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Faraimo J. Vai

ABSTRACT
This paper investigates regional and international inter-organizational doing, using and interacting (DUI) and science, technology and innovation (STI) collaborations as carriers for eco-innovation. Contextually, it studies a sample of Norwegian firms primarily based on the west coast of the country. Overall, the econometric analysis shows mixed results for regional and international inter-organizational collaborations. Results were significant for both regional DUI and STI inter-organizational collaborations. In addition, international DUI was also relevant; however, international STI inter-organizational collaborations consistently showed no effects. These latter findings challenge the notion that DUI collaborations are restricted to regional boundaries, whereas STI collaborations can overcome them.

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eco-innovation; collaboration; regional; international; knowledge; STI; DUI

INTRODUCTION

Eco-innovation (EI) has, in recent years, received an understandable amount of attention from practitioners, academics and policymakers as the world faces a race against the clock to transition to a more sustainable future. Consequently, academic research into what drives EI has flourished, especially in the last two decades. A popular definition for EI adopted by researchers, as we do here, is given by Kemp and Pearson (2008, p. 7), who define EI as:

> The production, assimilation or exploitation of a product, production process, service or management or business method that is novel to the organisation (developing or adopting it) and which results, throughout its life cycle, in a reduction of environmental risk, pollution and other negative impacts of resources use (including energy use) compared with relevant alternatives.

In its latter part, the definition differentiates EI from non-EI in that EI positively impacts the environment, which can either be an explicit goal or a side effect (Horbach et al., 2012).

In most recent review articles of the literature on the drivers of EI, several antecedents were identified as being particularly relevant. Firms that were more environmentally concerned (Zubeltzu-Jaka et al., 2018), through long-term-based EI orientation and management,

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dynamic green absorptive and adaptive capacity (Pham et al., 2019), were highlighted. In addition, more traditionally accepted antecedents such as environmental regulation, company size and research and development (R&D) activities (Bitencourt et al., 2020) were more likely to lead to an EI outcome. Common amongst these findings was the role of external information sources (Bitencourt et al., 2020) through collaborative networks (Zubeltzu-Jaka et al., 2018) with appropriate partners (Pham et al., 2019).

The beneficial role of external knowledge sources through collaboration has been well documented for innovation in general; however, these findings prove difficult to transfer to EI (Kobarg et al., 2020) because the concept of EI is fundamentally different from non-EI. EI is often characterized by relatively new technologies and a systemic nature due to the high complexity of environmental challenges (del Río et al., 2016; Horbach, 2008). The required organizational and technological competencies must often be drawn from sources beyond the firm's boundaries (Ben Arfi et al., 2018; Cainelli et al., 2015). Generally, research has shown that inter-organizational collaboration patterns differ concerning EI and non-EI (i.e., 'regular' innovation). Also, inter-organizational collaboration is more crucial for EI to be successful than non-EI (Fabrizi et al., 2018; Ghisetti et al., 2015), which lends weight to the multidimensionality and systemic nature of EI.

Recently, researchers have moved away from the relevance of inter-organizational collaboration per se as a driver for EI generally to consider more nuanced aspects such as how the breadth or depth of collaboration partners may impact the emergence of different types of EI typologies, such as product- and process-EI (González-Moreno et al., 2019; Kobarg et al., 2020; Marzucchi & Montresor, 2017). In particular, Marzucchi and Montresor (2017) considered how different types of collaboration partners inherently reflect specific 'types of knowledge' or 'innovation modes', science, technology and innovation (STI) exchanging analytical knowledge, or doing, using and interacting (DUI) exchanging synthetic knowledge. This collaboration partner distinction was made by Fitjar and Rodríguez-Pose (2013); however, Marzucchi and Montresor (2017) did not consider the important aspect of geographical proximity as was inherent in the original framing. This is especially relevant given that 'firms obtain knowledge from different sources, by use of different knowledge linkages, and from different geographical levels' (Isaksen & Trippl, 2017, p. 126).

Since then, researchers have begun to make inroads into the issue of geography of inter-organizational collaboration and EI. Arranz et al. (2019), without elaborating on some important issues, such as which type of inter-organizational collaboration partner is relevant for which particular type of EI, suggested that the density of companies in a region positively impacts EI as it facilitates learning, dissemination of knowledge and collaboration. Ocampo-Corrales et al. (2021) focused on renewable energy by evaluating the importance of scientific and technological knowledge flowing from distant and non-distant places. This analysis was based on non-patent literature citations from patent data, and not on collaboration partners nor did they consider DUI knowledge. Galliano et al. (2019) provide some important insights into the question of geographical proximity, knowledge sources and EI, specifically in five agro-ecological projects in peripheral areas, and highlight the importance of institutional actors at the regional level. However, as to which geographical location of collaboration partner is important for which type of innovation output, EI included, the empirical evidence remains unclear and is probably context specific (Doloreux et al., 2020). Local and global collaboration interactions exhibit advantages and limitations. Which of these linkages are most important is 'not a straightforward issue but instead a topic that should be analysed and tested empirically in several geographical contexts' (Parrilli & Alcalde Heras, 2016, p. 749).

Building on these works, and prompted by the latter, this paper explores the geography (international versus regional) of DUI and STI inter-organizational collaborations as potential carriers for product- and process-EI in Norway. Norway as a country is capable of generating comparatively higher innovation and economic output than others based on a given amount of R&D expenditure (González-Pernía et al., 2015; Parrilli & Alcalde Heras, 2016). Norwegian firms have generally invested less in intra-mural R&D and instead tended to pursue collaborative innovation strategies with external partners more than other European countries (Fagerberg et al., 2009). Innovation tends to rely more on DUI than on STI inter-organizational collaborations (Parrilli & Alcalde Heras, 2016), partially explained by its reliance on resource-based industries (Fagerberg et al., 2009).[1] The literature provides little evidence on how DUI and STI collaborations are related to product- and process-EI in such a context. This absence is problematic because many countries and regions find themselves in this similar situation (Parrilli & Alcalde Heras, 2016). In response to this research gap, we contribute by analysing the extent to which DUI and STI inter-organizational collaborations are associated with EI in a sample of 1201 Norwegian firms.

We contribute to the ongoing conversation about the relevance of geography to STI and DUI modes in general, and product- and process-EI in particular. We also contribute to the better understanding of which specific type of collaboration is relevant for the emergence of specific EI dimensions. In addition we contribute to the discussion of the fundamental difference between EI and non-EI and apply an approach similar to Horbach (2008). That is, we compare (1) enterprises with EIs with enterprises having no innovation at all; and (2) enterprises with EIs with enterprises having 'regular' or 'general' innovations not considered as particularly eco-friendly (i.e., non-EIs). Our motive for this approach is to gain a more nuanced understanding of potential carriers of the very concept of EIs.

The remainder of the paper is structured as follows. The next section considers theoretical aspects and introduces a few hypotheses. The third section outlines our methodology and empirical application. The fourth section reports the results of our analysis and discussion. The fifth section concludes.

THEORY AND HYPOTHESES

Modes of innovation

The concepts of modes of innovation were introduced by Lundvall and Johnson (1994), and the seminal paper by Jensen et al. (2007) explicitly defined the science and technology-based innovation mode (STI) and the learning-by-doing and interactions mode (DUI), which encompass both internal and external knowledge sourcing activities. The first of the modes is centred around high R&D investments as well as knowledge centres such universities and research institutions, and knowledge brokers who participate in the diffusion of knowledge. These sources of knowledge are seen as generators of codified and explicit or analytical knowledge that can be used to generate innovations by firms (Fitjar & Rodríguez-Pose, 2013). It is a type of knowledge that is typically associated with high-technology industries, pharmaceuticals, biotechnology and nanotechnology (Parrilli & Alcalde Heras, 2016). However, by acquiring this knowledge and understanding that it may also involve the transmission of tacit knowledge, there is always an element of learning-by-doing even when codified knowledge is transmitted and applied (Doloreux et al., 2020).

In contrast, the second innovation mode focuses on the relevance of informal relationships and mutual learning between firm employees and their local social ties (Doloreux et al., 2020). This is often expressed as know-how and know-who collaborative interactions. These interactions lead to the generation of a synthetic or tacit type of knowledge (Asheim & Coenen, 2005; Lundvall & Johnson, 1994) based on trust with less likelihood for codification. DUI-type knowledge is used for innovation typically seen in engineering based industries (Parrilli & Alcalde Heras, 2016).[2]

Fitjar and Rodríguez-Pose (2013), in a much-cited paper, classified the interactions with different external partners into STI collaborations and DUI collaborations. Collaborations with universities, research institutions and consultants are STI, and DUI collaborations are with suppliers, customers and competitors. Marzucchi and Montresor (2017), in the context of EI, labelled these as STEI and DUIEI collaboration. By adopting this perspective, 'EI is looked at through the lens of "innovation modes" where firms' innovative behaviours are systematized into a manageable and interpretable set of typologies of innovation practices, strategies, and performances' (Caravella & Crespi, 2020, p. 183).

Some researchers have addressed the complementarity between these two modes of innovation (Alhusen & Bennat, 2021; Parrilli & Alcalde Heras, 2016) finding evidence that a combination of the two modes seems to yield positive innovation outcomes. However, others have found that the two modes are substitutes for each other (Haus-Reve et al., 2019) and are difficult to combine (Marzucchi & Montresor, 2017). The latter confirms perhaps that while firms combine analytical and synthetic knowledge, in most cases they draw primarily on one of them (Asheim et al., 2019; Hansen, 2015; Menzel, 2015).[3]

Product-EI, process-EI and innovation modes

While the aforementioned multidimensionality of EI also extends to other types of innovation, such as business model or management innovation, 'a focus on technological innovation implies the differentiation between product- and process-EI' (Kobarg et al., 2020, p. 5). While the general innovation literature has found differences between product and process innovations, the EI literature has recognized that both product- and process-EI are different types of multidimensional constructs of EI and that both are dependent on complex and new technologies (Kobarg et al., 2020). Arguments have been presented that, generally, EI by its nature (and more specifically renewable energy) is an innovation that depends on analytical knowledge (Ocampo-Corrales et al., 2021). Some have argued that product-EI is dependent on synthetic knowledge, whereas process-EI is dependent on analytical knowledge (Marzucchi & Montresor, 2017). Empirical findings suggest that synthetic knowledge partners are more relevant than analytical ones for certain types of EIs over non-EIs (Kobarg et al., 2020; Marzucchi & Montresor, 2017). However, the majority of the relevant literature seem to be in consensus that the complexity of EI expressed in both typologies promotes the requirement of both types of knowledge (González-Moreno et al., 2019; Kobarg et al., 2020; Triguero et al., 2013). This perhaps is also a reflection that some form of DUI knowledge may be generated along with STI, and that DUI may be required to interpret STI knowledge (Doloreux et al., 2020; Parrilli & Alcalde Heras, 2016). We argue that despite any possible differences between product- and process-EI in terms of goals, strategies, processes and organizational aspects, both typologies of EI require multiple dimensions of knowledge; synthetic and analytical, DUI and STI.

The need for new environmental solutions that embrace the whole spectrum of elements in the technological system motivates the former of these results. The complexity of the knowledge that green innovations require, and its degree of scientific codification, have been argued to explain the latter.

(Ben Arfi et al., 2018, p. 213)

Geography of inter-organizational collaboration and innovation

In addition to classifying collaboration partners as STI or DUI, Fitjar and Rodríguez-Pose (2013) explored the geographical dimension, 'STI and DUI-mode interaction are often conducted at different geographical scales and may significantly affect the capacity of firms to produce different types of innovation' (p. 129). They explored this under the proposition that the codified nature of STI facilitates its flow irrespective of geographical borders, generally leading to firms seeking out 'global nodes of excellence' (p. 131). In contrast, the tacit and social interaction nature of DUI may restrict its diffusion to a local geographical dimension. Despite enthusiasm in the literature since the publication of the seminal paper by Jensen et al. (2007) on DUI and STI innovation modes, there are not many quantitative studies of how collaborations that reflect innovation modes are associated with different types of innovation, nor of the geography of these associations (Doloreux et al., 2020). The studies that have addressed this issue, however, led Parrilli and Radicic (2021) to suggest that these innovation modes are typically anchored to their innovation systems that are characterized by a peculiar culture and style of producing innovation, emphasizing earlier propositions by Parrilli and Alcalde Heras (2016) and Doloreux et al. (2020).

Regional DUI inter-organizational collaboration and EI

A long line of geography of innovation literature, including literature centred around innovation systems, argues that DUI given its tacit, implicit nature, requiring regular interaction is more likely local (Asheim et al., 2019). Even more recent contextual-based analysis of the geographical dimension of the two types of knowledge (Doloreux et al., 2020) as well as the EI literature itself (Marzucchi & Montresor, 2017) suggest the same. However, Fitjar and Rodríguez-Pose (2013) found that local DUI matters only slightly, whereas global DUI linkages are the most important for product or process innovation. Parrilli and Alcalde Heras (2016) confirmed this importance of global DUI for technological, non-technological and radical innovation, while finding no significance of local DUI.

For EI, the case for international DUI collaboration has yet to be empirically documented. Within the regional context, however, there have been indications that DUI collaborations with suppliers (Cainelli et al., 2012) are important, and that EI is largely reliant on local resources and networks and regional interactions (Arranz et al., 2019; Cainelli et al., 2012). Galliano et al. (2019) emphasized the reliance of EI on strong personal relationships built over time and on productive activities that already exist locally using local technologies and know-how. These local networks presumably will have a better understanding of the product and processes involved in local industries through interaction and experience (Asheim et al., 2019) allowing them to identify and offer better environmentally focused solutions. In addition, geographical proximity is beneficial for DUI inter-organizational collaboration because it makes industrial cooperation within the region more efficient (Fitjar & Rodríguez-Pose, 2013). If we then follow geography of innovation works that suggest DUI is more likely a regional or local phenomena, and that EI is more dependent on DUI than non-EI (Kobarg et al., 2020; Marzucchi & Montresor, 2017), our first hypothesis is:

Hypothesis 1: Regional DUI inter-organizational collaborations are positively associated with (a) product- and (b) process-EI.

In the absence of prior literature or evidence of EI international DUI inter-organizational collaboration, and despite the emergent empirical literature documenting the relevance of this for non-EI, we hesitate to put forward a hypothesis accordingly. We instead choose to follow the assumption taken by geography of innovation studies that DUI collaboration is primarily a regional phenomenon, like others before us (Doloreux et al., 2015, 2020; Fitjar & Rodríguez-Pose, 2013).

Regional and international STI inter-organization collaboration and EI

The widely accepted assumption from the years of geography of innovation literature is that firms usually source their innovations from their immediate vicinity as the region is the area where geographical and institutional (and often also social) proximity is present (Martin & Rypestøl, 2018; Ocampo-Corrales et al., 2021).[4] This exploitation of local knowledge sources instead of investment in internal R&D for innovation partially explains the success of countries such as Norway and Denmark and various other European regions (Asheim & Gertler, 2005;

Edquist, 2005). Keller and Yeaple (2013) also stated that the more knowledge intensive a process, which EI undoubtedly is, the less likely its knowledge will diffuse in space, and knowledge spillovers is primarily a local phenomenon (Isaksen & Trippl, 2017). Boschma (2005), in a discussion of dimensions of proximity, also states that short spatial distance may even be just as relevant for codified knowledge as it may have a component of tacit knowledge (Asheim et al., 2019). Parrilli and Alcalde Heras (2016) show that local STI connections are most closely related to innovation, and that a higher proportion of firms engage in local STI interactions rather than in transregional ones.

For EI, the literature has pointed to the important role of local universities and research institutions as determinant for EI over non-EI (Cainelli et al., 2012; Galliano et al., 2019; Horbach, 2014). Others have pointed to how regions facilitate learning, dissemination of knowledge and collaboration (Arranz et al., 2019). Rather than reaching for international collaboration partners, firms may restrict themselves to regional inter-organizational collaborations where other forms of proximity, which may also include cognitive, are inherent. Regional STI partners may be more aware of products and processes in local industries and how analytical knowledge provided by research can solve relevant environmental issues. These regional university–industry networks are important for STI (Asheim et al., 2019). We argue that in the search for collaborations to gain knowledge to solve specific complex problems (such as, for instance, EI), firms will form STI inter-organizational networks at the regional level.

Hypothesis 2: Regional STI inter-organizational collaborations are positively associated with (a) product- and (b) process-EI.

However, empirical works have documented the impact of extra-regional knowledge sources on the innovative performance of firms (Fitjar et al., 2016; Fitjar & Rodríguez-Pose, 2020). It is generally accepted that the codifiable nature of STI can facilitate its frictionless transfer regardless of geographical distance, meaning that interacting with regionally based STI partners may not lead to any added value, making global nodes of excellence much more attractive for innovative firms (Fitjar & Rodríguez-Pose, 2013). From the EI literature it has been suggested that the more important aspect of proximity here, perhaps, is not only geographical but also cognitive proximity (Ocampo-Corrales et al., 2021). Searching for sources of knowledge to develop EI, firms will usually begin this search with sources that are at a certain cognitive distance (González-Moreno et al., 2019); cognitive proximity may help overcome any friction imposed by geography. Some empirical findings on the dependence of EI, over non-EI, on STI knowledge from distant places have been positive (Galliano et al., 2019; Ocampo-Corrales et al., 2021). Additionally it has been suggested that seeking knowledge from distant places may help established industries break out of path-dependent trajectories (Asheim et al., 2019), which may be required for firms to transition into EI.

We additionally argue that firms will use all channels available in the search for STI knowledge, and because it is codifiable, geography will be less relevant.

Hypothesis 3: International STI inter-organizational collaborations are positively associated with (a) product- and (b) process-EI.

METHOD AND DATA

Empirical context

The data set used for this research was the result of a survey taken in 2018 that was carried out by telephone interviews of chief executive officers (CEOs) in the first months of 2018. The candidate firms were randomly selected from Statistics Norway, the statistics bureau of Norway. Firms having at least five employees and operating in most industries, except for the real estate and the public sector, were targeted for the survey. The response rate of those firms that were contacted was 34.8% and was consistent across firm size, firm location and industry classes.

Ipsos, a professional market research and consulting firm, carried out the survey interviews and the coding of the raw data. The raw data were merged with register data on firm size (number of employees), geographical location, year of establishment and the industry (NACE) code provided by Dun and Bradstreet.

The resulting data set contained 1201 firms, 800 firms in the counties of Rogaland, Hordaland, and Sogn and Fjordane on the west coast of Norway, and 401 firms from other parts of Norway.

Dependent variables

Data concerning firms' product or process innovations were assessed by applying operational definitions following the *Oslo Manual* (Bloch, 2007; OECD & Communities, 2005). The respondents were asked as follows concerning the concept of product innovation: 'Has your firm during the last three years introduced a new or substantially improved product or service?' Those firms that responded 'yes' were coded 1 as having a product innovation, and those that responded 'no', 'do not know' or did not respond at all were coded 0 as not having a product innovation.

In addition, process innovation was defined and assessed by the following phrase and question: 'Process innovation implies to start using new or substantially improved technology or methods of production, delivery, and distribution. Has your firm during the last three years introduced a new or substantially improved process innovation?' Those firms that responded 'yes' were coded 1 as having a process innovation, and those who responded 'no', 'do not know' or did not respond at all were coded 0 as not having process innovation.

A follow-up question was asked to those respondents who answered 'yes' to the first question concerning product innovation: 'Do you consider these new or substantially improved products and services to be especially environmentally friendly?' Another follow-up question was also posed in reference to process innovation: 'Do you consider these new or substantially improved processes to be especially environmentally friendly?' Those firms that responded 'yes' were coded as having either a product- or process-EI innovation, respectively (those who responded 'no', 'do not know' or did not respond at all were coded as not having either a product- or process-EI innovation, respectively). Product- or process-EI innovation, respectively, were coded as 1, and 0 otherwise. Table 1 shows these classifications and the share of firms surveyed in the context of product and process innovations, respectively.

Independent variables

To assess firms' inter-organizational collaboration, we adopted operational definitions similar to those used by the Community Innovation Survey (CIS). The respondents were asked: 'Has your firm during the last three years had collaboration with other firms or institutions concerning the development or improvements of products and processes?' Respondents who answered 'yes' were coded as 1, and those that answered 'no', 'do not know' or did not respond at all were coded as 0. Those that answered 'yes' were then asked to identify their collaboration partners

Table 1. Innovations developed in the last three years.

Innovation type	Number of firms	% of total firms sampled
Product-EI	494	41.13%
Non-EI product	274	22.81%
No product innovation	433	36.05%
Process-EI	331	27.56%
Non-EI process	197	16.40%
No process innovation	673	56.04%

and where they were located with the following question: 'Which type of collaboration partner has your firm had and where are these geographically located?' Partner type options were suppliers, customers, competitors, universities/technical colleges/research institutes and consultants.

Suppliers, customers and competitors were classified as DUI. Universities/technical colleges/research institutes, and consultants were classified as STI. Locations options were local/regional (regional), other places in Norway (national) or overseas (international), or 'not relevant'. Inter-organizational collaboration for each type, DUI or STI at each geographical dimension was coded as a summation or breadth of collaboration reported. For DUI collaborations this meant a possible value of 0, 1, 2 or 3 (one for each collaboration partner) for each geographical dimension. For STI this meant a possible value of 0, 1 or 2 for each geographical dimension.[5]

Variables for regional and international collaborations are related to our three hypotheses; however, we feel it appropriate to also include variables related to national collaboration. We include variables for national DUI and national STI collaboration since we otherwise cannot be sure that the regional effect, or the international effect for that matter, are genuine carriers. If national collaboration is omitted, we can falsely conclude that regional collaboration has an effect while it is national collaboration that genuinely has an effect. By including national collaboration as a variable, we clarify this issue and illustrate the genuine effects of regional and international collaboration. We include the variable for international DUI inter-organizational collaboration for similar reasons to clarify the genuine effects of our relevant independent variables as expressed in the hypotheses. Table 2 provides descriptive statistics on geography of collaboration for each innovation output.

Table 3 informs about how our control variables are related to each innovation output and hence also descriptive statistics on each of our subsamples of firms for each model.

Control variables

We include a dummy variable to control for enterprises located in the counties of Rogaland, Hordaland and Sogn og Fjordane on the west coast (coded 1, and 0 otherwise). The reason is that the sampling procedure was different for enterprises located in these counties versus the rest of the country. In the three counties representing the west coast of Norway, we sampled 800 enterprises, and in the rest of the country, we sampled 401 enterprises. As there are less enterprises in Western Norway than in the rest of the country, sampling a relatively large share of enterprises in Western Norway and a relatively small share of enterprises in the rest of the country may induce unobserved variation between these two groups of enterprises stemming from different sampling procedures.

Whether a firm is independent was assessed with the following question: 'Is your firm part of a larger corporation?' Those responding 'no' were coded 1 as an independent firm. Those responding 'yes, as a mother company' or 'yes, as a daughter company' were coded as 0. All firms responded to one of the three alternatives. We also control for age measured in number of years since establishment, and firm size measured in number of employees. In the survey, the following questions were also included: 'Has your firm over the last three years developed in any of the following ways?' Responding 'yes' to 'Having had growth in employees' was coded 1, and responding 'no' or not responding at all was coded 0, which we control for under the label 'Growth in employees'. We expect growth in employees, which we also consider as a proxy for overall growth in a firm, to positively affect product- and process-EI in that firms who are assumed to be experiencing growth can direct more resources, at the very least employees to activities outside their normal day-to-day operations. In addition, we include a control for the major owner of the firm being located overseas (Fitjar & Rodríguez-Pose, 2013), coded as a dummy and formulated from the following question: 'Where is the majority owner located?

Table 2. Geography of collaboration for each innovation type.

	Innovation type	Reported ≥ 1 collaboration	Mean	SD	Minimum	Maximum
Regional DUI	Product-EI	329	1.318	1.133	0	3
	Non-EI product	127	1.022	1.126	0	3
	No product innovation	104	0.822	1.142	0	3
	Process-EI	172	1.375	1.141	0	3
	Non-EI process	107	1.173	1.125	0	3
	No process innovation	217	0.893	1.137	0	3
National DUI	Product-EI	265	0.901	0.995	0	3
	Non-EI product	127	0.737	0.936	0	3
	No product innovation	104	0.418	0.832	0	3
	Process-EI	172	0.867	1.006	0	3
	Non-EI process	107	0.909	0.985	0	3
	No process innovation	217	0.538	0.881	0	3
International DUI	Product-EI	207	0.664	0.919	0	3
	Non-EI product	82	0.449	0.789	0	3
	No product innovation	65	0.222	0.595	0	3
	Process-EI	125	0.625	0.937	0	3
	Non-EI process	65	0.497	0.806	0	3
	No process innovation	184	0.360	0.723	0	3
Regional STI	Product-EI	242	0.656	0.748	0	2
	Non-EI product	102	0.489	0.697	0	2
	No product innovation	111	0.337	0.621	0	2
	Process-EI	172	0.710	0.767	0	2
	Non-EI process	83	0.569	0.737	0	2
	No process innovation	200	0.382	0.637	0	2
National STI	Product-EI	152	0.381	0.618	0	2
	Non-product-EI	60	0.259	0.523	0	2
	No product innovation	56	0.166	0.462	0	2
	Process-EI	100	0.387	0.638	0	2
	Non-EI process	60	0.355	0.576	0	2
	No process innovation	108	0.382	0.637	0	2
International STI	Product-EI	66	0.162	0.439	0	2
	Non-EI product	22	0.088	0.308	0	2
	No product innovation	18	0.046	0.231	0	2
	Process-EI	45	0.160	0.428	0	2
	Non-EI process	23	0.127	0.363	0	2
	No process innovation	38	0.068	0.296	0	2

Table 3. Control variables related to each innovation output.

Innovation type	Independent variables	Mean	SD	Minimum	Maximum
Product-EI	Major own int.	0.164	0.489	0	1
	Independent	0.686	0.464	0	1
	Age	18.670	15.798	1	165
	Size-employees	38.482	157.072	5	3098
	Growth	0.605	0.490	0	1
	West Coast	0.686	0.464	0	1
Non-EI product	Major own int.	0.128	0.334	0	1
	Independent	0.726	0.447	0	1
	Age	19.022	19.158	1	172
	Size-employees	30.595	56.018	5	464
	Growth	0.566	0.497	0	1
	West Coast	0.631	0.483	0	1
No product innovation.	Major own int.	0.092	0.290	0	1
	Independent	0.770	0.422	0	1
	Age	21.358	18.400	1	178
	Size-employees	30.607	42.076	5	431
	Growth	0.434	0.496	0	1
	West Coast	0.667	0.472	0	1
Process-EI	Major own int.	0.130	0.337	0	1
	Independent	0.665	0.473	0	1
	Age	18.858	16.485	1	176
	Size-employees	37.804	91.876	5	1321
	Growth	0.595	0.492	0	1
	West Coast	0.619	0.486	0	1
Non-EI process	Major own int.	0.188	0.392	0	1
	Independent	0.695	0.461	0	1
	Age	21.990	22.534	1	178
	Size-employees	31.848	48.912	5	464
	Growth	0.558	0.498	0	1
	West Coast	0.680	0.468	0	1
No process innovation	Major own int.	0.113	0.367	0	1
	Independent	0.764	0.425	0	1
	Age	19.478	16.402	1	165
	Size-employees	32.480	125.243	5	3098
	Growth	0.498	0.500	0	1
	West Coast	0.686	0.464	0	1

Alternatives offered were local/regional (regional), other places in Norway (national) or overseas (international), or do not know. Those who responded 'overseas' were coded as 1, while those who indicated one of other three alternatives were coded as 0. This control was included under the premise that firms who had a majority international owner may be more likely to use international links and networks for the collaborations in their owner's country of location.

RESULTS AND DISCUSSION

In addressing the research question, we fit regression models by using robust logistical regression with cluster (industry) robust standard errors, which correct for potential industry effects in terms of autocorrelation (industries are distinguished by using two-digit NACE codes). Robust logistical regression also corrects for potential heteroscedasticity in the data.[6]

We run a total of four separate models: model 1A compares firms with product-EI (coded 1) with those that have no product innovation at all (coded 0); model 1B compares firms with process-EI (coded 1) with those that have no process innovation at all (coded 0); model 2A compares firms with product-EI (coded 1) with those that have product innovation, but they are not EI (coded 0); and model 2B compares firms with process-EI (coded 1) with those that have process innovation, but they are not EI (coded 0). For each model, we include measures of maximum and average variance inflation factors (VIFs), which indicate that multicollinearity is not a problem in our data.

Model 1A

Hypothesis 1a is not confirmed. Regional DUI inter-organizational collaboration is not positively associated with product-EI when compared with no product innovation. However, Hypothesis 2a is confirmed. Regional STI inter-organizational collaboration is positively associated with product-EI. For example, Table 4, model 1A, reports 32% higher odds of occurrence in product-EI for firms with regional STI inter-organizational collaborations (cf. an odds ratio of 1.323, which we report in brackets).[7] Hypothesis 3a is not confirmed, which is surprising given the relative ease STI knowledge is assumed to diffuse across spatial distance and to the attraction international nodes of excellence would have for innovating firms (Fitjar & Rodríguez-Pose, 2013).

International DUI inter-organizational collaboration is significant with 57% higher odds of occurrence of product-EI. This is surprising given the focus of the literature on the importance of regions for DUI. In a more practical consideration, it is perhaps an indication that DUI partners often lie well outside regional borders, and that mechanisms, especially technological, may allow the transfer of tacit knowledge across geographical borders.

The negative significance of independent firms for product-EI is perhaps not surprising given the assumed lack of resources independent firms have compared with those who are part of a corporate group drawing from shared resources. In addition, the significance of growth in employees is understandable, with the assumption that large firms can allocate more resources to the exploration of activities outside their normal operations, which may include product-EI.

Model 1B

Hypothesis 1b shows $p < 0.1$ significance, and Hypothesis 2b is confirmed with 43% higher odds of occurrence for process-EI. Hypothesis 3b is not confirmed: international STI inter-organizational collaboration is not positively associated with process-EI. Again, the negative significance for our control variable of independent firm is noted. In addition, the negative significance of a firm located on the west coast for process-EI, which may be an indication that firms located on the west coast are not transitioning to process-EI. If one is to consider the nature of industry in this region, which is heavy resource based, transitioning to more environmentally friendly processes may involve considerable capital investment.

Model 2A

Hypothesis 1a is confirmed. Regional DUI inter-organizational collaboration has a positive relationship with product-EI when compared with non-EI product. The odds ratio suggests a 16% higher odds of occurrence. Hypotheses 2a and 3a are rejected. Neither regional STI nor international STI inter-organizational collaboration are positively associated with product-EI. There are no significant effects from any of our control variables.

Model 2B

Hypothesis 1b only shows a $p < 0.1$ level of significance, and both Hypotheses 2b and 3b are rejected. International DUI inter-organizational collaboration is significantly associated

Table 4. Results of logistic regressions.

	EI compared with no innovation (at all)		EI compared with non-EI	
	1A: Product-EI	1B: Process-EI	2A: Product-EI	2B: Process-EI
Inter-organization collaboration				
DUI region	0.131 (0.089)	0.178 (0.095)*	0.149 (0.070)**	0.142 (0.086)*
		[1.195]	[1.161]	[1.153]
STI region	0.281 (0.138)**	0.356 (0.145)**	0.125 (0.118)	0.123 (0.133)
	[1.325]	[1.428]		
STI international	0.300 (0.217)	0.209 (0.212)	0.211 (0.187)	0.090 (0.237)
DUI international	0.451(0.193)**	0.160 (0.111)	0.179 (0.124)	0.228 (0.109)**
	[1.570]			[1.257]
DUI national	0.185(0.108)*	0.049 (0.090)	−0.092 (0.143)	−0.243 (0.091)***
STI national	0.134(0.159)	0.192 (0.140)	0.208 (0.183)	0.080 (0.127)
Control variables				
Majority owner Inter	0.360(0.307)	−0.185(0.223)	0.171 (0.210)	−0.642 (0.299)**
				[0.784]
Independent firm	−0.419 (0.164)**	−0.551 (0.181)***	−0.128 (0.180)	−0.322 (0.290)
	[0.658]	[0.576]		
FirmAge	−0.006 (0.004)	0.000 (0.004)	0.000 (0.004)	−0.009(0.004)**
				[0.992]
FirmSize	0.000 (0.000)	0.000 (0.001)	0.000 (0.001)	0.002 (0.001)
Growth in employees	0.587 (0.142)***	0.249 (0.145)*	0.129 (0.129)	0.102 (0.237)
	[0.587]	[1.283]		
West Coast	0.022 (0.132)	−0.399 (0.133)***	0.224 (0.178)	−0.341 (0.170)**
		[0.671]		[0.711]
Constant	−0.434 (0.228)*	−0.740 (0.229)***	0.061 (0.241)	0.901 (0.478)*
Wald χ^2	156.477***	80.442***	51.472***	49.309***
Log pseudo-likelihood	−568.820	−591.336	−486.682	−336.824
Industries included	54	55	53	50
Maximum/average VIF	1.817/1.317	1.717/1.296	1.671/1.264	1.714/1.292
Observations	927	1004	768	528

Note: Coefficients are given with the robust standard errors adjusted for industry effects in parentheses. Reported are odds ratios below significant regressors in brackets. VIF, variance inflation factor.
$^*p < 0.1$; $^{**}p < 0.05$; $^{***}p < 0.01$.

with process-EI when compared with non-EI process innovation. Given the arguments presented in the hypothesis development about the possible regional restriction of DUI knowledge, this is surprising. A perplexing result is the negative significance of national DUI inter-organizational collaboration ($p < 0.01$). It is a finding contrary to the general assumption that collaboration in general is positively associated with EI. It seems to underline theoretical frameworks such as local buzz and global pipelines (Aarstad et al., 2016; Bathelt et al., 2004), and the general discussion on geographical dimensions where the regional and international geographical dimensions are usually discussed as the relevant distinction. We also note the negative significant effect of having an international majority owner for process-EI as well as the negative significant effect of firm age and being located on the west coast of Norway.

CONCLUSIONS

Discussion of the findings

In this paper, we have studied DUI and STI inter-organizational collaborations as potential carriers for EI. Empirically, we have studied a sample of 1201 Norwegian firms. As to the relevance of the region for inter-organizational collaboration, the findings are mixed. When comparing EI with no innovation, it is difficult to make a definitive statement about the relevance of regional collaboration. Whereas regional STI collaboration is significantly positively associated with both product- and process-EI, the same cannot be said for DUI collaboration. This finding is especially challenging for the argued regional relevance for the diffusion of DUI knowledge. This is underlined by the significance of international DUI collaboration in model 1A. Additionally it is challenging to the notion that STI collaboration can overcome geographical borders. Despite codified STI knowledge moving frictionless across geographical borders, and the proposition that firms will seek out international nodes of excellence, firms are choosing local sources.

When comparing EI with non-EI, these mixed results persist. For product-EI it is regional DUI inter-organizational collaboration that is significant. This is not surprising and makes sense for firms to build on their existing collaborations at the regional level. For process-EI, it is international DUI inter-organizational collaboration that is significant. Here we add our voice to the growing literature that challenges the assumption that DUI knowledge cannot transcend regional boundaries (Fitjar & Rodríguez-Pose, 2013; Parrilli & Alcalde Heras, 2016). Why the geographical dimension for inter-organizational collaboration differs for product- and process-EI is difficult to interpret, and we hesitate to offer definitive conclusions about the possible differences between these two typologies of EI. There have been suggestions that where knowledge originates, regionally or internationally, differs in its effect on different types of innovation, incremental or radical (Asheim et al., 2019), which may have some relevance here.

The findings that DUI inter-organizational collaboration is positively associated with both product- and process-EI (models 2A and 2B) is interesting given that neither regional nor international STI is positively associated with either. This may indicate that the historic dependence of firms in this context on DUI collaborations has led to a sort of familiarity. Not only in engaging in this type of collaboration, but also using the type of knowledge exchanged in these types of interactions for EI. There are suggestions that DUI knowledge when applied to innovation usually results in incremental improvements (Alhusen & Bennat, 2021), rather than radical innovations which require knowledge, usually STI that come from distant places (Asheim et al., 2019). This could indicate that Norwegian firms are engaging only in incremental EI, making small environmental improvements in both product and processes.

Overall, our findings show that inter-organizational collaboration patterns for EI differ from non-EI with regard to geography, which speaks to the fundamental difference between EI and non-EI. As to the geography of inter-organizational collaboration, the proposition that this is probably context specific (Doloreux et al., 2020; Parrilli & Alcalde Heras, 2016) seems to be supported. As to the relevance of regional versus international inter-organizational collaboration, we do not contradict those who suggest the importance of local networks, and resources for learning and knowledge dissemination for EI (Arranz et al., 2019; Cainelli et al., 2012; Horbach, 2014). We suggest, as have others have Galliano et al., 2019; Ocampo-Corrales et al., 2021), that other geographical dimensions, namely those at a distance, are also relevant for

EI. Finally, we find that the reliance of firms in positive innovation paradox regions such as Norway on DUI collaborations seems to be persistent even in regard to EI.

Policy implications

First, we recommend that policy efforts to facilitate the interaction between industry and knowledge institutions not only continue but also intensify. Our findings reveal that an opportunity for firms to achieve EI remains underutilized, namely STI inter-organizational collaboration, at both the regional and international levels. Policy to facilitate interactions between industry and DUI partners should be encouraged, and these findings show positive results for EI.

Limitations and future research

The inclusion of relevant exogenous variables and the use of a longitudinal research design could address several limitations of our study. Although the inclusion of variables such as firm size, firm age and geographical location provided by register data goes some ways to limiting potential endogeneity problems that arise by relying solely on our survey, these issues cannot be entirely discounted. Future research should include appropriate instrumental variables provided by register data or other sources. The use of longitudinal data could also provide insights into EI's persistency over time, which is not addressed in this study. Related to this is a more dynamic (Balland, 2012) or evolutionary approach used to understand the required knowledge for EI as well as EI itself (Galliano et al., 2019).

An additional limitation is that this study did not address the role collaboration may play in organizational routines and business practices concerning EI. Our data set did not allow us to explore such relationships. Much has also been said about refining product- and process-EI measures to classify them as incremental, radical, end-of-pipe or cleaner technologies to fully understand what specific types of EI are being influenced by which collaboration partners. We believe there is a relevant relationship between the location of collaboration partners and these specific types of EI and urge future research to explore this issue.

Given the persistence of relevance for DUI inter-organizational collaboration, this research raises questions about how firms may combine these external knowledge inputs with internal knowledge across their firm borders, a complex question that has been emphasized by recent research (Marzucchi & Montresor, 2017; Triguero et al., 2018). Haus-Reve et al. (2019) suggested that internal absorptive capacity may play a role in which type of external inter-organizational collaboration a firm may choose and may also affect the geography of that collaboration.

Lastly, given that our analyses were based on a sample of firms in Norway and the discussed peculiarities of Norwegian firms, this may potentially limit the validity of our results for other jurisdictions. However, our results may have more relevant implications for the so called 'positive innovation paradox' regions.

DISCLOSURE STATEMENT

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NOTES

[1] This situation for innovation in Norway, Denmark, and specifically regions such as the Italian industrial districts and the Basque Country has often been referred to as a 'positive innovation paradox'(Asheim & Gertler, 2005; Asheim & Parrilli, 2012; Edquist, 2005). The literature on innovation systems and the so-called 'innovation paradox' is where the debate on STI and DUI modes originates (Parrilli & Alcalde Heras, 2016).

[2] A third knowledge type is often discussed, the so-called symbolic mode, which seems more relevant for creative industries (Martin & Rypestøl, 2018). Symbolic knowledge entails those activities where innovation consists of the creation of meaning, images and symbols with aesthetic and cultural attributes (Ocampo-Corrales et al., 2021).

[3] This paper does not examine all dimensions of STI and DUI innovation: rather, in keeping with Fitjar and Rodríguez-Pose (2013) and others (Doloreux et al., 2020; Marzucchi & Montresor, 2017; Parrilli & Alcalde Heras, 2016), it limits the analysis to some specific dimensions.

[4] Boschma (2005) distinguishes between five proximity dimensions, of which geographical is only one, namely: cognitive, organizational, institutional and social proximity. These dimensions can overlap, but also substitute one another (Hansen, 2015; Menzel, 2015). Hansen (2015) specifically found that social and institutional proximity overlap with geography, but organizational and cognitive can act as substitutes.

[5] In the survey, universities/technical colleges/research institutes was given as a single option. This meant that at every geographical dimension, it was only possible to have a maximum value of 2 for STI, rather than the 3 for DUI collaboration.

[6] The use of a logit model is consistent with previous studies of innovation modes (Fitjar & Rodríguez-Pose, 2013; Haus-Reve et al., 2019; Marzucchi & Montresor, 2017).

[7] This can be interpreted as having one more regional STI inter-organizational partner results in 32% higher odds of occurrence for product-EI (see Szumilas, 2010; and Aarstad et al., 2016, for an interpretation of odds ratio).

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