Interaction and innovation across different sectors: Findings from Norwegian City Regions

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Abstract: This paper examines how different types of interaction affect the capacity of firms in different sectors to innovate. Using a sample of 1604 Norwegian firms with more than ten employees, we analyse how interactions within the firm, with industry partners, and with research institutions and consultancies affect levels of innovation across six different economic sectors – manufacturing; construction; retail; accommodation and food; transport; and other services. The results of a generalised ordinal regression analysis for product and process innovation show that the drivers of innovation differ widely across sectors. While exchanges internal to the firm tend to have a limited effect on innovation across the board, those with scientific and industrial partners prove to be important drivers of innovation not only for firms in sectors, such as manufacturing, traditionally deemed to benefit from these partnerships, but also for sectors regarded as less innovative, such as construction.

Keywords: Product innovation, process innovation, interaction, industrial sectors, firms, Norway.

JEL Codes: O31, O32

1. Introduction

The sources of innovation in firms have attracted considerable attention in the scholarly literature. Three key sources of innovation have been identified. First, early research on innovation tended to focus on the role of scientific knowledge and exchanges within the firm (Bush, 1945; Maclaurin, 1953). Larger firms and those with a greater capacity to invest in research and development (R&D) have been deemed to be more capable of innovating than those which, due to their limited dimensions or sector, lacked the same capacity to invest in R&D. A second important source of innovation has been linked to the presence of frequent interaction with scientific partners and consultancies. University-industry interactions, as well as exchanges with research institutes and consultancy firms, have been regarded as a rich source of innovation for firms (Audretsch and Feldman, 1996; Cantwell and Iammarino, 2003; Sonn and Storper, 2008). The more firms interact, either formally or informally, with these scientific institutions and consultancies, the greater the chance for firms to innovate. Finally, a third strand of thought in economic geography and innovation research has concentrated on the presence of incremental and networked innovation processes that emerge through frequent relations between firms and their suppliers and customers, often through informal networks and in geographically limited industrial districts (Becattini, 1987) or innovation systems (Lundvall, 1992). Purpose-built or casual interaction with suppliers and customers, but also with competitors, provide valuable exchange of both codified and tacit knowledge which fosters innovation within firms. These three sources of innovation are then combined with the role of government in triple-helix type systems (Etzkowitz and Leydesdorff, 2000; Leydesdorff, 2000), creating complex networks of knowledge exchange, with firms at the heart of these systems benefiting from a greater capacity to innovate.

Whether based on sources internal to the firm, on interaction with universities, research centres and consultancies, or on links with customers, suppliers and competitors, it is clear that innovation and knowledge generation require “a dynamic interplay between, and transformation of, tacit and codified forms of knowledge as well as a strong interaction of people within organizations and between them” (Asheim and Gertler, 2005: 294). The influence of these diverse sources of innovation has been the object of constant scrutiny, especially in determining how innovation is achieved in manufacturing firms or in specific sub-sectors within manufacturing. These studies have tended to highlight different sectoral patterns in the importance of these three basic sources, even within manufacturing industries (Pavitt, 1984). Recent research has also paid attention to services, in particular knowledge-intensive business services and other particularly innovative sub-sectors (e.g. Aslesen and Isaksen, 2007; Doloreux and Shearmur, 2012). However, less attention has been paid to the analysis of how each of these sources affects innovation across a wide range of different sectors and whether the sources of innovation vary widely across industries (Castellacci, 2008). The different interactions between potential sources of innovation have also been somewhat overlooked by the literature. Asheim and Gertler (2005: 294) argue that the knowledge bases of different sectors can be classified into two main types: synthetic and analytical. Innovation in firms or sectors with synthetic and analytical knowledge bases demands different approaches and different types of knowledge inputs. Hence, innovation will be the consequence of different forms of interaction across diverse types of industries, a factor which has been given relatively short shrift by research looking for the sources of firm innovation.

This paper aims to understand how different forms of interaction shape the genesis of new knowledge and innovation in firms working in different sectors, spanning both those with a more synthetic and a more analytical knowledge base. It will examine the role of interaction within the firm and with industrial and scientific partners in stimulating firm product and process innovation in six different Norwegian industries: manufacturing; construction; trade and retail; food and accommodation services; transport, storage, information and communications; and other services. The research draws on a survey of 1604 firms across the five largest city regions of Norway in order to probe through a series of ordered logit regression analyses the relative roles of cooperation internal to the firm, and with industrial (suppliers, customers, and competitors) and scientific (universities, research institutes, and consultancies) partners in affecting the probability of innovating among firms within each of these industries. The objective is thus to draw a more complete picture than earlier studies – which have frequently been limited to the sources of innovation within a single industry (e.g. Powell et al. 1996; Moodysson et al. 2008; Strambach, 2008) or across industries regardless of sectors (e.g. Tether, 2002; Jensen et al. 2007; Fitjar and Rodríguez-Pose, 2012) – on what determines firm-level innovation. Comparing the drivers of innovation in the manufacturing industries to those found in more service-oriented industries will allow us to paint a more complete portrait of the commonalities and differences in how innovation occurs across a range of economic activities.

The results of the analysis show that the drivers of innovation differ widely across sectors. While exchanges internal to the firm tend to have a limited effect on innovation across the board, firm innovation relies on sector-specific combinations of interactions with scientific and industrial partners. Scientific partners prove to be important drivers of innovation not only for firms in sectors, such as manufacturing, with a more analytical knowledge base and traditionally deemed to benefit from interaction with universities, research institutes, and consultancy firms, but also for sectors normally regarded as less innovative and with a more synthetic knowledge base, such as construction. Similarly, industry-type interaction is, as expected, at the source of innovation in a wide range of sectors, but while interaction with suppliers are important in some sectors, such as construction and services, interaction with customers matters more for product innovation in manufacturing.

The structure of the paper is as follows. In the next section we discuss how different types of knowledge exchange may affect innovation across different sectors. Section three introduces the research design and the methodology used in the analysis. The results of the empirical analysis are presented in section four. Finally, the conclusions and some preliminary policy implications are included in section five.

2. Knowledge exchange and innovation across different sectors

Traditionally, the scholarly literature looking at innovation has tended to identify three potential sources of innovation. First, innovation may be the result of sources internal to the firm. Many firms conduct R&D activities in-house and firms which devote a large amount of resources to R&D are generally more innovative than those that do not. Firm size is one of the key factors which determines whether a firm can benefit significantly from this type of innovation. Firm sector is another (Pavitt, 1984; Laursen and Salter, 2006). The structure of certain industrial sectors demands the need to invest heavily in R&D in order either to benefit from significant economies of scale or to maximise the appropriation of the returns of innovation and of the generation of new knowledge. This is for example the case of aeronautics or of firms in the aerospatial sectors and, to a lesser extent, of oil and gas. For this type of innovation to take place, the majority of the exchanges leading to knowledge generation will happen in-house, either within the same plant or across units within the same organisation and/or firm.

In other sectors, however, in-house research is either impractical or conducive to lower levels of new knowledge generation. Firms in these sectors may also lack the scale to host large R&D projects in-house. In these sectors, innovation comes mainly from interaction with outside sources and, in particular, from exchanges with centres generating new knowledge, such as universities or research centres (Keeble et al., 1999; Lawton Smith, 2007), or with external consultants (Foley and Watts, 1996; Lawton Smith et al., 2001). This sort of exchanges can be equated to what Jensen et al. (2007) have denominated as the 'science, technology and innovation' (STI) mode of innovation. In the STI mode of innovation, external scientific knowledge is heavily used as the fundamental source of new knowledge in product and process innovation. The interaction leading to new knowledge generation tends to be dominated by formal exchanges and to rely heavily on formal investment in science and technology by the organisations external to the firm (Jensen et al., 2007: 681) as the fundamental driver of new knowledge.

A third key source of new knowledge generation for innovation has been identified in repeated formal and informal interactions with suppliers, clients, and competitors (Lundvall, 1992;

Storper and Venables, 2004). Frequent exchanges with these types of partners lead to the transmission of codified and tacit knowledge, resulting in what Jensen et al. (1997) referred to as the ‘doing, using and interacting’ mode of innovation. In this mode, firms generate or acquire new knowledge by solving specific problems through exchanges of experience and know-how, without necessarily involving additional formal research in the process (Jensen et al., 2007). DUI-type innovation is generally not R&D intensive – apart from applied R&D aimed at addressing practical issues – and is contingent on experience, skills, and the sharing of these factors between workers.

The ability to utilise either of these three sources of innovation crucially depends on factors such as the type of management and ownership of the firm, its size, and, perhaps even more importantly, on the industrial sector. Different sectors will use different knowledge bases in order to generate new ideas and product and process innovations. Based on Laestadius (1998), Asheim and Gertler (2005) distinguish between two types of knowledge bases across different industries[1], each of which has implications for the relative importance of different types of interactions in the genesis and promotion of innovation.

The first knowledge base – analytical knowledge – is characterised by a strong reliance on scientific knowledge. New knowledge generation is the result of formal interaction in which codified knowledge is exchanged. These interactions are based on R&D activities and formal

[1] Asheim et al. (2007) have later introduced a third knowledge base – symbolic – in which the emphasis is on creating meaning and aesthetic qualities. This knowledge base has similar implications for interaction as a synthetic knowledge base, in so far as creative processes are strengthened primarily by relations to consumers and – in particular – to other producers, rather than to scientific communities.

contracts. Although tacit knowledge cannot be excluded as an important source of innovation, the exchanges at the base of new knowledge generation in industries with an analytical knowledge base imply more often than not a systematic quest for new products and processes and are most of the time purpose-built, rather than casual. As Asheim and Gertler underline (2005: 295), an analytical knowledge base is required in those sectors – such as biotechnology or nanotechnology – which require constant flows of new and cutting-edge knowledge in order to remain competitive. Industries with an analytical knowledge base will thus inevitably depend either on in-house research, when they have the right scale to develop large and state-of-the-art research projects, but more frequently on a combination of in-house research with the establishment of linkages with universities, research institutions and consultancies.

A synthetic knowledge base – the second dominating knowledge base – is characterised by "the application or novel combination of existing knowledge" (Asheim and Gertler, 2005: 294). New knowledge is generated as a result of the need to find specific solutions to existing problems in the production process. This sort of problems arise from demands from customers and/or suppliers, who will require specific and often incremental adaptations of the product or the production process in order to address specific needs or to remain competitive. While codified scientific knowledge remains essential for synthetic knowledge base-led innovation, direct interaction between firms and their customers and suppliers is by far the fundamental source of innovation (Caraça et al., 2009). Learning, doing and using are thus key to a process in which tacit knowledge plays a role at least as important as codified knowledge. Hence, in the case of a synthetic knowledge base, the presence of R&D facilities is far less significant than in industries relying on analytical knowledge bases. Innovation in industries with a synthetic base is dominated by frequent exchanges in order to test and experiment with potential solutions to problems or address specific challenges. Synthetic knowledge bases are found in more traditional and mature industries, such as general manufacturing, construction, and market-led services.

By combining different types of interactions with the two knowledge bases identified by Asheim and Gertler (2005), we can develop the following matrix (Table 1).

Table 1. Interaction and knowledge bases matrix

Knowledge-base			Synthetic knowledge	Analytical knowledge
Interactions	In-house	Characteristics	• In-house problem solving • Inductive learning processes • Interaction between departments within the firm	• Creation of in-house R&D labs or departments • Large firms • Capital intensive sectors
	In-house	Industries	• Aeronautics • Aerospatial industry • Petroleum and energy	
	Doing, using, learning	Characteristics	• Based on frequent, often informal, interaction • Important role for tacit knowledge • Process innovations and incremental product innovations	• Formal interactions between in-house R&D units and research centres • Key role for codified knowledge • Radical product innovations
	Doing, using, learning	Industries	• General manufacturing • Construction • Retail trade	
	Science, technology, innovation	Characteristics	• Role of R&D constrained to applied research	• Formalised interaction • Key role for scientific research and models • Radical and complex product and process innovation
	Science, technology, innovation	Industries	• Specialised manufacturing • Biotechnology • Nanotechnology	

The effect of different types of interactions on innovation may thus not be homogeneous across industries and sectors with different knowledge bases. While in-house or STI-type interaction is likely to have an important effect on both product and process innovation in industries with an analytical knowledge base (e.g. nanotechnology or aeronautics), where innovation is likely to be fundamentally research-led, DUI-interaction may lead to greater innovation in industries, such as retail or construction, where contacts with customers or suppliers are bound to be much more frequent and the research-led element of innovation lower. We therefore hypothesise that the types of interaction needed in order to generate innovation will be radically different across different sectors, leading to diverse forms of interaction-led innovation across Norwegian industries.

3. Research design and methodology

In order to test whether this is the case, we base our analysis on a survey of firms across six different sectors of the Norwegian economy: manufacturing; construction; wholesale and retail trade; accommodation and food services; transport, storage, information and communications; and other services. A random sample of firms with more than 10 employees, located in the five largest urban areas of Norway (Oslo, Bergen, Stavanger, Trondheim, and Kristiansand) and operating in any sector of the economy, was drawn from the Norwegian Register of Business Enterprises, where all firms are required to register. More than 5800 firms were approached, and with a response rate of 27.2 percent, we reached a sample of 1604 firms. The division of the firms sampled into sectors is as follows: 296 manufacturing firms, 258 construction firms, 276 trade and retail firms, 129 hotels and restaurants, 124 transport and communications firms, and 432 service firms[2]. Descriptive data on the sample in each industry is provided in Table 2.

[2] The sample also included 88 firms in the sectors mining and quarrying; electricity, gas, and water supplies; and financial and insurance activities. In each of these three sectors, the number of units was below 50, which was deemed too few to allow robust hypothesis tests of our model. These 88 firms were therefore excluded from further analysis.

Table 2. Descriptive data on the sample

No. of employees	**Manuf.**	**Constr.**	**Trade**	**Hotels & restaur.**	**Transp. & comm**	**Other services**
0 – 19	38.2	52.5	47.5	42.6	32.3	38.9
20 – 49	31.4	31.5	34.1	34.1	33.1	33.8
50 – 99	14.9	11.7	9.8	12.4	10.5	13.4
100 – 999	14.2	4.3	8.7	8.5	22.6	13.9
1000 or more	1.4	0.0	0.0	1.6	1.6	0.0
N	296	257	276	129	124	432

Ownership	**Manuf.**	**Constr.**	**Trade**	**Hotels & restaur.**	**Transp. & comm**	**Other services**
Fully foreign owned	7.1	1.2	20.7	3.9	13.7	10.4
Partly foreign owned	3.0	1.1	3.9	0.0	3.4	7.2
Fully Norwegian owned	89.9	97.7	75.4	96.1	83.9	82.4
N	296	258	276	129	124	432

Region	**Manuf.**	**Constr.**	**Trade**	**Hotels & restaur.**	**Transp. & comm**	**Other services**
Oslo	15.5	15.1	42.4	23.3	19.4	30.1
Bergen	28.0	31.0	22.1	22.5	32.3	20.1
Stavanger	31.1	26.4	17.0	28.7	19.4	24.3
Trondheim	17.9	21.7	12.7	18.6	18.6	21.3
Kristiansand	7.4	5.8	5.8	7.0	10.5	4.2
N	296	258	276	129	124	432

Data on innovation activities were collected through telephone interviews with the manager or CEO of each firm, conducted by the professional market research firm Synovate (later renamed Ipsos) in the spring of 2010. The questions were derived from Community Innovation Survey indicators, which were adjusted by the authors to fit the needs of the present analysis and supplemented with a range of additional questions concerning both the characteristics of the firm and of its manager or CEO.

For the dependent variables, managers were asked whether their firm had introduced any new and/or significantly improved goods or services during the preceding 3 years (*product innovation*), and also whether they had introduced any new and/or significantly improved methods or processes for production or delivery of products during the same time frame (*process innovation*). Successful innovators were asked whether any of the products were new to the market (*radical product innovation*) or only new to the firm (*incremental product innovation*), and, equivalently for process innovation, whether any of the processes were new to the industry (*radical process innovation*) or only new to the firm (*incremental process innovation*). We combine the responses to the two questions on innovation vs. no innovation and radical vs. incremental innovation into two ordinal variables, one for product innovation and another for process innovation, each with the three categories ‘no innovation’, ‘incremental innovation’ and ‘radical innovation’.

Table 3 shows the distribution of responses to these four questions in each of the six sectors included in the analysis. The manufacturing sector has the highest share of innovative firms, with 64 percent reporting product innovation and 63 percent reporting process innovation. It also has the highest share of firms – 44 percent – reporting radical product innovation. For product innovation, it is followed by trade/retail and other services, both overall and for radical innovation. The ‘other services’ sector does even better for process innovation, having the second highest share of innovative firms – 57 percent – and the highest share of firms reporting radical process innovation – 27 percent. At the other end of the scale, only 28 percent of construction firms report any form of product innovation, which is by far the lowest share. For radical product innovation, the transport/storage/information/communications sector stands out with only 2.6 percent of firms registered in this category. For process innovation, it is the hotel/restaurants sector that performs worst, with only 4.7 percent of firms indicating radical process innovation for the reporting period, ahead of trade/retail with 10.1 percent.

Table 3. Percent of firms reporting incremental and radical innovation, by sector

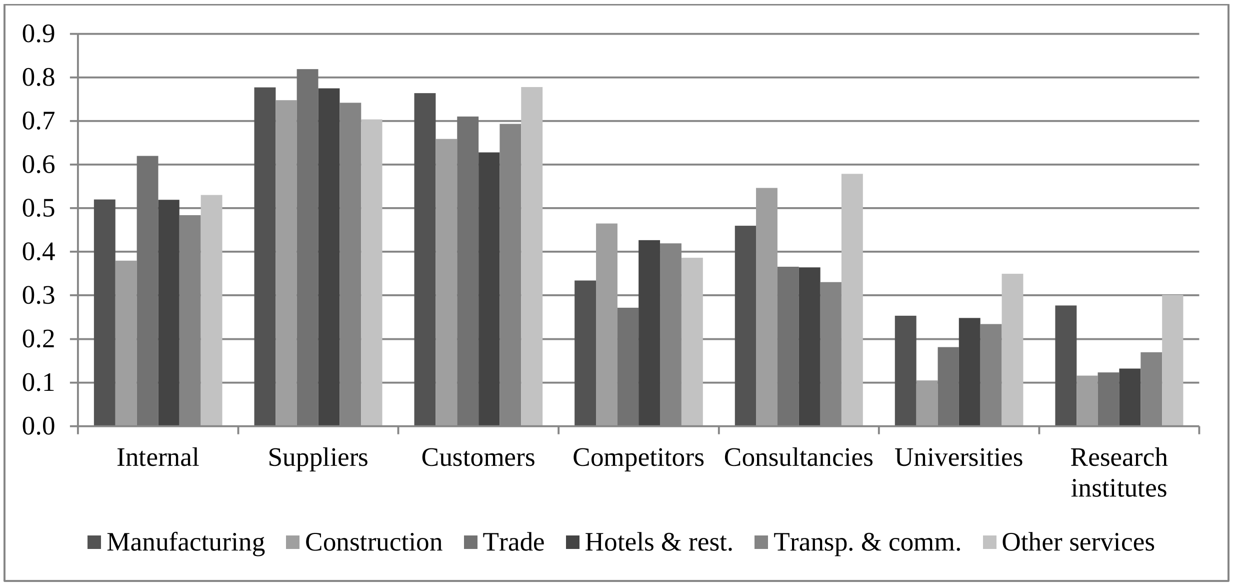
	Manuf.	**Constr.**	**Trade**	**Hotels & restaur.**	**Transp. & comm**	**Other services**
Product innovation						
No innovation	35.8 (2.8)	71.7 (2.8)	39.1 (2.9)	55.8 (4.4)	49.2 (4.5)	40.7 (2.4)
Incremental innovation	21.3 (2.4)	16.3 (2.3)	24.6 (2.6)	25.6 (3.9)	24.2 (3.9)	24.5 (2.1)
Radical innovation	43.9 (2.9)	12.0 (2.0)	36.2 (2.9)	18.6 (3.4)	2.6 (4.0)	34.7 (2.3)
Process innovation						
No innovation	37.5 (2.8)	62.4 (3.0)	65.2 (2.9)	62.8 (4.3)	63.7 (4.3)	43.5 (2.4)
Incremental innovation	39.2 (2.8)	20.9 (2.5)	24.6 (2.6)	32.6 (4.1)	20.2 (3.6)	29.6 (2.2)
Radical innovation	23.3 (2.4)	16.7 (2.3)	10.1 (1.8)	4.7 (1.9)	16.1 (3.3)	26.9 (2.1)
N	296	258	276	129	124	432

The top number in each cell denotes the percentage share, with the standard error listed below in parentheses

In order to examine the impact of collaboration with external agents on firms' potential for innovation, managers were asked whether the firm had collaborated with any of seven different types of partners, representing either in-house collaboration (other units in the conglomerate), DUI mode interaction (suppliers, customers, and competitors), and STI mode exchanges (consultancies, universities, and/or research institutes) during the preceding three years. Figure 1 shows the distribution of responses to this question for each sector. For DUI type collaboration, there is not much difference between the sectors. The share of firms that collaborate with suppliers varies from 70 percent in other services to 82 percent in trade/retail, whereas the share of firms that collaborate with customers varies from 63 percent of hotels/restaurants to 78 percent in other services. There is more variation in the level of cooperation between competitors, with only 27 percent of trade/retail firms participating in such partnerships, compared to 47 percent of construction firms. The differences are also higher for STI type collaboration. Firms in 'other services' collaborate most frequently with STI partners, a pattern that holds for all three types of partners. 58 percent of firms in other services collaborate with consultancies, 35 percent with universities, and 30 percent with research institutes. STI collaboration is also quite common among manufacturing firms, with 25 percent collaborating with universities and 28 percent with research institutes. At the other end of the scale, construction firms collaborate least frequently with universities (only 10 percent of them do so) and with research institutes (12 percent), although a high share – 55 percent – of them collaborate with consultancies. Finally, in-house collaboration between different plants is most common in retail trade and least common in construction, with levels of in-house interaction being relatively similar across the remaining industries.

It is also worth noting that DUI type interaction –in particular, with customers and suppliers – is by far the most common type of interaction. This is followed by in-house exchanges, while the more formal STI type of interaction is the least frequent, especially with universities and research centres.

Figure 1: Proportion of firms that collaborate with outside agents, by sector



3.1 Model specification

In order to test whether innovation in firms in different sectors is sustained by different types of interaction, we conduct a series of generalised ordinal regression analyses (Williams 2006), examining how collaboration with different types of partners – specifically with scientific and research communities and with other firms – affect firms' ability to innovate. We pay particular attention to whether these impacts vary across sectors with diverse knowledge bases and core activities. The analytical model used to test the main hypothesis adopts the following form:

$$\text{logit}[\Pr(\textit{Innovation}_i > j)] = \alpha_j + \beta_j\, \textit{Partners}_i + \gamma_j\, \textit{Controls}_i + \varepsilon_i,\ j = \text{incremental, radical}$$

where the dependent variable is measured in terms of the probability of firm *i* belonging to the *j*th category or higher on the trichotomous measure of innovation, rather than to any lower-order categories. We fit two different models – one for product innovation and another for process innovation – for each of the six sectors: a total of 12 regression analyses. The innovation outcome is hypothesised to depend on the firm's values on two different vectors: First, a vector of the partners (*Partners*) with which the firm has collaborated during the same time frame, estimated through a set of seven dichotomous variables indicating whether the firm has interacted with a partner of the relevant type. Second, a vector of controls (*Controls*) which may affect both the firm's use of partners and its innovation outcome, the contents of which are further specified below. In each case, the slope coefficients are allowed to depend on the category *j* of interest, i.e. on whether the model estimates the probability of incremental or radical innovation over no innovation, or the probability of radical innovation over incremental or no innovation. However, for each individual parameter, we test the hypothesis that $\beta_{incremental} = \beta_{radical}$ and constrain β to be the same[3] if we fail to reject this hypothesis at P=0.05. In such cases, the model simplifies to:

$$\text{logit}[\Pr(\textit{Innovation}_i > j)] = \alpha_j + \beta\ \textit{Partners}_i + \gamma\ \textit{Controls}_i + \varepsilon_i,\ j = \text{incremental, radical}$$

The model also includes two intercepts α_j, one for each of the *j* categories, and an idiosyncratic error ε.

We apply a set of six different control variables, which concern the characteristics of the firms and of their managers. Regarding the characteristics of the firm, we first control for the size of the firm, measured in terms of its number of employees, to which we apply a base-e logarithmic transformation due to the skewness of the variable and the expectation that the impact of

[3] The same holds for each parameter γ.

additional employees will decline with increasing size. Second, we include in the analysis the proportion of shares held by foreign owners, measured on a continuous scale from 0 to 1. Third, the region in which the firm is located is included in the analysis, measured by a set of dummy variables representing the five different city regions, as region-specific characteristics may affect the probability of innovation in a given firm.

Concerning the characteristics of the manager, we first look at his/her level of education by measuring the highest level of education completed by the manager in number of years beyond compulsory schooling. We also control for the manager's age and personal network in other firms. The latter is measured in terms of the number of directorships held on boards of other firms and log transformed for the reasons stated above for company size.

4. Results

Table 4 shows the results of the generalised ordinal regression analyses for product innovation as the dependent variable. If $\beta_{incremental} = \beta_{radical}$ for an individual parameter in the analysis of a specific sector, the joint coefficient for both incremental and radical innovation is shown in the row for $\text{Variable}_{incremental}$. Furthermore, if $\beta_{incremental} = \beta_{radical}$ for all sectors, only one row is listed for the variable, showing the joint coefficient.

4.1. Product innovation

Table 4. Generalised ordinal regression analysis of product innovation

	Manufact.	Construct.	Trade	Hotels & restaur.	Transport & comms.	Other services
Partner types						
Within the	0.11	0.27	0.37	0.22	0.83*	0.26
conglomerate	(0.25)	(0.32)	(0.28)	(0.41)	(0.48)	(0.20)
Suppliers$_{incremental}$	0.16	1.04**	-0.30	1.52**	0.09	0.57**
	(0.30)	(0.48)	(0.34)	(0.64)	(0.59)	(0.23)
Suppliers$_{radical}$		-1.03		-0.41		
		(0.67)		(0.82)		
Customers$_{incremental}$	0.66**	-0.01	0.39	-0.94*	-0.02	0.94***
	(0.30)	(0.38)	(0.28)	(0.51)	(0.46)	(0.26)
Customers$_{radical}$				0.62		
				(0.64)		
Competitors$_{increm.}$	0.01	-0.29	-0.37	-0.32	-0.91*	-0.52***
	(0.27)	(0.34)	(0.32)	(0.44)	(0.51)	(0.20)
Competitors$_{radical}$			-1.41***		0.41	
			(0.37)		(0.55)	
Consultancies$_{increm.}$	0.30	-0.36	-0.35	0.71	2.28***	-0.03
	(0.25)	(0.36)	(0.30)	(0.44)	(0.70)	(0.20)
Consultancies$_{radical}$		1.30**	0.40		0.56	
		(0.58)	(0.30)		(0.57)	
Universities	0.88***	1.26**	0.89**	-0.14	0.47	0.15
	(0.32)	(0.53)	(0.37)	(0.49)	(0.54)	(0.25)
Research institutes	0.16	0.99**	-0.14	0.54	-0.53	0.08
	(0.30)	(0.47)	(0.42)	(0.63)	(0.74)	(0.26)
Control variables						
Education$_{incremental}$	0.03	0.03	0.02	-0.29***	-0.09	0.03
	(0.05)	(0.06)	(0.05)	(0.10)	(0.08)	(0.05)
Education$_{radical}$				-0.04		
				(0.11)		
Manager's age	-0.01	-0.01	-0.01	-0.01	-0.04*	0.00
	(0.01)	(0.02)	(0.01)	(0.02)	(0.02)	(0.01)
Company dir.ships	0.07	-0.27	0.09	0.69*	0.50*	0.27**
	(0.18)	(0.21)	(0.17)	(0.36)	(0.29)	(0.14)
Ln employees	0.18	0.41**	0.33**	0.11	-0.10	0.01
	(0.14)	(0.20)	(0.16)	(0.23)	(0.20)	(0.10)
Foreign owned$_{incr.}$	0.10	0.32	1.50***	0.18	-0.78	0.74**
	(0.50)	(1.22)	(0.45)	(1.38)	(0.88)	(0.32)
For. owned$_{radical}$			0.47		1.23	
			(0.36)		(0.86)	
Region	Contr.**	Contr.**	Contr.	Contr.**	Contr.**	Contr.
Constant$_{incremental}$	-0.18	-4.35***	-1.13	0.32	2.27	-1.44*
	(0.92)	(1.59)	(1.00)	(1.25)	(1.59)	(0.86)

Constant$_{radical}$	0.84 (0.92)	-3.31** (1.64)	-2.23** (1.01)	-1.56 (1.39)	0.14 (1.61)	-2.57** (0.86)
N	296	257	276	129	124	432
Pseudo R^2	0.08	0.16	0.13	0.15	0.21	0.06

Note: * = P < 0.10 ** = P < 0.05 *** = P < 0.01

The top number in each cell denotes the coefficient, with the standard error listed below in parentheses.

When looking at product innovation, the results indicate that the sources of innovation – proxied by partnerships with different actors – vary considerably across sectors. However, and rather unexpectedly, the types of partnerships leading to innovation are not always those predicted by the theory for firms with synthetic or analytical knowledge bases. Collaboration with STI partners has the largest impact on innovation for firms in a sector which can be firmly placed in the synthetic knowledge camp: the construction sector. In this sector, all the STI type partners – consultancies (for radical innovation), universities, and research institutes – significantly improve a firms' likelihood of introducing new products. In fact, construction is the only sector in which collaboration with research institutes significantly affects the likelihood of product innovation, whereas collaboration with universities also has a significant positive effect on innovation in the manufacturing and trade/retail sectors. In other synthetic knowledge base sectors, such as the more service-based industries – hotels/restaurants, transport/storage/information/communication, and other services – STI partners are less important for innovation. Collaboration with universities and research institutes does not significantly affect innovation in any of these sectors, whereas consultancies have a large positive effect on incremental innovation in the transport/storage/information/communication sector, but are otherwise unimportant.

It is worth noting that the construction and trade/retail sectors, where STI partners are most effective, are also where these types of partners are used the least. The proportion of firms collaborating with universities is far lower in construction than in any other industry, followed by trade/retail firms. The same ranking order applies to collaboration with research institutes, although the differences to other sectors are smaller. The main exception is that construction firms collaborate frequently with consultancies. Conversely, the 'other services' sector displays the highest level of collaboration with each of the STI partner types, but none of them significantly affect product innovation in this sector. This is perhaps a reflection of the more general idea that innovation depends on access to relatively rare or unique knowledge, whereas production factors that are ubiquitous or used by a large number of firms are unable promote firms' competitiveness as they are equally available to all or most competitors (Maskell and Malmberg, 1999; Asheim and Gertler, 2005). Diverging somewhat from this general pattern, firms in manufacturing collaborate fairly frequently with universities and research institutes, and the former partner type also significantly affects innovation in this sector.

The results are more mixed when it comes to collaboration with DUI partners. With the exception of trade/retail and transport/communications, at least one DUI partner has a significant positive effect on the probability of innovation in each of the sectors, regardless of whether we consider sectors with a synthetic or an analytical knowledge base. Suppliers have a significant positive effect in the construction, hotel/restaurant and other services sectors, although only on incremental innovation in the former two sectors. Collaboration with customers is relevant for manufacturing and other services, whereas it has a significant *negative* effect on incremental innovation for hotels and restaurants. Overall, collaboration with DUI partners is perhaps most important for firms in the ‘other services’ sector, where both suppliers and customers have a positive effect on innovation, but collaboration with some of these partners tend to be important in most sectors.

However, the effect is very different for collaboration with the final type of DUI partner: competitors. Except for manufacturing, the effect of collaboration with competitors is negative in all industries, significantly so in trade/retail (for radical innovation), transport/storage/information/communication (for incremental innovation), and other services (for both outcomes).

Finally, the effect of in-house collaboration across plants on innovation is weak across the board. It is not significant for any of the sectors considered, with the only exception of transport and communications, where the association displays a positive and mildly significant coefficient.

As for the control variables, it is worth noting that the effect of company size is mainly important in construction and trade/retail, whereas it does not significantly affect innovation in the more service-oriented sectors. Conversely, the personal networks of management in other firms are important in these sectors, whereas they do not significantly affect innovation in manufacturing, construction and trade/retail. Foreign ownership also significantly affects innovation in trade/retail (incremental) and other services. In the other four industries, location in particular city regions significantly affects innovation. This suggests a pattern where global pipelines through the presence of multinational enterprises are important for innovation in some sectors, whereas in others, firms rely more on their location in a particular regional environment.

4.2. Process innovation

Table 5 shows the results of the generalised ordinal regression analyses for process innovation as the dependent variable. In this case, we had to make an exception for one of the sectors: We fit a regular ordinal regression model for hotels/restaurants, as generalised ordinal regression could not be run for this sub-sample. The reason is that binomial logit regression analysis of radical innovation versus incremental or no innovation in this sector returns four regressors that predict either success or failure perfectly and are therefore automatically dropped from the model, leaving only 55 units available for analysis. However, the model simplifies to a regular ordinal regression model also for manufacturing and trade/retail firms – and except for a few parameters even for construction and other services.

Table 5. Generalised ordinal regression analysis of process innovation

	Manuf.	Constr.	Trade	Hotels & restaur.	Transp. & comm.	Other services
Partner types						
Within the conglomerate	-0.30 (0.25)	-0.00 (0.29)	0.24 (0.32)	0.66 (0.44)	-0.29 (0.53)	-0.00 (0.20)
Suppliers$_{incremental}$	0.56* (0.31)	1.41*** (0.42)	0.36 (0.38)	0.44 (0.58)	1.24* (0.72)	0.65*** (0.23)
Suppliers$_{radical}$		0.64 (0.48)				
Customers$_{incremental}$	0.25 (0.30)	-0.65* (0.33)	0.07 (0.31)	0.42 (0.47)	-0.70 (0.56)	0.50** (0.25)
Customers$_{radical}$					1.10 (0.83)	
Competitors	0.09 (0.26)	0.37 (0.30)	-0.86** (0.34)	-1.01** (0.48)	-0.19 (0.50)	-0.17 (0.20)
Consultancies$_{increm.}$	0.31 (0.24)	-0.38 (0.31)	0.45 (0.30)	0.89* (0.48)	1.00* (0.59)	-0.08 (0.20)

Consultancies$_{radical}$					-2.55**	
					(1.11)	
Universities$_{incr.}$	0.22	0.19	0.81**	0.58	-0.65	0.04
	(0.30)	(0.49)	(0.37)	(0.52)	(0.65)	(0.24)
Universities$_{radical}$					-3.97***	
					(1.51)	
Research inst.$_{incr.}$	0.56*	1.39***	0.29	-0.01	-0.76	0.09
	(0.30)	(0.44)	(0.41)	(0.65)	(0.92)	(0.27)
Research inst.$_{radical}$					5.84***	0.74***
					(1.87)	(0.28)
Control variables						
Education	-0.08*	0.08	-0.05	-0.12	0.15	0.06
	(0.05)	(0.06)	(0.06)	(0.10)	(0.09)	(0.05)
Manager's age$_{incr.}$	0.01	-0.00	-0.02	0.02	-0.02	0.01
	(0.01)	(0.02)	(0.01)	(0.02)	(0.03)	(0.01)
Manager age$_{radical}$					0.12**	
					(0.05)	
Dir.ships$_{incr.}$	0.10	0.46**	-0.26	0.26	-0.19	-0.07
	(0.17)	(0.19)	(0.20)	(0.37)	(0.35)	(0.13)
Dir.ships$_{radical.}$		0.05				
		(0.24)				
Ln employees$_{incr.}$	0.31**	0.13	0.52***	0.02	-0.20	0.18*
	(0.13)	(0.19)	(0.17)	(0.23)	(0.24)	(0.10)
Ln employees$_{radical}$					0.84**	
					(0.40)	
Foreign owned$_{incr.}$	0.26	-0.80	0.04	1.20	1.53*	-0.02
	(0.47)	(1.18)	(0.37)	(1.21)	(0.83)	(0.31)
For. owned$_{radical}$					-4.24***	
					(1.57)	
Region	Contr.**	Contr.	Contr.	Contr.	Contr.**	Contr.
Constant$_{incremental}$	-0.55	-2.16*	-1.84*	-0.82	0.06	-2.01**
	(0.93)	(1.22)	(1.10)	(1.32)	(1.81)	(0.83)
Constant$_{radical}$	-2.46***	-2.46**	-3.61***	3.92***	-13.06***	-3.57***
	(0.94)	(1.25)	(1.11)	(1.38)	(3.82)	(0.84)
N	296	257	276	129	124	432
Pseudo R^2	0.07	0.11	0.09	0.10	0.26	0.05

Note: * = P < 0.10 ** = P < 0.05 *** = P < 0.01

The top number in each cell denotes the coefficient, with the standard error listed below in parentheses.

The benefits of collaborating with STI partners are spread more evenly across industries for process innovation than what was the case in the analysis of product innovation above. In this case, they affect both sectors with a synthetic and with an analytical knowledge base in a similar way. In each of the six sectors, at least one STI type partner has a significant positive effect on the likelihood of product innovation. In manufacturing and construction, collaboration with research institutes significantly increases the likelihood of process innovation, while collaboration with universities has a non-significant, but still positive impact. In trade/retail, the roles are reversed: collaboration with universities significantly improves the chances of innovation, while the coefficient for research institutes is also positive, but not significant. Collaboration with consultancies is not significantly related to innovation in any of these industries, but has a positive effect for hotels and restaurants, where collaboration with universities and research institutes seems to matter less, if at all. For firms in 'other services', the coefficients for most STI partners are close to zero, but there is a significant positive effect from collaborating with research institutes on the likelihood of radical process innovation. Finally, the results for the transport/storage/information/communications sector are somewhat eccentric, in particular when it comes to radical process innovation, where the likelihood is drastically increased for firms that collaborate with research institutes, but also strongly reduced for firms that collaborate with universities and consultancies. For incremental innovation, the coefficients are not significant, except for collaboration with consultancies, which has a positive effect.

In the DUI mode, it is mainly cooperation with suppliers, rather than with customers or competitors, that is beneficial to innovation. Collaboration with suppliers has a positive effect in all six industries, significantly so in four of them: manufacturing, construction (although only for incremental innovation), transport/storage/information/communications, and other services. Collaboration with customers has a significant positive effect only in 'other services' – and a significant *negative* effect in construction. Once more, the effect of collaborating with competitors is also significantly negative in two of the industries: trade/retail and hotels/restaurants, for both incremental and radical innovation.

As in the case of product innovation, collaboration in-house is the least conducive to process innovation. Collaboration within the conglomerate does not significantly affect process or radical process innovation in any of the sectors considered.

When it comes to the control variables, company size seems to be important in a larger number of industries for process innovation than for product innovation. The coefficient is positive and significant in manufacturing, trade/retail, transport/storage/information/communications (for radical innovation only) and other services. Conversely, personal networks in other firms are less important, having a significant effect only on incremental innovation in the construction sector. Region and foreign ownership are generally also less important for process innovation. Region has a significant effect in only two of the sectors – manufacturing and transport/communications – whereas foreign ownership has a significant effect only in the latter.

5. Conclusion

In this paper, we have looked at whether the sources of innovation of firms vary according to the sector to which the firm belongs. We hypothesised that innovations in sectors with different knowledge bases – synthetic or analytical – would be linked to different types of interactions. While collaborations in sectors with an analytical knowledge base, such as manufacturing, are more likely to be driven by STI-type interactions, those relying more on synthetic knowledge bases, such as construction or retail trade, would benefit more from DUI-type interactions for innovation. In-house interaction was considered to be conducive to innovation in both types of knowledge-base.

The analysis of firm-level innovation in a large sample of Norwegian firms of more than ten employees reveals that the sources of firm product and process innovation do indeed differ significantly across sectors, but that the type of interactions driving innovation in each sector are not necessarily those predicted by the theory. First, interaction with universities and research institutes – what has been dubbed as STI interaction – is an important source of both product and process innovation, not just for sectors with an analytical knowledge base, such as manufacturing, but also for many sectors with a synthetic knowledge base, such as construction and retail firms, where innovation was expected to be driven mainly by DUI-type interactions. Even though interaction with scientific partners is significantly less common in the latter sectors, STI-type exchanges seem to be important for several types of innovation. This possibly underlines that many firms in the construction and retail sectors have an unrealised potential for innovation, which can surface through greater interaction with universities and scientists, rather than through the more traditional exchanges with clients and suppliers. In the three other service sectors examined – with the exception of interaction with consultancies, which seem to be an important driver of innovation for food and accommodation and for transport and communication firms – interaction with scientific partners does, however, not lead significantly higher levels of innovation. In fact, greater collaboration with universities and research centres does not, depending on the sectors, always necessarily result in greater innovation. For firms in ‘other services’, the sector in which links to universities and research institutes are most common, collaboration with suppliers and customers remains the most important source of both product and process innovation.

Most DUI-type interactions – fundamentally supplier and customer relations – tend to significantly affect innovation also among manufacturing and construction firms. However, other DUI-type interactions, such as exchanges with competitors, do not improve the likelihood of innovation in any industry. This type of interactions have a negative effect both in the trade and retail and in the other services sector. Frequent in-house interaction across different plants also has a much weaker impact than expected. In fact, interaction within the conglomerate rarely leads to significant innovation in the Norwegian case. However, our data does not address the impact of interaction *within* each plant, which may still be an important driver of innovation.

The contrasts between the empirical findings and the theoretical expectations provide some food for thought and potentially have implications for both research and policy on innovation. The results of the analysis indicate that interaction with universities and other scientific partners is not only important for firms in typically science-based industries that draw heavily on analytical knowledge bases. Rather, firms in industries where interaction with research communities is relatively uncommon and the knowledge base is largely synthetic, such as construction and retail, may significantly improve their potential for innovation by developing closer relations to universities. However, the results also indicate that promoting STI-interaction must not necessarily come at the expense of DUI-type interaction. In other service sector industries, it may be more important to further encourage firms to develop relations to suppliers and customers that allow the exchange of product information and more tacit knowledge. In general, the results underline the complexity of the sources of innovation across sectors and highlight that no two sectors follow the same path or rely on the same sources of innovation. Different combinations of exchanges with outside agents lead to different innovation dynamics across industries and not always what are considered to be the most common or adequate sources of innovation for a particular sector reveal themselves as the most appropriate or prone to generate new products and processes. Hence, further research is needed in order to get a deeper understanding of the potential role of how sources of innovation which have so far attracted relatively little attention in certain industries may play or may potentially play a greater role in stimulating innovation than hitherto considered.

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