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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

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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^{TM}, 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 will provide 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.

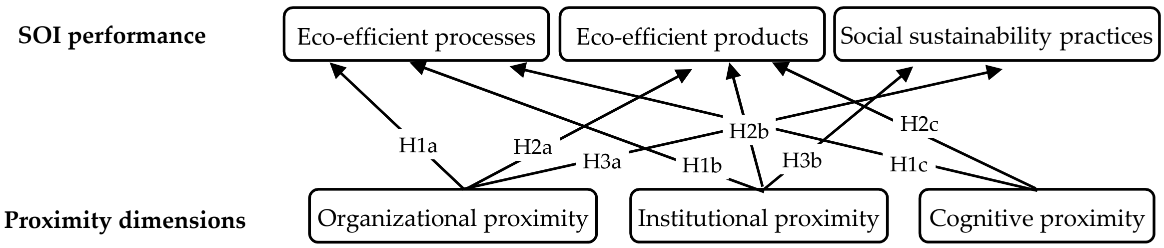

Figure 1. Non-spatial proximity dimensions as determinants of (SOI) performance.

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:

Hypothesis 1a (H1a). *Organizational proximity is positively related to eco-efficient process innovations.*

Hypothesis 1b (H1b). *Institutional proximity is positively related to eco-efficient process innovations.*

Hypothesis 1c (H1c). *Cognitive proximity is positively related to eco-efficient process innovations.*

Hypothesis 2a (H2a). *Organizational proximity is positively related to eco-efficient product innovations.*

Hypothesis 2b (H2b). *Institutional proximity is positively related to eco-efficient product innovations.*

Hypothesis 2c (H2c). *Cognitive proximity is positively related to eco-efficient product innovations.*

Hypothesis H3a (H3a). *Organizational proximity is positively related to new social sustainability practices.*

Hypothesis H3b (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:

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

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).

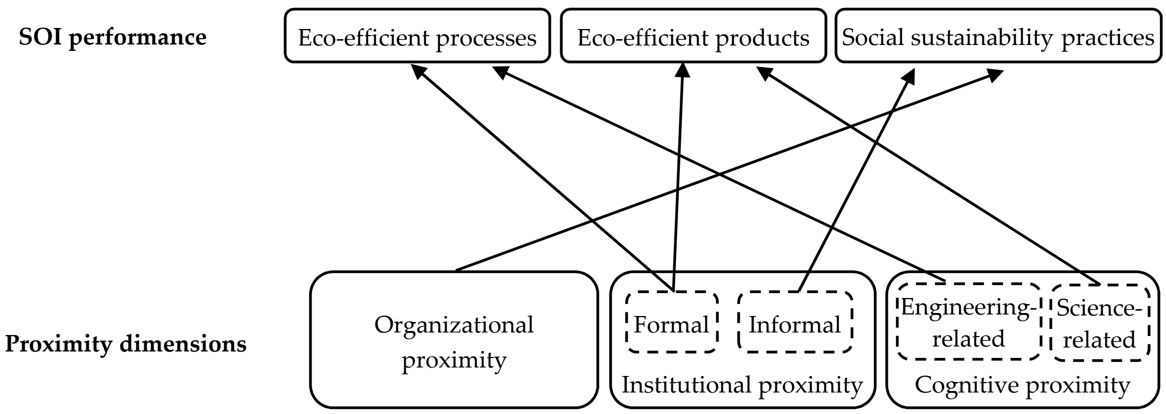

Figure 2. The confirmed relationships between proximity dimensions and SOI performance

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.

Supplementary Materials: The following is available online at http://www.mdpi.com/s1, Questionnaire items and microdata from survey on innovation activities in Norway's minerals industry covering the years 2013–2015.

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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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