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

by

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Abstract: This article examines how different types of interaction are related to the capacity of firms to innovate in different sectors. Using a sample of 1604 Norwegian firms with more than ten employees, the paper analyses how interactions within the business group, with industry partners, and with research institutions and consultancies impinge on the probability of innovation for firms in six different economic sectors – manufacturing; construction; retail; accommodation and food; transport; and professional and business services, and six sector-by-skill categories – high-skilled and low-skilled manufacturing, construction, and services. The results of ordinal regression analyses for product and process innovation show that the drivers of innovation differ widely across sectors. While exchanges internal to the firm tend to be disconnected from 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. This pattern even holds for low-skilled firms in the manufacturing and construction sectors.

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

JEL Codes: O31, O32

Interacción e innovación en distintos sectores: Resultados de las ciudades-región noruegas

Resumen: En este artículo se examinan cómo los diferentes tipos de interacciones se relacionan con la capacidad de las empresas para innovar en distintos sectores. Partiendo de una muestra de 1604 empresas noruegas de más de diez empleados, en el artículo se analizan como las interacciones dentro del grupo de empresas, con socios industriales y con instituciones de investigación y firmas consultoras influyen sobre la probabilidad de innovación en seis sectores económicos distintos – manufacturas; construcción; ventas al por menor; alojamiento y alimentación; y servicios profesionales y de negocio – así como en seis categorías de sectores, de acuerdo al grado de formación – manufactura, construcción y servicios de alto y bajo nivel de formación. Los resultados de los análisis de regresión ordinal para innovaciones de producto y de proceso ponen de manifiesto que los motores de la innovación difieren radicalmente entre sectores. Mientras que la interacción en el interior de la empresa no está particularmente ligada a la innovación independientemente del sector, los intercambios con socios en centros industriales y de investigación son importantes para la innovación en sectores, como el manufacturero, dónde tradicionalmente se puede esperar que estos intercambios den frutos, pero también en sectores considerados menos innovadores, como la construcción. Este patrón se mantiene incluso para las empresas en sectores de bajo nivel de cualificación tanto en el sector manufacturero como en la construcción.

Palabras clave: Innovación de producto, innovación de proceso, interacción, sectores industriales, empresas, Noruega.

Códigos JEL: O31, O32

1. Introduction

Cooperation and interaction have been at the heart of evolutionary economic geography (Mackinnon et al. 2009). Firms – which are the fundamental object of analysis of this strand of research – adjust and adapt to changing socioeconomic conditions. This can be achieved through two types of mechanisms: either by innovation through in-house research or, as suggested by Asheim and Gertler (2005:294), as a result of "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 internal structure, configuration, procedures, and more importantly for this article, the interaction between firms determines how individual firms evolve. Much of this interaction leading to the formation of partnerships and networks is a consequence of exchanges with sources external to the firm, such as customers, suppliers and competitors, on the one hand, and centres generating knowledge, such as universities, research centres and consultancies, on the other. The importance of internal vs. external sources of innovation and the specific influence of diverse knowledge-generating partnerships 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 different sources of innovation, even within manufacturing industries (Pavitt, 1984). Recent research has also paid attention to services, in particular knowledge-intensive business services and other highly innovative sub-sectors (e.g. Aslesen and Isaksen, 2007; Doloreux and Shearmur, 2012). 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). Yet, as Malerba (2005:380) notes, "innovation greatly differs across sectors in terms of characteristics, sources, actors involved, the boundaries of the process, and the organization of innovative activities”. Innovation in firms or sectors with varying production and market conditions and skills structures demands different approaches and different types of knowledge inputs, being the consequence of different forms of interaction across diverse types of industries. If this hypothesis is correct, variation across sectors in terms of the use of different types of partners, as well as in how closely these different types of collaboration are associated with innovation outcomes, can be expected. Hence, the understanding of how interaction affects firm adaptation and evolution remains somewhat limited.

This paper, which is part of a special issue on evolutionary economic geography, aims to contribute to fill this gap, by understanding how different forms of interaction shape the genesis of new knowledge and innovation in firms working in different sectors. 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 professional, scientific, technical and business services (hereafter professional services). Furthermore, the article distinguishes between knowledge-intensive and low-skilled firms and compare the role of interaction across the two types of firms in manufacturing, construction, and services industries. 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 shaping the probability of innovating among firms within each of these industries.[1] 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, 2013) – on what determines firm-level innovation.

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 association with innovation across the board, firm innovation relies on sector-specific combinations of interactions with scientific and industrial partners. Scientific partners prove to be closely connected with innovation not only for firms in sectors, such as manufacturing, that are traditionally deemed to benefit from interaction with universities, research institutes, and consultancy firms, but also for sectors normally regarded as less innovative and R&D intensive, such as construction. Even among low-skilled construction firms, those firms that collaborate with universities are significantly more likely to innovate. Similarly, industry-type interaction is, as expected, closely associated with innovation in a wide range of sectors, but while interaction with suppliers is important in the service sector, interaction with customers matters more for product innovation in manufacturing.

[1] This type of approach, relying on a single survey, can only identify associations and not whether these are the result of causal relationships, However, the analysis can probe whether there are differences in the association between collaboration and innovation for firms in different sectors, and, if so, whether these different levels of association conform to what would be expected, given the theoretical predictions of different drivers of innovation in the sectors. This is a necessary first step towards empirically assessing the claims made about sector differences in the literature.

The structure of the paper is as follows: The next section discusses 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. Firms frequently conduct scientific research which leads, directly or indirectly, to innovation (Bush, 1945; Maclaurin, 1953). In particular, larger firms and those with a greater capacity to invest in research and development (R&D) in-house have been deemed to be more capable of innovating than those which, due to their limited dimensions or sector, lack the same capacity to invest in R&D, making firm size one of the key factors behind 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. Hence, in order for these firms to innovate, they have to rely on a second source of innovation: interaction with outside sources, ranging from other firms which may act as suppliers or customers to scientific partners and consultancies. In particular, 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) represent a rich source of additional knowledge. The more firms interact, either formally or informally, with these scientific institutions and consultancies, the greater the chance for firms to innovate (Audretsch and Feldman, 1996; Cantwell and Iammarino, 2003; Sonn and Storper, 2008). This interaction can take on various forms, e.g. contract research, technical assistance, technology transfer, joint projects, etc., and serve different purposes. These sort of exchanges all fall in the category of 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 is related to 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). Repeated exchanges with suppliers, clients, and competitors represent a conveyor belt for the transmission of codified and tacit knowledge (Lundvall, 1992; Storper and Venables, 2004), resulting in what Jensen et al. (1997) referred to as the 'doing, using and interacting' (DUI) 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. Once more, the interaction can take on different forms, e.g. development projects, focus groups, joint ventures, strategic alliances, etc.

These three fundamental sources of innovation can then be combined with the role of government to form triple-helix type systems of innovation (Etzkowitz and Leydesdorff, 2000; Leydesdorff, 2000; Ranga and Etzkowitz, 2013), creating complex networks of knowledge exchange, with firms at the heart of these systems benefiting from a greater capacity to innovate.

The ability to utilise any 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 resort to each of the three sources of knowledge to different degrees in order to generate new ideas and product and process innovations. Of course, the definition of sectors can be done at various levels of aggregation, depending on the objectives of the analysis. Even within fairly specific sectors, the heterogeneity across sub-sectors may be great, e.g. between hardware and software producers in the IT industry, or between platform developers and specialized producers within software, which nowadays also includes software-as-a-service providers (Malerba, 2005).

This paper employs a high level of aggregation with the aim of generalising across a large number of firms. It distinguishes between manufacturing and service industries, which is one of the most fundamental divisions in the economy. Innovation in services has been the subject of increasing attention in the literature on innovation, which for many years remained focused almost exclusively on manufacturing (Gallouj and Weinstein, 1997; Miles, 2005; Chesbrough, 2011). Within services, two further distinctions are made. Firstly, according to the type of service provided, noting that there is a great deal of diversity across different service providers depending on the activities that they deliver. Secondly, according to the level of knowledge-intensity, as the service sector encompasses both high-technology and routine activities. The same can be said for manufacturing, where the same distinction is employed.

How are the drivers of innovation expected to vary across different industries? Pavitt's (1984) taxonomy remains the classic treatment of this topic. In his taxonomy, Pavitt distinguishes between sectors which are scale-intensive, science-based, and supplier-dominated. This division maps onto the distinction made above between in-house sources of innovation, scientific/STI-type interaction, and industrial/DUI-type interaction, respectively. In addition, Pavitt includes a category of specialized suppliers, which rely heavily on interaction with customers.

Pavitt's taxonomy mainly applies to manufacturing industries and services are only included within the category of supplier-dominated industries. In these industries, the sources of innovation tend to be external to the firm and are fundamentally developed by suppliers for application by the focal firm. However, other authors have discussed more thoroughly the question of how manufacturing and services industries differ in terms of the sources of innovation. Miles (2005) notes that service provision is a highly interactive activity, where the service is often customized to individual customers. This puts great emphasis on interaction with users. Customers could thus be expected to play a larger role for innovation in services than in manufacturing. On the flipside, service firms are often poorly connected to universities and other producers of scientific knowledge, as they are often less technology-intensive, although consultancies may play a greater role. Survey data tend to confirm this pattern (Tether, 2005; Tether and Tajar, 2008).

Within the service sector, Miozzo and Soete (2001) have extended the Pavitt taxonomy to classify different services into the same categories. They note that personal services (such as hotels and restaurants) and public services are supplier-dominated and mainly deliver minor process innovations. Transport and wholesale are scale-intensive services, while communications are network-intensive services, with a general reliance on in-house R&D and input from suppliers. Software and specialised business services are science-based and specialised suppliers, with close links to scientific knowledge producers and knowledge being produced within the sector.

Another key distinction involves the degree of knowledge-intensity involved. The service sector encompasses sub-sectors ranging from knowledge-intensive services and high-technology IT firms to mainly low-skilled retailers and personal service providers. A similar range can be found in manufacturing, from nanotechnology and biotechnology firms to routine industrial production of simple products. The conventional approach to analysing these differences, in policy as well as in academia, has been to classify sectors as high-tech or low-tech. However, as von Tunzelmann and Acha (2005) indicate, technology content is hard to measure and may also vary a lot across firms and national contexts within individual sectors. On this basis, they suggest placing more emphasis on the knowledge intensity of industries. This approach recognises that knowledge inputs to innovation processes may take other forms than basic or applied research and development of technologies. For instance, many service industries have low inputs of technology, but rely heavily on the application of workers' cognitive capacities to providing value-added for the customer. This is reflected in the large number of highly educated workers in these industries.

Less knowledge-intensive firms may be expected to rely more on learning by doing and using than on research and interaction with scientific partners in their innovation processes. Due to their lower absorptive capacity, collaboration with partners – in particular, science-based ones – may be expected to have a smaller effect on innovation in these firms.

3. Research design and methodology

In order to test the above assumptions and predictions, the analysis is based 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 professional 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. The final sample includes1604 firms. This response rate is similar to that of other surveys which have targeted top-level managers and included many small and medium-sized firms. For instance, Bartholomew and Smith (2006: 85) report an average response rate of 27 percent for surveys published in two leading entrepreneurship and small business journals between 1998 and 2004, with a declining trend over time. 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 professional service firms.[2] Descriptive data on the sample in each industry is provided in Table 1.

[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 the model. These 88 firms were therefore excluded from the first part of the analysis.

Table 1. Descriptive data on the sample

No. of employees	Manuf.	Constr.	Trade	Hotels & restaur.	Transp. & comm	Prof. 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	Prof. 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	Prof. 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

In order to assess the risk of non-response bias, a non-response analysis was conducted. The aim of this is to assess whether those who responded to the survey differ in any systematic way from those who did not respond (Baruch and Holtom, 2008: 1155). This typically involves as the first step to examine whether there are any systematic differences between the respondents and non-respondents on variables where the value is known for the entire population. In the database, the variables that satisfy this criterion are the location, size and industry of each firm. By design, the sample overrepresents firms in the four smaller city-regions and underrepresents firms in Oslo and the sample will thus not be representative of the population in terms of location. As regions have different industry structures and size profiles, the sample cannot be compared directly with the national population for the other two variables. Instead, the composition of the sample must be compared with the five regional sampling populations, i.e. the share of firms with more than 10 employees belonging to different industries and size bands within each region.

Table 2 shows the share of firms in the sample compared to the sampling population within each region by sector and firm size, which is helpful in assessing the risk of non-response bias. As the table shows, the sample is broadly representative of the population in terms of sector, with some overrepresentation of manufacturing and professional services firms, and an underrepresentation of hotels and restaurants. Consequently, the survey is likely to be somewhat more representative of the population in the former sectors, and somewhat less representative in the latter. Larger firms are also overrepresented. Firms with more than 50 employees make up 26.1 percent of firms in the sample compared to 18.8 percent in the region-weighted sampling population.

A second step in non-response analysis is to assess the impact of non-response on the results (Rogelberg and Stanton, 2007). In this case, the share of innovative firms is higher in the sectors where the response rates are higher (manufacturing and professional services), as the analysis later in the paper will show (Table 3). Rates of collaboration also tend to be higher in these industries. The aggregate shares of innovative firms and collaborating firms may thus overestimate the shares in the overall population. A pressing question arising from this is whether the likelihood of non-response was affected mainly by the sector, or by the firms' innovation and collaboration activities. However, the latter seems less likely, as neither innovation nor collaboration was mentioned in the presentation of the survey to interviewees. Rather, the survey was presented as a study of management, value generation and business development. The differences in response rates across industries are also fairly minor compared to the differences in innovation levels and collaboration patterns.

The differences across sectors may also have been driven by underlying differences in firm size, which seems to have a larger impact on response rate. In this case, the impact of non-response is lower, as firm size only has a significant impact on innovation in a few industries, as the regression analyses later in the paper will show. The non-response bias on this variable should therefore not have a major impact on the results. Size is furthermore controlled for in the final analysis to further reduce the risk of bias.

A final step in non-response analysis is to assess the reasons for non-response. In this case, the majority of non-responding firms – 2366 firms – could not be contacted by the interviewers. This group consists completely of passive non-respondents, reducing the risk of bias (Rogelberg and Stanton, 2007). Difficulty in contacting firms could partly account for the lower response among smaller firms, who have smaller administrative capacity and may be more likely to have contact details that are not up-to-date[3]. Another 1917 firms refused to participate in the survey, making

[3] Unfortunately, no data on the sector and size of firms that refused compared to those who could not be contacted are available.

for a response rate of 45.6 percent among firms that were actually contacted by the interviewers. This group includes both passive (e.g. those who did not have time) and active non-respondents, and thus carries a greater risk of bias. As discussed above, the survey was not introduced as a survey of innovation to avoid generating active non-response among non-innovative firms. The relatively small differences between innovative and less innovative sectors also does not appear to suggest that this has been the case.

Table 2. Share of the sampling population included in sample, by sector and size

Region	**Manuf.**	**Constr.**	**Trade**	**Hotels & restaur.**	**Transp. & comm**	**Prof. services**	**Total**
Oslo	9.5 %	5.8 %	10.4 %	6.3 %	6.1 %	8.6 %	8.2 %
Bergen	37.6 %	31.1 %	36.7 %	23.2 %	36.7 %	30.9 %	33.1 %
Stavanger	33.3 %	29.8 %	31.3 %	26.8 %	26.7 %	35.8 %	31.2 %
Trondheim	39.0 %	31.8 %	32.1 %	18.3 %	31.5 %	39.3 %	33.2 %
Kristiansand	22.0 %	13.9 %	23.2 %	17.3 %	26.5 %	25.0 %	21.3 %
Total	24.3 %	17.8 %	17.0 %	14.0 %	17.4 %	18.1 %	18.3 %

Region	**< 24 empl.**	**25 – 49 empl.**	**> 50 empl.**	**Total**
Oslo	7.5 %	8.2 %	10.1 %	8.2 %
Bergen	29.7 %	33.2 %	46.0 %	33.1 %
Stavanger	26.5 %	32.1 %	43.7 %	31.2 %
Trondheim	27.4 %	34.6 %	54.2 %	33.2 %
Kristiansand	17.3 %	25.0 %	30.8 %	21.3 %
Total	16.2 %	19.1 %	23.6 %	18.3 %

A further distinction is made between high-skilled and low-skilled firms, employing the education level of the firm's manager as a proxy. The firms with university-educated managers are classified as high-skilled and firms with non-university-educated managers as low-skilled. This is admittedly an imperfect proxy, as there will necessarily be several low-skilled firms with educated managers, as well as possibly some high-skilled firms with non-educated managers.

However, as a general pattern, it is reasonable to expect university-educated managers to be more prevalent in high-skilled firms. Despite large firms being overrepresented, the majority of the firms included in the sample remain fairly small: the median size is 22 employees. Most firms below this size will not have a professional (e.g. business school educated) manager, but rather be run by an entrepreneur with a background in the field in which the business specializes (e.g. a plumber running a plumbing firm, or a lawyer running a law firm). In this context, the education level of the manager can be expected to reasonably reflect whether or not the firm operates in a sector where university education is common or required.

In order to achieve a reasonable sample size, and to simplify comparison, the firms are reclassified when employing this distinction. In this analysis, firms are therefore divided into 2x3 categories, depending on their manager's education level and their inclusion in the three broad categories manufacturing (now also including mining), construction[4], and services (trade, hotels/restaurants, transport/communications, financial services, and professional services). The firms are classified either as low-skilled manufacturing (94 firms), high-skilled manufacturing (233 firms), low-skilled construction (122 firms), high-skilled construction (136 firms), low-skilled services (245 firms), or as high-skilled services firms (762 firms).

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

[4] Construction is a service industry, but its innovation processes and activities are often quite different from other industries (Reichstein et al. 2005), and it is therefore often treated separately in industrial classifications (e.g. in the EU's Structural Business Statistics, which uses three categories: Industry, Construction, and Distributive Trades and Services).

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*). The responses to the two questions on innovation vs. no innovation and radical vs. incremental innovation are combined 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. In line with earlier findings of lower levels of innovation in services (Miles, 2005; Tether and Tajar, 2008), the manufacturing sector has the highest share of innovative firms for both product and process innovation, as well as for radical product innovation. However, the professional services sector has the highest share of firms reporting radical process innovation, which is also in line with expectations of high levels of innovation in this sector, particularly in terms of processes (Aslesen and Isaksen, 2007; Doloreux and Shearmur, 2012). There is more variety at the other end of the scale, with construction firms reporting the lowest level of product innovation, while transport/storage/information/communications has the lowest share of radical product innovation. For process innovation, it is the hotel/restaurants sector that performs worst. Hence, physical services tend to be, as expected, less innovative, although types of innovation vary across different physical services. Distinguishing by skill structure, high-skilled firms display higher levels of both product and process innovation, as well as of radical innovation, than low-skilled firms in the same sector, which is also as expected. Furthermore, manufacturing firms display higher levels of all types of innovation than services and construction firms of the same skill level.

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

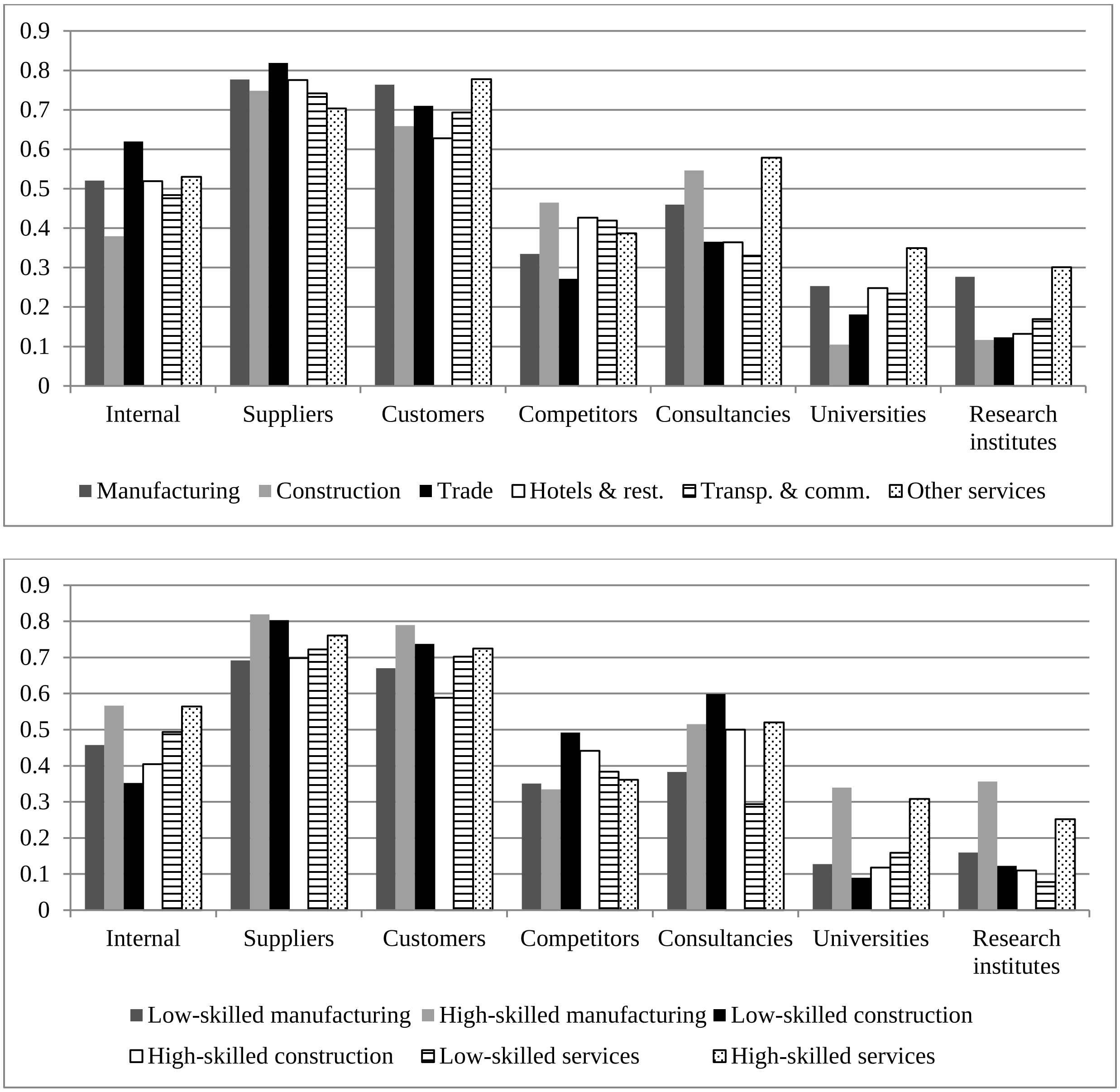
	Manuf.	**Constr.**	**Trade**	**Hotels & restaur.**	**Transp. & comm**	**Prof. services**
Product innovation						
No innovation	35.8	71.7	39.1	55.8	49.2	40.7
Incremental innovation	21.3	16.3	24.6	25.6	24.2	24.5
Radical innovation	43.9	12.0	36.2	18.6	2.6	34.7
Process innovation						
No innovation	37.5	62.4	65.2	62.8	63.7	43.5
Incremental innovation	39.2	20.9	24.6	32.6	20.2	29.6
Radical innovation	23.3	16.7	10.1	4.7	16.1	26.9
N	296	258	276	129	124	432

	Low-skill manuf.	**High-skill manuf.**	**Low-skill constr.**	**High-skill constr.**	**Low-skill services**	**High-skill services**
Product innovation						
No innovation	47.9	33.5	73.8	69.9	46.5	41.6
Incremental innovation	17.0	20.6	16.4	16.2	24.9	26.1
Radical innovation	35.1	45.9	9.8	14.0	28.6	32.3
Process innovation						
No innovation	40.4	38.6	65.6	59.6	63.7	52.5
Incremental innovation	37.2	36.9	22.1	19.9	26.5	27.6
Radical innovation	22.3	24.5	12.3	20.6	9.8	20.0
N	94	233	122	136	245	762

In order to examine the relationship between collaboration with external agents and 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), or 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 and customers is high across all industries. In manufacturing and to some extent in services, collaboration levels tend to be higher among high-skilled firms, while the situation is reversed in construction. There is more variation in the level of cooperation between competitors (with low-skilled firms tending to collaborate more), as well as for STI type collaboration. In the latter case, collaboration is particularly common in professional services for all three types of partners, and also quite common among manufacturing firms, while construction firms collaborate least frequently with universities and research institutes, although a high share – 55 percent – of them collaborate with consultancies. This conforms to expectations of more science-based innovation approaches in manufacturing and professional services. In manufacturing and services, there is also a sharp difference between high-skilled and low-skilled firms in STI collaboration levels. However, the difference is much smaller and not significant in construction. In-house collaboration between different plants is most common in retail trade and least common in construction. It is also more common among high-skilled firms.

It is also worth noting that DUI type interaction – in particular, with customers and suppliers – is by far the most common type of interaction in all industries. 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 associated with different types of interaction, a series of ordinal regression analyses are conducted, examining how collaboration with different types of partners – specifically with scientific and research communities and with other firms – is connected to a firm's ability to innovate. Particular attention is paid 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:

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

j = 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. Two different models are fitted – one for product innovation and another for process innovation – for each of the six sectors, as well as for each sector-by-skill category: a total of 24 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. The model also includes two intercepts α_j, one for each of the *j* categories,[5] and an idiosyncratic error ε.

[5] The model was also run using a generalised ordinal specification (Williams 2006), in which the slope coefficients β_j and γ_j were allowed to depend on the category *j* of interest if the hypothesis that $\beta_{incremental} = \beta_{radical}$ at p=0.05 is

A set of six different control variables are applied. These concern the characteristics of the firms and of their managers. Regarding the characteristics of the firm, the paper first controls for the size of the firm, measured in terms of its number of employees, to which a base-e logarithmic transformation is applied, due to the skewness of the variable and the expectation that the impact of additional employees will decline with increasing size. Second, the proportion of shares held by foreign owners is included in the analysis, 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, the paper first looks at his/her level of education by measuring the highest level of education completed by the manager in number of years beyond compulsory schooling[6]. The manager's age and personal network in other firms is also controlled for. 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

rejected. For most coefficients, the hypothesis could not be rejected and the model simplified to an ordinal regression. In the cases where there were differences, the results were compatible with the findings from the ordinal regression, with somewhat higher explanatory power due to the less parsimonious model.

[6] In the analyses by sector-by-skill category, the education variable is used to define the different categories and is therefore not used as a control variable in the model.

Table 4 shows the results of the generalised ordinal regression analyses for product innovation as the dependent variable.

Table 4. Ordinal regression analysis of product innovation, by sector

	Manufact.	Construct.	Trade	Hotels & restaur.	Transport & comms.	Prof. services
Partner types						
Within the conglomerate	0.11 (0.25)	0.27 (0.32)	0.39 (0.27)	0.30 (0.40)	0.55 (0.43)	0.26 (0.20)
Suppliers	0.16 (0.30)	0.74 (0.46)	-0.34 (0.33)	0.79 (0.56)	0.38 (0.55)	0.57** (0.23)
Customers	0.66** (0.30)	-0.01 (0.38)	0.39 (0.28)	-0.32 (0.43)	-0.11 (0.43)	0.94*** (0.26)
Competitors	0.01 (0.27)	-0.32 (0.33)	-0.83*** (0.29)	-0.39 (0.43)	-0.39 (0.42)	-0.52*** (0.20)
Consultancies.	0.30 (0.25)	-0.06 (0.35)	-0.04 (0.27)	0.63 (0.43)	1.11** (0.47)	-0.03 (0.20)
Universities	0.88*** (0.32)	1.02** (0.51)	0.90** (0.37)	-0.05 (0.49)	0.09 (0.50)	0.15 (0.25)
Research institutes	0.16 (0.30)	1.09** (0.46)	-0.12 (0.41)	0.73 (0.62)	-0.13 (0.66)	0.08 (0.26)
Control variables						
Education	0.03 (0.05)	0.04 (0.06)	0.02 (0.05)	-0.19** (0.09)	-0.10 (0.08)	0.03 (0.05)
Manager's age	-0.01 (0.01)	-0.01 (0.02)	-0.00 (0.01)	-0.01 (0.02)	-0.04** (0.02)	0.00 (0.01)
Company dir.ships	0.07 (0.18)	-0.28 (0.21)	0.08 (0.17)	0.68** (0.35)	0.54** (0.26)	0.27** (0.14)
Ln employees	0.18 (0.14)	0.39** (0.20)	0.31** (0.16)	0.07 (0.22)	-0.07 (0.19)	0.01 (0.10)
Foreign owned	0.10 (0.50)	0.35 (1.21)	0.76** (0.33)	-0.23 (1.25)	0.49 (0.70)	0.74** (0.32)
Region	Contr.**	Contr.*	Contr.	Contr.	Contr.	Contr.
$Constant_{incremental}$	-0.18 (0.92)	3.73*** (1.50)	0.94 (0.99)	-0.31 (1.21)	-2.07 (1.46)	1.44* (0.86)
$Constant_{radical}$	0.84 (0.92)	4.96** (1.51)	2.11** (0.99)	1.08 (1.21)	-0.83 (1.46)	2.57** (0.86)
N	296	257	276	129	124	432
Pseudo R^2	0.08	0.11	0.09	0.08	0.10	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.

4.1. Product innovation

The results indicate that the sources of product innovation – proxied by partnerships with different actors – vary considerably across sectors. However, the types of partnerships more closely related to innovation are not always as expected. Collaboration with STI partners has the largest impact on innovation for firms in a mainly low-tech sector: construction. In this sector, the most basic R&D partners – universities and research institutes – are associated with a significantly higher likelihood of introducing new products. It is worth noting that this sector is also where these types of partners are used the least. STI partners tend to be less important for innovation in the service industries, in line with findings in other surveys (Miles, 2005; Tether and Tajar, 2008). This even holds for the professional services sector, which displays the highest level of collaboration with each of the STI partner types, but in which none of them are significantly connected to product innovation.

The results are more mixed when it comes to collaboration with DUI partners. Collaboration with DUI partners seems to be most important for firms in the professional services sector, where both suppliers and customers are positively associated with innovation. Customers also have a significant positive effect in manufacturing. Conversely, the relationship with collaboration with competitors is negative in most industries, significantly so in trade/retail and professional services. Finally, the association between innovation and in-house collaboration across plants is weak across the board.

As for the control variables, it is worth noting that the effect of company size is mainly important in construction and trade/retail, which appear to be more scale-intensive than the other serviceoriented sectors, partly confirming Miozzo and Soete's (2001) classification. Foreign ownership is also significantly related to innovation in trade/retail and professional services. In manufacturing and construction, 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.

Table 5. Ordinal regression analysis of product innovation, by sector-by-skill category

	Low-skilled manufact.	High-skilled manufact.	Low-skilled construct	High-skilled construct	Low-skilled services	High-skilled services
Partner types						
Within the conglomerate	0.22	0.15	0.96*	-0.17	0.53*	0.25*
	(0.53)	(0.29)	(0.52)	(0.46)	(0.28)	(0.15)
Suppliers	0.10	0.22	0.47	0.69	0.60*	0.30*
	(0.58)	(0.36)	(0.75)	(0.61)	(0.32)	(0.18)
Customers	0.88	0.70**	0.29	-0.07	0.06	0.61***
	(0.54)	(0.35)	(0.66)	(0.52)	(0.31)	(0.17)
Competitors	0.02	0.05	-1.05**	0.15	-0.74***	-0.56***
	(0.53)	(0.30)	(0.53)	(0.47)	(0.29)	(0.15)
Consultancies	0.63	-0.13	-0.41	0.44	0.36	0.22
	(0.50)	(0.28)	(0.53)	(0.50)	(0.31)	(0.15)
Universities	1.69**	0.55*	1.29*	0.39	-0.39	0.41**
	(0.76)	(0.33)	(0.74)	(0.80)	(0.42)	(0.18)
Research institutes	0.01	0.30	0.18	2.29***	0.81	0.01
	(0.68)	(0.32)	(0.68)	(0.76)	(0.55)	(0.19)
Control variables						
Manager's age	-0.03	-0.02	-0.00	-0.02	-0.03**	0.01
	(0.02)	(0.02)	(0.03)	(0.03)	(0.01)	(0.01)
Company dir.ships	-0.31	0.17	-0.09	-0.48	0.62***	0.18*
	(0.38)	(0.20)	(0.35)	(0.32)	(0.20)	(0.10)
Ln employees	0.45	0.18	0.19	0.61**	0.18	0.05
	(0.31)	(0.13)	(0.33)	(0.29)	(0.17)	(0.07)
Foreign owned	0.05	-0.22	Dropped[a]	0.32	0.94*	0.81***
	(1.04)	(0.44)		(1.30)	(0.53)	(0.21)
Region	Contr.**	Contr.	Contr.	Contr.*	Contr.	Contr.
$Constant_{incremental}$	-0.52	-0.39	2.78	4.17*	-0.17	0.35**
	(1.57)	(1.08)	(2.09)	(2.36)	(0.98)	(0.53)
$Constant_{radical}$	0.38	0.56	4.18*	5.43**	-0.42	2.54***
	(1.57)	(1.08)	(2.11)	(2.38)	(0.58)	(0.54)
N	94	233	122	135	245	762
Pseudo R^2	0.14	0.06	0.13	0.18	0.08	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.

[a] Only two firms were partly foreign-owned in this category, and none were fully foreign-owned. This created limited variability in the variable, which was therefore dropped from analysis.

Table 5 shows the same analysis for the six sector-by-skill categories. In manufacturing, there is not a lot of difference between low-skilled and high-skilled firms in terms of which partner types are important. In both cases, universities have a significant positive association, with a stronger coefficient (but also a higher standard error) for low-skilled firms. In addition, cooperation with customers has a significant positive connection for high-skilled firms, but not for low-skilled firms, although the coefficient is equally strong for the latter category, which comprises fewer firms. In construction, in-house collaboration has a significant positive association for low-skilled firms, while cooperation with competitors has a significant negative association. In this sector, STI collaboration is also important for both low-skilled and high-skilled firms, with low-skilled firms seeming to benefit from interactions with universities, while high-skilled ones derive a particular premium from collaborating with research institutes. Again, this is somewhat at odds with the common perception of these firms as having low absorptive capacity (Reichstein et al., 2005).

External interaction tends to be most important in the services sector for both high-skilled and low-skilled firms, but the types of partners that matter differ depending on skill level. Innovation in low-skilled firms tend to be more closely related to collaboration within the conglomerate and with suppliers, although both of these partner types are also positively associated with innovation for high-skilled firms. However, the most important partners for high-skilled service firms tend to be customers and universities, neither of which makes any difference for innovation in low-skilled firms. This conforms to expectations of high-skilled firms having a more science-based approach to innovation. Finally, cooperation with competitors is significantly negatively connected to innovation for both types of service firms.

4.2. Process innovation

Table 6 shows the results of the ordinal regression analyses for process innovation as the dependent variable.

Table 6. Ordinal regression analysis of process innovation, by sector

	Manuf.	Constr.	Trade	Hotels & restaur.	Transp. & comm.	Prof. services
Partner types						
Within the	-0.30	0.01	0.24	0.66	0.10	0.00
conglomerate	(0.25)	(0.29)	(0.32)	(0.44)	(0.47)	(0.20)
Suppliers	0.56*	1.26***	0.36	0.44	0.70	0.66***
	(0.31)	(0.42)	(0.38)	(0.58)	(0.62)	(0.23)
Customers	0.25	-0.63*	0.07	0.42	-0.41	0.48*
	(0.30)	(0.33)	(0.31)	(0.47)	(0.47)	(0.25)
Competitors	0.09	0.35	-0.86**	-1.01**	-0.22	-0.17
	(0.26)	(0.30)	(0.34)	(0.48)	(0.46)	(0.20)
Consultancies	0.31	-0.36	0.45	0.89*	0.23	-0.10
	(0.24)	(0.31)	(0.30)	(0.48)	(0.46)	(0.20)
Universities	0.22	0.18	0.81**	0.58	-0.69	0.04
	(0.30)	(0.49)	(0.37)	(0.52)	(0.55)	(0.24)
Research inst.	0.56*	1.37***	0.29	-0.01	0.83	0.39
	(0.30)	(0.44)	(0.41)	(0.65)	(0.73)	(0.26)
Control variables						
Education	-0.08*	0.14	-0.05	-0.12	0.12	0.06
	(0.05)	(0.19)	(0.06)	(0.10)	(0.08)	(0.05)
Manager's age	0.01	-0.00	-0.02	0.02	-0.01	0.01
	(0.01)	(0.02)	(0.01)	(0.02)	(0.02)	(0.01)
Dir.ships	0.10	0.35**	-0.26	0.26	-0.24	-0.07
	(0.17)	(0.18)	(0.20)	(0.37)	(0.29)	(0.13)
Ln employees	0.31**	0.14	0.52***	0.02	-0.04	0.17*
	(0.13)	(0.19)	(0.17)	(0.23)	(0.20)	(0.10)
Foreign owned	0.26	-0.85	0.04	1.20	0.32	-0.05
	(0.47)	(1.17)	(0.37)	(1.21)	(0.69)	(0.31)
Region	Contr.**	Contr.	Contr.	Contr.	Contr.	Contr.
$Constant_{incremental}$	0.55	2.11*	1.84*	1.13	0.75	2.10**
	(0.93)	(1.21)	(1.10)	(1.32)	(1.57)	(0.83)
$Constant_{radical}$	2.45***	3.37**	3.61***	3.92***	-1.95	-3.45***
	(0.94)	(1.22)	(1.12)	(1.38)	(1.58)	(0.84)
N	296	257	276	129	124	432
Pseudo R^2	0.07	0.09	0.09	0.10	0.07	0.04

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 four of the sectors, at least one STI type partner is significantly positively associated with the likelihood of process innovation. In the DUI mode, it is mainly cooperation with suppliers, rather than with customers or competitors, that is beneficial to process innovation. Collaboration with suppliers has a positive sign in all six industries, significantly so in three of them. Collaboration with customers has a significant positive sign only in professional services – and a significant *negative* association in construction. Once more, collaborating with competitors is also significantly negatively connected to innovation in two of the industries. As in the case of product innovation, collaboration in-house is the least conducive to process innovation of the three broad sources of innovation. Collaboration within the conglomerate is not significantly related to 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. Conversely, personal networks in other firms are less important, having a significant effect only in the construction sector. Region and foreign ownership are generally also less important for process innovation. Region has a significant effect only in manufacturing, whereas foreign ownership does not have a significant effect in any of the industries.

Table 7. Ordinal regression analysis of process innovation, by sector-by-skill category

	Low-skilled manufact.	High-skilled manufact.	Low-skilled construct	High-skilled construct	Low-skilled services	High-skilled services
Partner types						
Within the conglomerate	-0.44 (0.51)	-0.48* (0.28)	0.73 (0.45)	-0.74* (0.44)	-0.05 (0.30)	0.15 (0.15)
Suppliers	0.30 (0.54)	0.79** (0.38)	0.31 (0.68)	1.87*** (0.58)	0.45 (0.35)	0.34* (0.19)
Customers	0.14 (0.52)	0.40 (0.36)	0.73 (0.60)	-1.43*** (0.47)	0.24 (0.33)	0.29* (0.18)
Competitors	0.42 (0.50)	0.12 (0.29)	0.48 (0.47)	0.30 (0.42)	-0.70** (0.31)	-0.20 (0.15)
Consultancies	0.85* (0.49)	-0.06 (0.27)	-0.87* (0.48)	0.21 (0.45)	0.63* (0.32)	0.31** (0.15)
Universities	-0.02 (0.64)	0.15 (0.32)	0.19 (0.73)	-0.35 (0.84)	0.16 (0.42)	0.25 (0.18)
Research institutes	-0.04 (0.64)	0.58* (0.32)	0.58 (0.61)	2.35*** (0.78)	0.28 (0.56)	0.48** (0.19)
Control variables						
Manager's age	0.02 (0.02)	-0.01 (0.02)	0.00 (0.03)	-0.02 (0.02)	-0.01 (0.01)	0.00 (0.01)
Company dir.ships	0.13 (0.34)	0.17 (0.19)	1.00*** (0.31)	-0.07 (0.27)	-0.33 (0.22)	0.01 (0.10)
Ln employees	0.68** (0.31)	0.21* (0.13)	-0.05 (0.34)	0.30 (0.26)	0.24 (0.18)	0.17*** (0.07)
Foreign owned	-0.32 (1.00)	0.40 (0.44)	Dropped[a]	-0.49 (1.23)	0.53 (0.56)	-0.03 (0.21)
Region	Contr.	Contr.*	Contr.	Contr.	Contr.	Contr.
$Constant_{incremental}$	2.71 (1.65)	0.44 (1.08)	2.68 (1.91)	1.03 (1.87)	1.49 (1.13)	1.91*** (0.54)
$Constant_{radical}$	4.64*** (1.70)	2.20** (1.09)	4.24** (1.93)	2.31 (1.88)	3.28*** (1.15)	3.29*** (0.55)
N	94	233	122	135	245	762
Pseudo R^2	0.10	0.06	0.12	0.16	0.06	0.04

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.

[a] Only two firms were partly foreign-owned in this category, and none were fully foreign-owned. This created limited variability in the variable, which was therefore dropped from analysis.

Table 7 shows the same analyses for the six sector-by-skill categories. The association with STI partners follow a distinct pattern across different skill levels: For research institutes, the connection is positive and significant for all high-skilled sectors, whereas the association is weaker and not significant in any of the low-skilled sectors, supporting the hypothesis that innovation is more science-based in high-skilled firms. Conversely, consultancies have a significant relationship in all the low-skilled sectors – positive in manufacturing and services, but negative in construction. Here, the association is weaker in the high-skilled sectors and only significant in services. Collaboration with universities is not significant in any of the categories.

For the DUI partners, the connection of collaboration with suppliers with innovation also tends to depend on skill level: It is significant and positive for all of the high-skilled sectors, but not significant in any of the low-skilled ones. Collaboration with customers has a significant positive association only in high-skilled services, while it has a significant negative sign in high-skilled construction. Thus, high-skilled firms appear better placed also when it comes to industrial collaboration, whereas low-skilled firms lack the absorptive capacity to exploit external knowledge inputs. Collaboration with competitors is negatively associated with innovation mainly in the service sector, significantly so for low-skilled firms. In-house collaboration also has a negative association in two of the high-skilled sectors: Manufacturing and construction.

5. Conclusion

This paper has looked at whether the sources of innovation of firms vary according to the sector to which the firm belongs. The hypothesis was that innovations would be linked to different types of interactions in services and manufacturing industries, and in knowledge-intensive and low-skilled firms. Services industries were expected to rely more on industrial interactions and have less scientific inputs than manufacturing firms, in particular in personal services, such as construction, trade and hotels/restaurants. Low-skilled firms were expected to benefit less from interaction in general due to their lower absorptive capacity, and in particular from interaction with scientific knowledge producers.

These expectations were largely confirmed when it comes to firms' use of different types of partners. Manufacturing and professional services firms tend to collaborate more with scientific knowledge producers, while other types of service firms interact mainly with industrial partners. Similarly, high-skilled firms interact more than low-skilled firms with scientific partners. While there is substantial variation across sectors in interaction with scientific partners, there is little variation when it comes to industrial partners, in particular suppliers and customers, which is high across all sectors.

While the use of partners conforms to theoretical expectations, the pattern changes when looking at the association between collaboration and innovation outcomes. The types 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 closely connected with both product and process innovation, not just in manufacturing, but also in construction and retail firms, where innovation was expected to be driven mainly by DUI-type interactions. Even low-skilled construction firms seem to benefit from interaction with universities. Even though interaction with scientific partners is significantly less common in construction and retail, 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, interaction with scientific partners is, however, not associated with 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 professional 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. However, the pattern is different for high-skilled firms in these sectors, which tend to benefit from interaction with STI partners in terms of increased likelihood of both product and process innovation.

Most DUI-type interactions – fundamentally supplier and customer relations – tend to be significantly associated with innovation also among manufacturing 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 display a negative relationship to innovation both in the trade and retail and in the professional 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, the 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 manufacturing and professional services, which tend to use these types of partners the most. Rather, firms in industries where interaction with research communities is relatively uncommon, 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 factors considered to be the most common or adequate sources of innovation for a particular sector do not always reveal themselves as the most appropriate or prone to generating 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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