainability. As discussed in section 1.3, the driving force for pursuing these aspects of sustainability in the minerals industry is the great significance for them of profitability and long-term survival. This creates an imperative for firms to act with a broader approach to sustainability by means of, for instance, engaging external stakeholders in their daily operations and pursuing SOI.

Fourth and finally, all three papers included in the thesis draw on cross-sectional data that is not appropriate for examining changes over time. Although not the objective of the thesis, a longitudinal study could have been applied to examine the evolution of firm-stakeholder relationships and changes in SOI outputs, as they are path-dependent and may vary in character over time. The main reason that prevented use of a longitudinal design was the time limitation, combined with the probable inability of firms to provide answers about their stakeholder engagement activities and innovative outputs for the three year period preceding the date of the survey (2017). This might have led to attrition bias and a high non-response rate in the first wave, for example if the firms were asked to report on these variables in the period 2011-2013 (in addition to the conducted survey for the reference period 2013-2015).

6.4 Implications for policy and practice

During recent years, organization and management scholars are being increasingly called upon to develop useful implications for policy and practice (Bartunek & Rynes, 2010; Macintosh et al., 2017). In this regard, research should not only increase awareness of specific phenomena, but also discuss the intended outcomes from recognizing the implications (Bartunek et al., 2010). The thesis has highlighted the complexity of open SOI by demonstrating its reliance on various mechanisms for external stakeholder engagement and internal capability building. The findings also signify the importance of this type of innovation for the long-term survival of firms operating in sectors with demanding sustainability requirements. As such, the findings can inform policies at national and local levels in designing appropriate structures for innovation in industries that are subject to sustainable development. Moreover, the study has important implications for firms regarding how to tackle the aforementioned complexity by embracing the value of stakeholder engagement.

6.4.1 Implications for policymakers

In general, Norwegian politicians perceive the minerals industry and its further development as a double-edged sword. One the one hand, and besides their widespread use in everyday products, minerals are required for the development of a wide range of renewable technologies and green infrastructures, which are highly relevant to the rising political support for sustainable development (Heldal et al., 2016). Conversely, the environmental and social issues arising from mineral exploration and production reduce political interest in the industry because the legal and informal power of indigenous people, youth organizations, environmentalists and labor unions can damage the reputation of governing political parties. This has led to occasions when such opposing entities have been responsible for stopping or postponing exploration and production operations, even after the government has granted the required licenses. Therefore, the Norwegian governments' desire throughout the years to develop the minerals industry has mostly remained a verbal promise, but not put into practice.

The findings of this thesis provide an important message for policymakers if they want to overcome this situation: they should facilitate firm-stakeholder relationships in order to create the momentum for SOI. Owing to its potential in integrating economic, environmental and social sustainability, SOI can assist the minerals industry to pursue environmental and social imperatives, without compromising its profitability. In this regard, the overarching policy implication from the thesis is the need to design and implement supporting schemes that not only address the external mechanisms (e.g. proximity dimensions), but also the firms' internal capabilities (e.g. employee training), in order to close the knowledge gap between mineral firms and their stakeholders.

As far as the external mechanisms are concerned, specific attention should be paid to ensuring that there is sufficient recognition of various stakeholder groups who provide technical, market, social and legal knowledge. From an innovation supply perspective, the minerals industry is heavily dependent on the acquisition of technologies and technical services from suppliers, universities and research centers. Therefore, providing stable financing possibilities to create industrial clusters and university-industry linkages is of utmost importance for securing the flow of technical knowledge to the industry. Taking a demand-side perspective, the government should support existing intermediary organizations (e.g. the Association of Norwegian Mineral Industry) to strengthen their links with national and international agencies such as Innovation Norway and the European Innovation Partnership (EIP) on Raw Materials, which will accelerate the industry's link with potential markets for raw materials. Moreover, to create effective communication between mineral firms and environmental/societal stakeholders, the thesis suggests that policymakers direct their efforts towards establishing transparent mechanisms for stakeholder engagement (van der Have & Rubalcaba, 2016), which entails using established frameworks for evaluating environmental/societal performance. A big advantage of these frameworks (e.g. Towards Sustainable Mining in Canada or Finland) is that they offer key indicators for measuring the impacts of the minerals industry, and thereby create mutual commitment to shared sustainability objectives in which none of the parties will be able to override the agreed terms.

The thesis has also found that there is a need for policymakers to make a clear distinction between formal and informal institutional environments in promoting SOI. The analysis of the proximity dimensions indicated that while formal institutions can increase the ability of firms to achieve process and product innovations, they play a minor role (or no role) in achieving social innovations. Increasing the coordination between formal structures such as environmental and innovation policies is necessary for investment in and the diffusion of sustainability-oriented processes and products, as a lack of such coordination could result in the market and system failures of these innovations (Ghisetti et al., 2015). On the other hand, policies that aim to promote social innovations should address cultural norms and values by, for example, nurturing trust-based relationships between mineral firms and local communities. In this regard, local governments can act as neutral entities to facilitate the trust building process and close the normative gap between the minerals industry and societal stakeholders.

Considering firms' internal capabilities, the findings point to a critical need for policies that aim to augment employee training programs, as well as the breadth and depth of higher education in disciplines related to the minerals industry. Indeed, what differentiates policy requirements in the context of SOI from general innovations is that governmental support for the former should include more than the R&D subsidies and financial incentives offered through generic policy schemes. An exemplary scheme in this respect is SkatteFUNN, the tax incentive scheme in Norway that is designed to stimulate R&D activities throughout all industries. As training programs in areas related to broader sustainability approaches such as environmental management systems require substantial human and financial resources, implementing an incentive system similar to SkatteFUNN could encourage firms to devote their resources to development areas in which immediate financial benefit is not evident.

6.4.2 Implications for firms

The call made in the thesis for policies that address both internal and external firm aspects of open SOI resonates directly with the need for firm-level strategies and practices that consider these two aspects. On the one hand, it is no longer an alternative for managers to isolate their firms from external stakeholders' knowledge. However, the findings presented throughout the thesis also indicate that shifting focus to external stakeholders does not imply ignoring the internal capabilities required for utilizing the external knowledge.

Besides the importance of practices such as employee training that enable mineral firms to understand external knowledge and to assess its relevance, managers' attention should be drawn to the importance of setting specific objectives when dealing with social and environmental issues. The insights from the interviews specified that engaging a wide range of stakeholders, particularly those without any interest in the long-run financial condition of firms, will most likely expand the scope of social and environmental expectations. This will then pose a significant challenge for mineral firms to find a balance between their own and these stakeholders' interests, which might consequently lead to ineffective knowledge exchange and failure to take any innovative action. Instead, designing clear objectives and communicating

them to external stakeholders not only facilitates mutual understanding, but also enables managers to better locate the required external knowledge as the objectives become narrower.

Concerning internal capabilities, another important implication for firms is that they should strengthen their organizational routines for knowledge assimilation, which simply implies dissemination and integration of externally acquired knowledge internally. In this regard, efforts are particularly needed to accelerate knowledge sharing across different organizational functions by means of assigning formal knowledge coordinators. While the use of informal practices of knowledge assimilation such as peer-to-peer interaction is more prevalent in the minerals industry, creating a balance between formal and informal structures is well suited to managers who want to optimize their organizational proximity to external stakeholders. This is because such a combination can assist firms to control their external knowledge transactions through hierarchical frameworks, while at the same time keep a certain level of flexibility to ease access to novel ideas and solutions.

The final remark about practical implications revolves around the external (to the firm) aspect of SOI mechanisms, specifically highlighting the necessity to consider both the relational and transactional types of stakeholder engagement in acquiring external knowledge. What we have seen so far in this respect is an unbalanced focus on reinforcing networks, industrial clusters and R&D alliances, which all aim to nurture collaborations between firms and external stakeholders. Although not reducing the significance of these relational mechanisms, this study, in agreement with Mothe et al. (2017), strongly advises managers to establish stable search platforms to secure timely access to external knowledge. On some occasions, collaboration may lay the basis for such a platform when firms draw on their previous relationship with a specific stakeholder to continuously look for relevant knowledge in ongoing SOI processes. Other examples include creating/maintaining links with universities via employees who graduated from the same institute, or recruiting new employees from competitors or supplier companies.

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Appendix 1: An overview of the interviewees and date of interviews

Company	Sector	Interviewee's position	Date of interview
A	Natural and dimension stone	Sales manager	15.12.2015
B	Metallic ores	CEO	18.12.2015
C	Construction minerals	CEO	21.12.2015
D	Metallic ores	CEO	11.01.2016
E	Construction minerals	Production manager	19.01.2016
F	Construction minerals	CEO	16.02.2016
G	Industrial minerals	CEO	18.02.2016
H	Industrial minerals	CEO	09.03.2016
I	Construction minerals	Regional manager	10.03.2016
J	Industrial minerals	R&D manager	06.04.2016
K	Construction minerals	Production manager	07.04.2016
L	Natural and dimension stone	CEO	08.04.2016
M	Natural and dimension stone	Business development manager	21.04.2016
N	Metallic ores	Chief commercial officer	03.05.2016
O	Industrial minerals	Process development manager	06.05.2016
P	Industrial minerals	CEO	11.05.2016

Appendix 2: Interview protocol for paper 1

Interviewee: …….. Company and Position: …….

Date and time: ……... Duration: ……

Pre-interview comments: …….

……..

Introduction

To facilitate note-taking, I would like to record our conversation. For your information, only researchers on the project will be privy to the recorded interviews, which will be eventually deleted after they are transcribed.

We have planned this interview to last no longer than one hour. During this time, we have several questions that we would like to cover. If time begins to run short, it may be necessary to interrupt you in order to push ahead and complete this line of questioning. Besides these questions, our line of discussion might raise some extra questions and comments.

You have been invited to participate in this research because you have been identified as someone who has a great deal to share about innovation, knowledge exchange and capability building in the minerals industry. This PhD research project as a whole focuses on the improvement of innovation performance in the industry, with particular interest in understanding how the flow of knowledge and relevant capabilities contribute to that performance. Our study does not aim to evaluate your company's activities or your own experiences. Rather, we are trying to learn more about innovation process, and internal and external practices that are important in this regard.

Interview questions

1. Could you please tell me about the main challenges of your company regarding innovation?
2. How do you deal with these challenges?
3. What are the main opportunities in your business?
4. How can these opportunities be maximized and result in value creation?
5. How does innovation help your company to deal with the challenges and opportunities?
6. Please describe the innovation process in your company.
7. Who are mostly involved in the innovation activities of your company? Both in terms of business units and organizational levels.
8. Please briefly describe how you look for knowledge outside your company.
9. What kinds of practices do you use for bringing in the external knowledge?
10. For which purposes do you use external knowledge in your activities?
11. Could you give me an example of a successful collaboration and a failure example?
12. In your company, what are the internal resources and skills required to do innovation?
13. What motives or purposes are pivotal when you want to choose an external knowledge source?
14. Are there any particular characteristics regarding the type of knowledge you use in your different innovation activities?
15. What are the main knowledge exchange arenas in this industry in Norway?
16. Please briefly describe how knowledge flow happens in those arenas.

Post-interview comments: ……

……

Appendix 3: An overview of the questionnaire used for the survey

Question	Measurement scale
Number of employees with a master degree or above, at the end of 2015	Continuous
Number of employees with a bachelor degree or vocational certificate at the end of 2015	Continuous
Whether the company is partly/entirely owned by a family	Binary
Whether the company is part of a conglomerate	Binary
Whether the company is partly/entirely owned by a foreign company	Binary
The minerals sector	A dummy consisting of 4 categories
In which geographic market(s) did the company sell product(s) during 2013-2015? (more than one alternative possible) Local market within Norway Other regions of Norway Other European countries All other countries	Multiple choice
During 2013-2015, did your enterprise introduce new/significantly improved organizational practice or methods of extraction/manufacturing that: Use less energy Use less raw materials Control the amount of waste and/or pollution Are based on renewable energy sources (e.g. hydroelectric)	Binary
Were any of process innovations introduced during 2013-2015 new to your market?	Binary
During 2013-2015, did your enterprise introduce product innovations in any of the following categories: 1) products that can serve as an input for developing renewable energy technologies 2) products with higher degree of purity and recyclability	Binary
Were any of product innovations introduced during 2013-2015 new to your market?	Binary
During 2013-2015, did your enterprise introduce? New procedures for communicating the potential environmental impacts of the enterprise's activities New initiatives to advance health, education and employment opportunities for the communities New routines for involving the local community in the development of your mines	Binary

Question	Measurement scale
Did your company have the following activities regarding the innovations during 2013-2015? In-house R&D Contracting out R&D services to other enterprises or research organizations Acquisition of machinery, equipment and software Competence building such as courses and practical training Acquisition of existing knowledge from other enterprises or organizations, for example patents Market introduction of innovations Design activities	Binary
During 2013-2015, how often did you search for knowledge from each of the following sources? Within the company or conglomerate Suppliers in the local region Suppliers in other regions of Norway Suppliers in other European countries Suppliers in all the other countries Customers (potential customers) in the local region Customers (potential customers) in other regions of Norway Customers (potential customers) in other European countries Customers (potential customers) in all the other countries Competitors/other companies in this industry in the local region Competitors/other companies in this industry in other regions of Norway Competitors/other companies in this industry in other European countries Competitors/other companies in this industry in all the other countries Universities/research institutes in the local region Universities/research institutes in other regions of Norway Universities/research institutes in other European countries Universities/research institutes in all the other countries Conference and other meeting places Professional or academic journals and publications The industrial associations in Norway The industrial clusters in Norway Public organizations such as local and national authorities Interest organizations and NGOs	Five-point Likert scale from never (=1) to very often (=5)

Question	Measurement scale
During 2013-2015, did your company cooperate on any of your innovation activities with the enterprises listed below? Suppliers in the local region Suppliers in other regions of Norway Suppliers in other European countries Suppliers in all the other countries Customers (potential customers) in the local region Customers (potential customers) in other regions of Norway Customers (potential customers) in other European countries Customers (potential customers) in all the other countries Competitors/other companies in this industry in the local region Competitors/other companies in this industry in other regions of Norway Competitors/other companies in this industry in other European countries Competitors/other companies in this industry in all the other countries Universities/research institutes in the local region Universities/research institutes in other regions of Norway Universities/research institutes in other European countries Universities/research institutes in all the other countries Public organizations in the local region Public organizations in other regions of Norway Public organizations in other European countries Public organizations in all the other countries NGOs in the local region NGOs in other regions of Norway NGOs in other European countries NGOs in all the other countries	Binary
Indicate your level of agreement with the following statements about your relationships with external knowledge sources). We and our external knowledge sources follow similar rules and laws We and our external knowledge sources have similar norms and values	Five-point Likert scale from strongly disagree (=1) to fully agree (=5)
Indicate your level of agreement with the following statements about your internal routines for knowledge sharing. In our company ideas and concepts are communicated cross-departmental. Our management emphasizes cross-departmental support to solve problems. In our company there is a quick information flow, e.g., if a unit/employee obtains important information, it will be then communicated promptly to others. Our management demands periodical cross-departmental meetings to interchange new ideas, problems, and achievements.	Five-point Likert scale from strongly disagree (=1) to fully agree (=5)