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Firm Collaboration and its Impact on Product and Process Innovations

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Abstract

This paper examines the influence of different external knowledge sources used by firms in Jönköping County, Sweden, on the probability that a firm develops product innovations, process innovations, both types of innovations, or no innovation. The analysis is done by building a logit model for each of the four innovation outcomes. The external sources considered are STI (Science, Technology and Innovation) collaboration partners, and DUI (Doing, Using and Interacting) collaboration partners. An STI collaboration comprises knowledge linkages to universities and colleges, public R&D institutes, private R&D institutes, and consultancies. DUI collaborations are interactions with firms within the same corporate group, within the same industry, within the supply chain (supplier, client), and outside the supply chain (competitor). The results indicate a generally higher importance of DUI collaboration partners than of STI collaboration partners for the development of innovations. Firms that develop product innovations use a more diversified set of external sources of both DUI and STI type, with a focus on partners from the same concern and private R&D institutes. On the contrary, firms developing process innovations use a less diversified set of external sources and focus on partnerships both within the same concern and the same industry, as well as with suppliers. Regarding the spatial dimension of collaboration, intra-, extra-regional and international knowledge linkages generally matter for being innovative, where the focus lies on cooperation within the country. Overall, the regression results for the different innovation types show similarities, which imply that there is an interconnection of the development of product and process innovations.

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1 Introduction

Innovations are the driving force for economic growth, and firms' incentive to invest in innovations is to generate profits and to distinguish themselves from competitors (Schumpeter, 1934). This widely shared notion raises the question, which resources a firm needs for the successful development and implementation of an innovation, and if those resources are found among the firm's internal capabilities, or outside the firm.

The question of combining internal and external knowledge sources in the innovation process has been discussed extensively during the last decades. The literature finds much evidence for advantageous effects of firm collaboration on the development of innovations (Rosenberg, 1982; von Hippel, 1988; Lundvall, 1992; Chesbrough, 2003; Belderbos et al., 2012). Jensen et al. (2007) analyze the effect of different types of collaboration partners on the probability of firms to be innovative. They distinguish between two types of collaboration partners for firms that seek to innovate: The STI (Science, Technology and Innovation) partners, and the DUI (Doing, Using and Interacting) partners. STI collaboration partners are a source of science-based and codified knowledge. By contrast, DUI partners deliver tacit knowledge, which is based on on-the-job learning. Fitjar and Rodrígez-Pose (2013) differentiate those two types even further by clearly assigning universities, research institutes and consultancies to the STI group, whereas suppliers, customers, competitors and firms from the same conglomerate fall into the DUI group. The authors also make a distinction between product and process innovations.

This paper follows a similar line by analyzing the influence of different forms of firm collaboration on the probability that firms develop product innovations, process innovations, both types of innovations, or no innovation at all. This analysis is done on the basis of survey data about innovation and collaboration activities of 624 firms in the county of Jönköping, Sweden. The main contribution of this paper lies in the ambition to find out how the collaboration with different types of partners relates to the likelihood of firms to develop different types of innovations. The vast majority of the literature strand about the relation of firm innovation and collaboration neither offers such a differentiated look at innovation types, nor at collaboration types. A particular focus will be on the impact of DUI collaboration, which will be analyzed with regard to an organizational, cognitive and spatial proximity between partners. Moreover, the impact of the firm size will be considered, since there is a high degree of small firms in the county of Jönköping. The regression results for the different innovation outcomes indicate similarities in the magnitudes of the coefficients. However, two main implications can be derived: Small firms focus on the development of product innovations and rely on a diversified set of external knowledge sources. With increasing firm size, they tend to develop both product and process innovations, and rely less on external sources.

The paper is structured as follows. Section 2 gives an overview over the theoretical background behind the relationship of external knowledge sources and innovation. The DUI and STI collaboration partner types and their relevance as external knowledge sources for innovation processes will be highlighted in more detail, and findings of related studies will be presented. Afterwards, assumptions about the regression outcomes are formulated. Section 3 covers the description of the data used for the analysis and gives some insight about Jönköping County. Section 4 shortly describes the methodology and section 5 presents and discusses the results from the analysis. Finally, section 6 offers a conclusion and suggestions for further research.

2 Theoretical background and literature review

2.1 Innovation and external knowledge

In his work "The Theory of Economic Development", Schumpeter (1934) already points out the importance of innovations for economic growth, and the need of different knowledge sources for the innovation process. He defines innovations as new combinations of production factors, which suppress, and eventually destroy, old market structures. Schumpeter (1934) calls this process of economic renewal 'creative destruction', and stresses that it can only be achieved by the combined knowledge inputs of heterogeneous firms. He stresses that if a firm merely adopts an already existing innovation, firm heterogeneity decreases, and less new ideas are developed on the market. However, if a firm builds on the innovative knowledge of another firm and replenishes it with its own ideas, the firm heterogeneity increases and accelerates economic growth.

Still, according to Schumpeter's theory, firms are competing and trying to have a first mover advantage when developing an innovation. Consequently, they do not want to share their knowledge and new technologies right from the start. Mueller (2003) describes the early stages of the product life cycle with a Schumpeterian perspective. In the first stage, the innovation stage, a monopolist develops the innovation. If a patent protects the innovation, the firm can stay a monopolist for several years. Otherwise, imitators can immediately initiate the imitation stage. During this phase, further product improvements are achieved, due to the imitators' focus on varying their product designs compared to the initial inventor's design. Consequently, output grows and prices fall, and R&D costs are at a modest level. This phenomenon shows the importance of external knowledge in the way that the innovation process, and thus economic growth, is accelerated and broadened thanks to the contribution of different ideas of the various heterogeneous and imitating firms.

Schumpeter's conception about the importance of innovations is also reflected by Solow's (1957) growth model, in which the only factor that drives economic growth in the long run is technological progress. From the 1980s onwards, many researchers have revised the early Schumpeterian model. They suggest that market actors should intentionally cooperate with each other already in the initial innovation stage (Rosenberg, 1982; von Hippel, 1988; Lundvall, 1992). In 2003, Chesbrough introduced the term 'Open Innovation'. He updated his definition of this term in 2006 by stating that "Open Innovation is the use of purposive inflows and outflows of knowledge to accelerate internal innovation, and expand the markets for external use of innovation, respectively" (Chesbrough, 2006, p. 1). Chesbrough (2003b) says that firms have changed their innovation strategy away from only focusing on investments in internal R&D to working together with external sources. He bases this approach on the increasing competition in a globalized world, which results in the pressure on firms to produce and innovate faster, and at the same time to reduce costs for R&D (Gassmann and Enkel, 2006). "The Open Innovation paradigm can be understood as the antithesis of the traditional vertical integration model where internal research and development (R&D) activities lead to internally developed products that are then distributed by the firm" (Chesbrough, 2006, p. 1).

Gassmann and Enkel (2006) distinguish between three core processes of Open Innovation: The outside-in process, the inside-out process and the coupled process. The outside-in process describes the replenishment of a firm's internal knowledge with external knowledge from different kinds of actors. These may be partners within the supply chain, such as suppliers and clients, but also outside the supply chain, namely firms from another sector or even the same sector, and universities and other research institutes. The inside-out process instead supports the external commercialization of an innovation. With the help of licensing, new ideas are launched more quickly on the market and technologies are faster and more easily duplicated than with relying on internal exploitation only. Finally, the coupled process defines the combination of both using external knowledge and externalizing internal knowledge with the ambition to form alliances, joint ventures and innovation networks, which are based on the balance between give-and-take.

Jensen et al. (2007) contrast two modes of innovation, whose differences lie in the kind of knowledge source they are based on. These two modes relate to the outside-in process described above. The first one is the Science, Technology and Innovation (STI) mode. The second is called the Doing, Using and Interacting (DUI) mode. An STI mode innovation distinguishes itself by firms' investments in R&D, science and technology, and their interaction with knowledge producing centers. It is therefore mostly the result of a firm's cooperative work with research centers and universities. Furthermore, it can include the help of consultancies (Fitjar and Rodrígez-Pose, 2013). These types of partnerships offer a formal and codified knowledge input, which Lundvall and Johnson (1994) call 'know-what' and 'know-why'. These terms describe that not only the practice, but also the understanding of the delivered knowledge is of importance. By contrast, the DUI mode innovation refers to collaboration either within the supply chain, such as with other firms in the conglomerate, suppliers and customers, or outside the supply chain, what applies to competitors (Fitjar and Rodrígez-Pose, 2013). The purpose of a DUI type of collaboration is to address existing problems caused by the market and by the workflow within the supply chain. Solutions shall be found by repeated interactions with partners and other actors, it is therefore based on practical experiences and has a more informal and tacit nature. Lundvall and Johnson (1994) describe this learning by doing process as the know-how and know-who, where the practice rather than the understanding of the why is of importance (Nelson, 2004). There is a quite extensive body of literature available about the importance of the two collaboration types for innovation. It mainly addresses relevance to both types (von Hippel, 1976; Rothwell, 1977; Pavitt, 1984) and even finds strong evidence of the merit of using them interactively (Kline and Rosenberg, 1986; Lundvall, 1988). The nature of the DUI and STI collaboration types will be highlighted more in detail with respect to their relation to different proximity dimensions in the next section.

2.2 Proximity dimensions related to the use of external knowledge for innovations

In the context of innovation and interactive learning, Boschma (2005) distinguishes between five different dimensions of proximity, namely cognitive (sharing a common knowledge and technology base), organizational (ties within a hierarchically organized network), institutional (sharing common norms and values), social (personal relations) and geographical proximity. They can be associated to different degrees with the different kinds of collaboration considered in this paper. Concerning the four non-geographical dimensions, a closer look needs to be taken at the DUI collaboration, because of the informal and tacit nature of the involved knowledge. Since tacit knowledge is not written down, but learnt 'on the job', collaboration partners transmit it by repeated interactions with each other (Gertler, 2003). This process is facilitated by any kind of proximity between the partners. Such closeness is less relevant for the knowledge transfer of STI partners, because their information is written down and codified in a way that people with different knowledge backgrounds commonly understand it (Lundvall, 2007).

With regard to DUI collaboration, a certain degree of cognitive, organizational, institutional and social proximity is usually found between firms that share the same value chain, since they have the ambition to improve the workflow as a merit for both partners. Such proximity is less common in the case of interactions outside the supply chain, since they have a more indirect nature and are often the cause of unintentional knowledge spillovers rather than that of direct collaboration (Marshall, 1890; Jacobs, 1969; Gertler, 2003). This spillover is again often the consequence of a close cooperation of a firm with its partners within the supply chain, who diffuse information quickly around the industry, enabling competitors to absorb it after some time. Nonetheless, also intended cooperation takes place between rivals for the reason to trade ideas and, to some part, to get in ahead of a later unintended spread of one's own ideas (von Hippel, 1987). With regard to the collaboration within the same corporate group, a high level of organizational proximity can be found, thanks to the use of common codes of information, what makes the communication between the partners more efficient as opposed to outsiders (Arrow, 1974; Lundvall, 1988). In addition, a cognitive proximity is favorable for the communication and knowledge flows between firms. This closeness is facilitated by sharing similar problems and similar technologies and is therefore to a strong extent provided among firms from the same or a related sector (Boschma, 2005; Fitjar and Rodrígez-Pose, 2013).

Furthermore, spatial proximity plays a role for firms to find an appropriate collaboration partner to act as an external knowledge source for innovations. In this context, most research investigates a broader concept of knowledge diffusion, which can be intended or not. Collaboration, by nature, is intended, while knowledge spillovers rather take the form of externalities and describe an initially unintended spread of ideas (Audretsch and Feldman, 1996; Breschi and Lissoni, 2001). Still, this strand of literature gives some relevant insight, concluding that spatial clusters of economic actors provide a nourishing ground for knowledge exchange. Further, the spatial proximity of firms and knowledge producing organizations can form a knowledge network, in which resources for innovations are pooled, and the generation, transmission and absorption of knowledge is facilitated. The success of such innovation systems depends both on the single performances and on the interaction of the different entities within the system (Jaffe et al., 1993; Feldman and Audretsch, 1999; Asheim and Isaksen, 2002).

Also the concept of spatial proximity is not to the same extent relevant for the DUI and STI mode of innovation. Tracey and Clark (2003) suggest that a geographical closeness of partners is of less relevance for STI collaboration. The formal nature of knowledge producing organizations and their use of universal codes of information enables them to serve a wider range of firms with different cultural backgrounds. This broadness goes hand in hand with high costs, and firms will look out for the best and most suitable research partners, who are not necessarily located in close proximity (Bathelt et al., 2004; Laursen and Salter, 2006). Regardless of the universality aspect of STI collaboration, a prerequisite to such global linkages still is a common knowledge or organizational base between the two partners, so that the advantage of geographical proximity can be outweighed by the merits of a cognitive or organizational proximity (Nooteboom, 2000). This is in accordance with the findings of Boschma (2005), who argues that geographical proximity itself is likely to strengthen the other four proximity dimensions to the degree that they even act as substitutes to geographical closeness. The spatial dimension of proximity should therefore not be regarded in isolation, but rather in the interplay with the other dimensions.

Regarding the DUI types of collaboration in the context of spatial proximity, a higher importance than for the STI type can be identified. Since DUI collaboration is based on the sharing of similar practical problems among the partners and repeated work flows, the knowledge involved is rather tacit and requires more local and cultural understanding and face-to-face contact (Storper and Venables, 2004; Asheim and Gertler, 2005). Again, a separate look at relationships within and outside the supply chain needs to be taken. Within the supply chain, the interplay of geographical proximity with the other proximity dimensions, as described by Boschma (2005), plays a big role, in which the collaborators either attach the higher importance to spatial proximity and at the same time profit of the locally available other dimensions, or they accept the lack of regional closeness and rather put the focus on benefitting from the other proximity dimensions at more distant places. The collaboration outside the supply chain, instead, i.e. with competitors, is more geographically constrained, due to its more informal nature and the necessity of being close to the partner when the knowledge is tacit (Gertler, 2003).

As opposed to the above described merits of the different dimensions of proximity, they can also have a negative impact on innovation. Boschma (2005, p. 62) calls this problem "lock-in", which describes the detrimental effect of too much proximity and can occur in all the five dimensions. Especially the coincidence of excessive cognitive proximity in a bounded geographical space may induce repeated interaction between collaborators, which will rather not create new knowledge and decrease the probability to innovate (Rallet and Torre, 2005; Fitjar and Rodrígez-Pose, 2013).

2.3 Comparable studies

The most closely related study to the underlying paper has been conducted by Bjerke and Johansson (2014). They use the same data set and address a similar research question, with the exception that they reduce their analysis to innovative activities in general without a separate investigation of product and process innovations. Furthermore, they only cover DUI types of collaboration, and not the STI types. Nevertheless, the results can be useful for a comparison, especially with the analysis of the probability not to innovate, since this is just the opposite of being innovative, which Bjerke and Johansson use as their outcome variable. Their research identifies that both a collaboration offering organizational and cognitive proximity have a positive effect on the likelihood to innovate, in which the impact of the former is much higher than the impact of the later. Moreover, both forward and backward collaborative linkages in the supply chain matter in a positive way, the cooperation with clients slightly more than the one with suppliers. Horizontal linkages turn out to have no effect. Regarding the spatial dimension, a positive impact of extra-regional collaboration is identified. Furthermore, international knowledge linkages, as expressed by exporting activities of a firm and by being part of a multinational concern, show some relevance. Being a small firm is negatively associated with the probability to innovate, as long as the firm does not have access to a larger knowledge network.

In addition, the study by Fitjar and Rodrígez-Pose (2013) offers an appropriate reference. This study is especially suitable for a comparison since firstly, it considers product and process innovations separately, secondly, it analyzes both STI and DUI types of collaboration, and thirdly, it uses data about firms in Norway, a country that offers economic and geographic similarities to Sweden. A drawback is that the regions covered by the Norwegian survey are large urban agglomerations, as opposed to the data used for this paper, which comprises only one county, which is moreover a rather rural area. Additionally, they do not include small firms (1 to 9 employees) in their analysis, while almost half of the firms included in the Jönköping survey fall into this category. The authors find a relevant association with the probability to innovate for both STI and DUI collaboration types. While the collaboration with suppliers has a positive effect on both innovation types, which has a higher magnitude for process than for product innovations, an interaction with clients and with partners in the conglomerate only favors product innovations. Cooperation outside the supply chain, instead, is even detrimental to the development of product innovations. Furthermore, Fitjar and Rodrígez-Pose (2013) find a strong importance of extra-regional collaboration with both STI and DUI partners for any type of innovation. They conclude that cognitive, organizational and geographical proximity are of less importance, contrary to the theory of regional innovation systems, and that Norwegian firms rather tend to search for partners, who meet their specific needs, both at cognitive and geographical distance.

2.4 Assumptions

On the basis of the theoretical background and previous studies, assumptions about the regression outcomes are formulated. For each of the four dependent variables (product innovation, process innovation, both innovations, no innovation), a logit regression model is built, which all include the same independent variables. Table 1 presents the description of each regressor and the motivation for choosing them for the regression analysis. The variables are grouped in four categories: Firm characteristics that can be relevant for the relation between firm collaboration and the likelihood to innovate, DUI collaboration partners describing the structural dimension of DUI collaboration, followed by the DUI collaboration variables that depict the regional dimension, and finally the STI collaboration partners.

The education level of the employees (*High education*) is used as a proxy for the 'absorptive capacity' of a collaborating firm. This term has been introduced by Cohen and Levinthal (1990, p. 128) and describes an important prerequisite for the recipient firm to successfully adopt and implement external knowledge. Bjerke and Johansson (2014) use the same variable in their analysis. Other characteristics of the human capital of a firm that also go into the direction of absorptive capabilities are the age (*Older than 60*) and cultural background (*Born abroad*) of the employees. The age can have a negative effect on the likelihood to innovate, due to an increased level of risk aversion among older people. Employees with a migratory background can both be the cause and effect of an open-mindedness of a firm and be beneficial for the interaction with an international cooperation partner. Fitjar and Rodrígez-Pose (2013) include similar control variables in their study.

Moreover, the size of a firm is presumed to be positively associated with the likelihood of innovation, since large firms have a larger pool of human and physical capital at their disposal. Nevertheless, small firms can counter their lack of resources by the advantage of less bureaucracy, which provides them with more freedom and flexibility (Gilder, 1988; Rogers, 1990). With regard to this, a small firm size (*Small firm*) is assumed to impact rather the probability to develop process innovations negatively than product innovations, since complex processes that are subject to persistent improvements are more likely to be found in larger firms. Furthermore, linkages to international markets and knowledge thanks to exporting activities (*Exporter*) or to being part of a multinational concern (*Multinational*), which functions as a mediator of knowledge, are regarded as favorable for innovative purposes (Blomström, M. and A. Kokko, 1998). The industry variable[1] (*Industry*) controls for possible industry effects.

Different proximity dimensions are associated with the different DUI collaboration variables. The collaboration within the conglomerate (*Same corporate group*) relates to an organizational proximity between partners, since they use common codes of information, which facilitates the communication and accelerates the innovation process. The collaboration within the same industry (*Same industry*) relates to the cognitive proximity dimension, due to similarities in technological expertise and faced problems. This will also facilitate and fasten the innovation process, and is assumed to contribute positively to the development of any kind of innovation.

Both the collaboration with suppliers (*Supplier*) and clients (*Client*) are often related to strategic alliances that aim at increasing efficiency and decreasing costs. A backward integration relates to an interaction with suppliers and is expected to have a strong relation to the development of process innovations in the way that the delivery and integration of supplies are improved. This collaboration form is also supposed to be relevant for product innovations, which are likely to benefit from an improvement of materials delivered by suppliers. In contrast, a forward integration is supposed to support product innovations more than process innovations, since both the producing firm and the client have an interest to improve the product that will be traded between them (Davenport, 1992). An interaction with competitors (*Competitor*) refers to horizontal linkages between firms. While von Hippel (1987) suggests that this collaboration form can be favorable in the way that the sharing of ideas improves the innovation process, this is not supported by previous studies. This variable is therefore assumed to have no or a negative effect on the outcome.

The DUI interaction variables on a spatial dimension cover *Intra-regional*, *Extra-regional* and *International* collaborations and relate to the geographical proximity dimension. Previous studies indicate discrepant results about the effect of spatial proximity. Here, it is expected to have no or a positive effect. Since Jönköping County is a small region and offers a low degree of innovative partners, Bjerke and Johansson (2014) suggest that firms search to a large extent for collaboration partners outside the region. Due to this, the extra-regional and possibly the international variable are supposed to have a positive effect on the likelihood to innovate.

The STI collaboration partners are subdivided into *Universities and colleges*, *Public R&D institutes*, *Private R&D institutes*, and *Consultancies*. Assumptions about the interaction with STI collaboration partners are less easily defined, since they are not distinguished according to their structural relation with the recipient firm, as it is the case for the DUI partner variables, but rather on the basis of the knowledge they provide. While universities, colleges and public R&D institutes provide to a large extent basic and scientific knowledge in the form of publications (World Bank and OECD, 2013), which have a more universal nature, private R&D institutes are likely to focus on applied research, which is more market-oriented (González-Pernía et al., 2015). Furthermore, consultancies offer expert advice to address particular business problems (Oxford Dictionaries, 2015). Since Sweden is a university-centered country in the way that a higher proportion of public research is performed in universities than in public R&D institutes, the collaboration with universities and colleges is

[1] The categories used are: (1) manufacturing, (2) wholesale and retail, (3) other service activities, (4) construction, (5) transportation and storage, (6) water and electricity, (7) agriculture and mining. The categorization is based on the SNI Swedish Standard Industrial Classification 2007.

assumed to have a stronger effect on the outcome variables than the interaction with public research institutes (World Bank and OECD, 2013).

Table 1. Explanatory variables included in the regression analysis

Variable	***Description***	***Motivation***
Firm characteristics		
High education	Share of employees who have a university degree	Absorptive capacity
Born abroad	Share of employees who are born abroad	International communication skills
Older than 60	Share of employees who are older than 60 years	Risk aversion
Small firm	Having 1-9 employees	Human resources
Exporter	Exporting to international markets	Linkages to international markets and knowledge
Multinational	Belonging to a multinational corporate group (with facilities in at least two countries)	Structural access to international markets, knowledge and experiences
Industry	Categorical variable describing the respective industry sector a firm belongs to	Control for industry effects
DUI collaboration partner		
Same corporate group	Collaboration partner belongs to the same corporate group	Knowledge access through organizational proximity
Same industry	Collaboration partner belongs to the same industry	Knowledge access through cognitive proximity
Supplier	Collaboration partner is a supplier	Backward vertical integration
Client	Collaboration partner is a client	Forward vertical integration
Competitor	Collaboration partner is a competitor	Horizontal linkages
DUI collaboration region		
Intra-regional	Collaboration partner is located within the same region	Spatial proximity
Extra-regional	Collaboration partner is located outside the region	Spatial distance, national
International	Collaboration partner is located abroad	Spatial distance, international
STI collaboration partner		
Universities and colleges	Collaboration partner is a university or college	Basic research, scientific nature
Public R&D institutes	Collaboration partner is e.g. a national statistics institute	Basic research, scientific nature
Private R&D institutes	Collaboration partner is e.g. a private market research institute	Applied research
Consultancies	Collaboration partner is e.g. a financial consultancy	Expert advice in a particular field

3 Data and descriptive statistics

A prerequisite before working with innovation data is to define the term innovation. The Oslo Manual for measuring innovation distinguishes between four types of innovation: Product, process, marketing and organizational innovation (European Commission and Eurostat, 2005). This paper will only cover the first two types, since the Jönköping data survey does not cover the last two. Product innovation is defined as a "good or service that is new or significantly improved. This includes significant improvements in technical specifications, components and materials, software in the product, user friendliness or other functional characteristics", while process innovation is defined as a "new or significantly improved production or delivery method. This includes significant changes in techniques, equipment and/or software" (OECD, 2015).

There are ongoing debates about the practicality of splitting innovations into product and process innovations in research analyses. The literature shows no clear results about that issue. Mairesse and Robin (2012, p. 128), who are using innovation as an independent variable by investigating the effect of product and process innovation on labor productivity in manufacturing firms, state "that it is actually difficult to disentangle the respective effects of process and product innovation. Both types of innovation actually seem to capture 'overall' innovation". Bhoovaraghavan et al. (1996) clearly distinguish between the two respective innovation types, but stress that it is important for firms to pursue an integrated strategy of both product and process innovation for being successful on the market. Not many studies have investigated yet firm collaboration types and their relation to those two different forms of innovations. One of the few is the study by Fitjar and Rodrígez-Pose (2013) on innovative activities of Norwegian firms, as already mentioned in section 2. Additionally, Santamaría et al. (2009) investigate external knowledge sources of Spanish manufacturing firms and how those are differently relevant for either product or process innovations. Both studies find significant differences between the results for the two innovation types, what supports the applicability of a separate investigation.

The county of Jönköping is a rural region located in southern Sweden (Figure 1). It has about 324000 inhabitants and comprises 13 municipalities with an area of 10475 m^2. It is Sweden's sixth largest region and, thanks to its favorable location in the middle of southern Sweden, it serves as an important location for logistics solutions (Region Jönköpings län, 2015).

The empirical analysis is based on data from the "Tillgänglighet, Innovationsprocesser, Tillväxt" (TIPT) survey among firms in the county of Jönköping. The survey was conducted in 2012/2013 on behalf of the Jönköping International Business School with the purpose to investigate the firms' innovation and collaboration activities during the period from 2008 to 2011. It is comparable to the Community Innovation Survey (CIS), which is carried out on a two-year frequency by the EU member states and comprises enterprises within the EU with at least 10 employees. The Jönköping survey, though, comprises all firm sizes starting from 1 employee. Nevertheless, the data is not fully representative for the population of firms in Jönköping County, since there is a bias towards a larger firm size. This is because a higher proportion of large firms than of small firms has been contacted for an interview. Therefore, the descriptive statistics and the regression results can only indicate a tendency for the innovation and collaboration activities of the firms in Jönköping County.

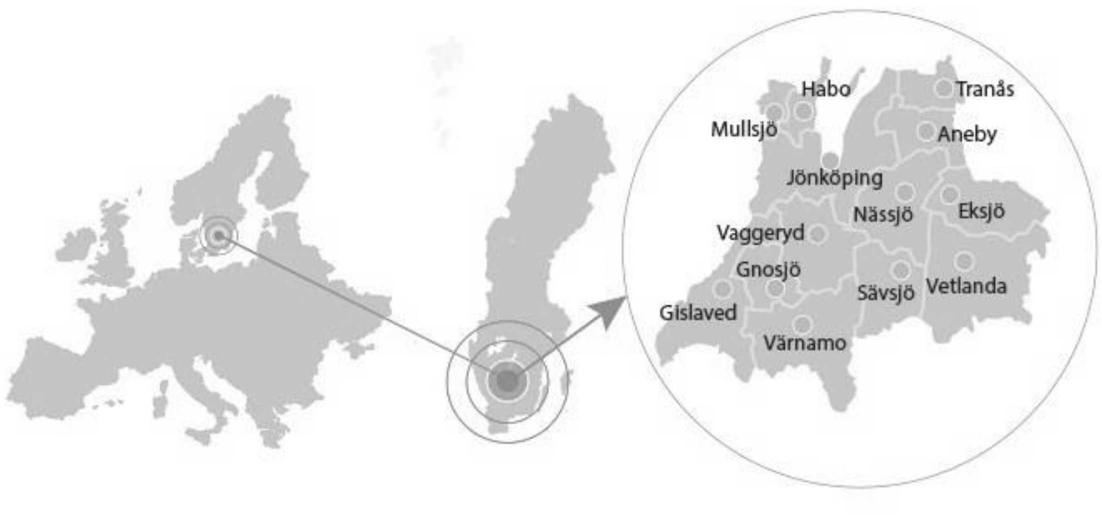

Figure 1. Jönköping County in the world and in Sweden, source: Region Jönköpings län, 2015

In the county of Jönköping, there is a total number of 8151 firms with at least one employee. For the survey, Statistics Sweden provided a sample of 3313 firms, from which a random subsample of 985 firms was drawn to be interviewed. Out of those contacted firms, 624 were successfully interviewed, while 349 firms were excluded from the survey due to their refusal to participate, lack of time, or contacting problems. Further 12 firms were not interviewed for unknown reasons. The sample considered in this paper thus comprises 624 observations and will be covered in the analysis. In the following, some descriptive statistics based on the analysis sample are presented.

Figure 2 provides information about some firm characteristics that can affect the likelihood to be innovative in terms of available resources. One half of the firms in the analysis sample are exporting, and also one half are small firms with 1 to 9 employees. Only 20 percent belong to a multinational concern.

Figure 3 gives an overview over the firms' innovation activities as recorded in the survey. 384 firms say that they have developed a product innovation between 2008 and 2011. This accounts for 62 percent of the analysis sample. Product innovations are thus more common than process innovations, which have been conducted by 297 firms and account for 48 percent of the sample. As a comparison, the study by Fitjar and Rodrígez-Pose (2013) about innovation activities of firms in Norway indicates a similar percentage for process innovations conducted by firms in Norway (47 %), while product innovations are by 9 percentage points lower in the Norwegian sample (53 %) than in the Jönköping sample.

Moreover, 230 firms have conducted both product and process innovations, whereas 173 did not innovate. A high rate of 72 percent is innovative in general terms. Interestingly, the percentage of firms that develop solely process innovations is relatively low with 11 percent, compared to 25 percent that develop solely product innovations.

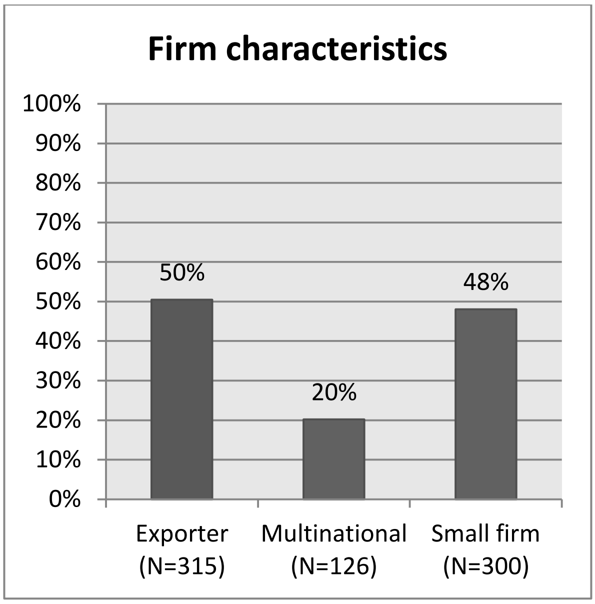

Figure 2. Number and share of firms in the analysis sample (N=624) that are exporters, belong to a multinational concern or are small in size

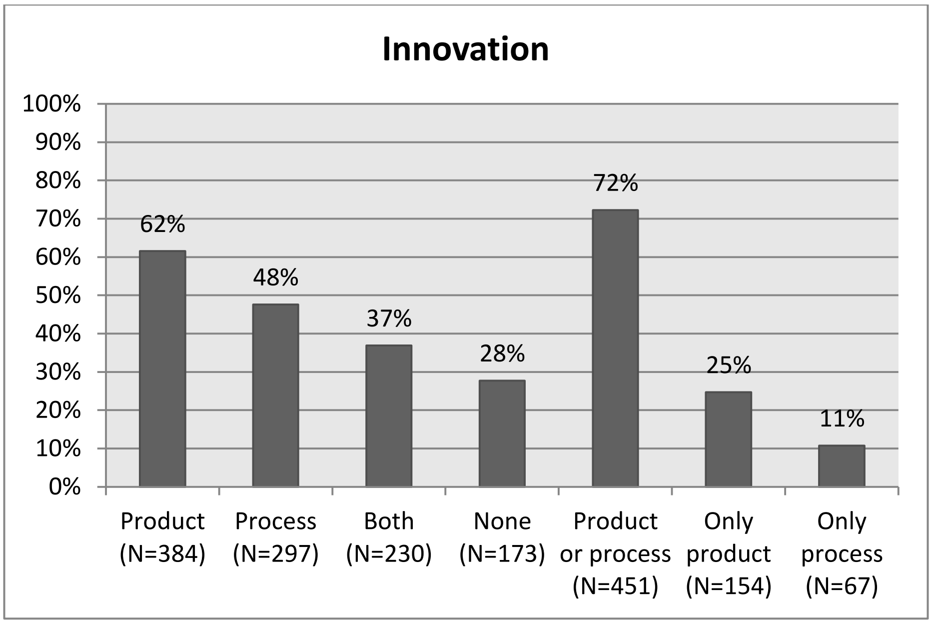

Figure 3. Number and share of the innovation types developed by the firms in the analysis sample (N=624)

The higher degree of product innovations compared to process innovations is somewhat against the expectations, since in Jönköping County there is a high rate of manufacturing firms, which are likely to be confronted with complex production processes (Figure 4). 36 percent of the firms in the analysis sample do manufacturing and consequently form the biggest sector, followed by wholesale and retail trade firms with 23 percent and other service activities[2], to which 21 percent of the firms belong.

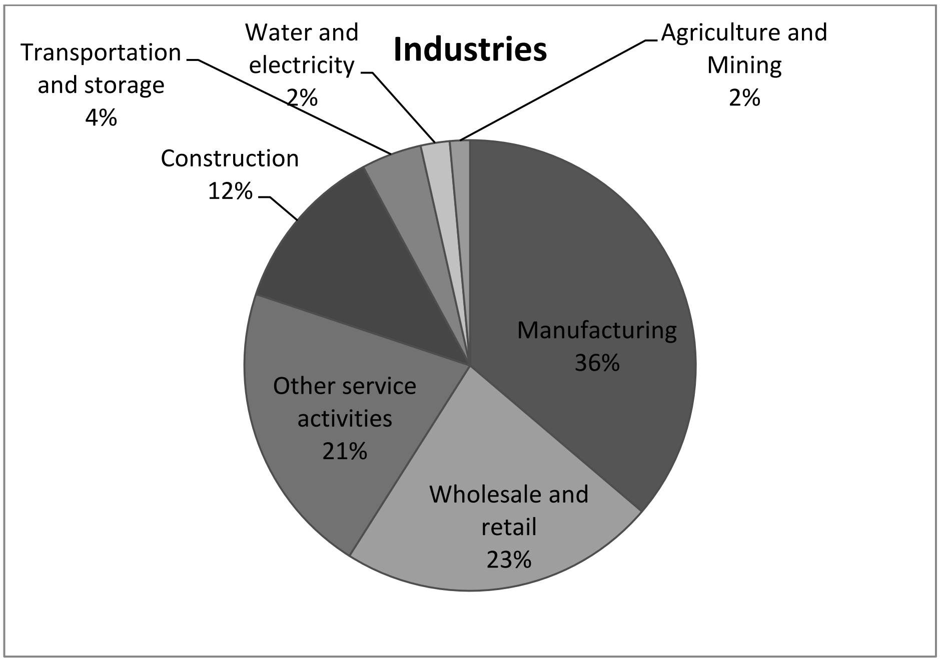

Figure 4. Distribution of industries in the analysis sample (N=624)

Comparing the innovative activities in the different industries, it is visible that the manufacturing sector is the most innovative one. Figure 5 indicates that manufacturing firms focus almost as much on process (63 %) as on product (67 %) innovations. 47 percent of the manufacturing firms develop both product and process innovations. This high value supports the idea that there is an interconnection of the two innovation types. However, in the service sectors, the gap between product and process innovation is much stronger. It is prevailing in the wholesale and retail trade sector and especially in the other service activities sector, where process innovations do not even reach 40 percent, in contrast to more than 60 percent of product innovations. The construction sector is one of the least innovative sectors, with both innovation types reaching less than 50 percent. The further sectors are too small to draw representative conclusions.

[2] Other service activities comprise firms within the following sectors, as defined by the SNI Swedish Standard Industrial Classification 2007: Accomodation and food service activities; information and communication; financial and insurance activities; real estate activities; professional, scientific and technical activities; administrative and support service activities; public administration and defense, compulsary social security; education; human health and social work activities; arts, entertainment and recreation; other service activities

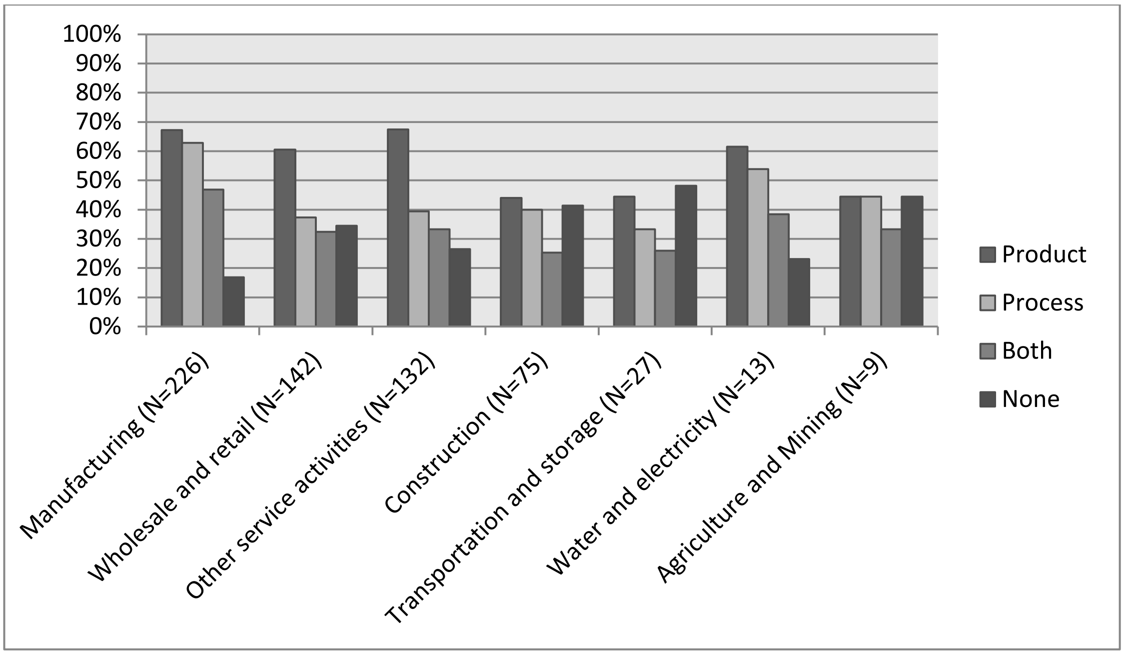

Figure 5. Number and share of innovation types developed in the different industry subsamples

The DUI (Doing, Using and Interacting) and STI (Science, Technology and Innovation) types of collaboration are displayed in Figure 6. Collaborations within the same concern, within the same industry, within the supply chain (supplier, client) and outside the supply chain (competitor) fall into the DUI category. Universities and colleges, private and public research institutes, as well as consultancies are STI collaboration partners. Strikingly, more than twice as many firms collaborate on a DUI mode than on an STI mode, namely 77 percent compared to 34 percent. In addition, out of all firms that collaborate with research organizations, only 3 percent do not also cooperate with firms.

Among the DUI collaboration types, the interaction with firms from the same industry is the most common one with 62 percent, followed by linkages to partners within the supply chain (clients = 55 %, suppliers = 54 %), and to partners outside the supply chain (competitors = 36 %). 20 percent of the firms cooperate with partners from the same concern. With regard to the STI collaboration types, linkages to universities and colleges are prevailing (27 %). 14 percent cooperate with consultancies, and both public and private R&D institutes are consulted by only 8 percent of the firms.

Data about regional collaboration is only available for the DUI type of collaboration. It is displayed in Figure 7. More than one half of the firms collaborate extra-regionally and 62 percent collaborate within the own region. International cooperation is less frequent, as it is done by one fourth of the firms.

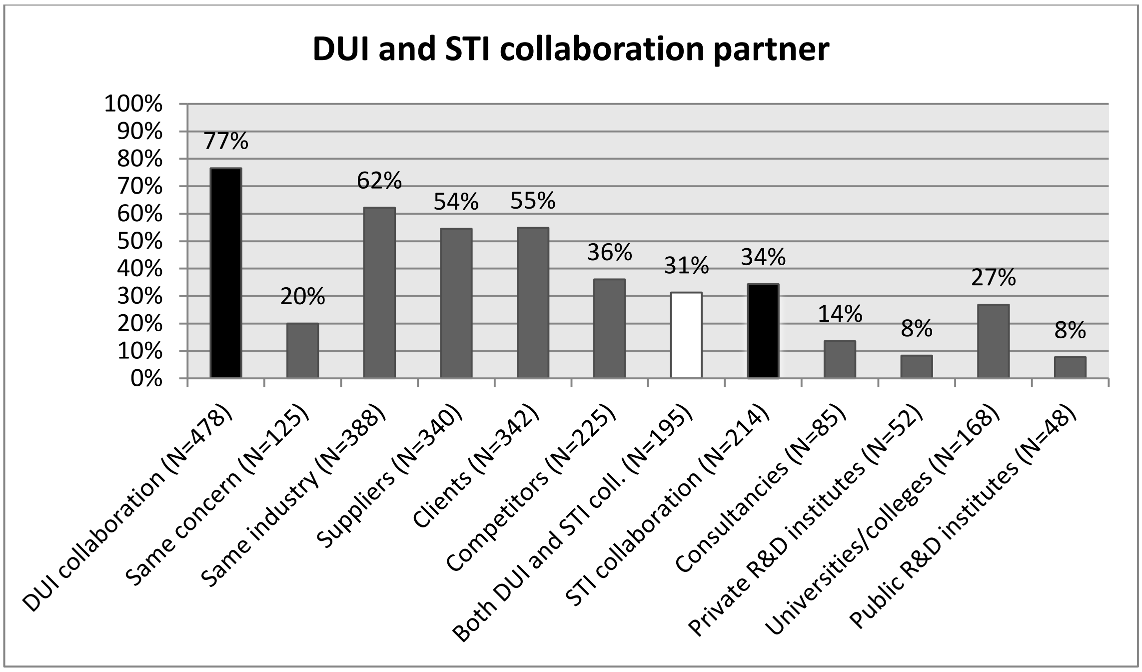

Figure 6. Number and share of firms in the analysis sample (N=624) that collaborate with different types of partners

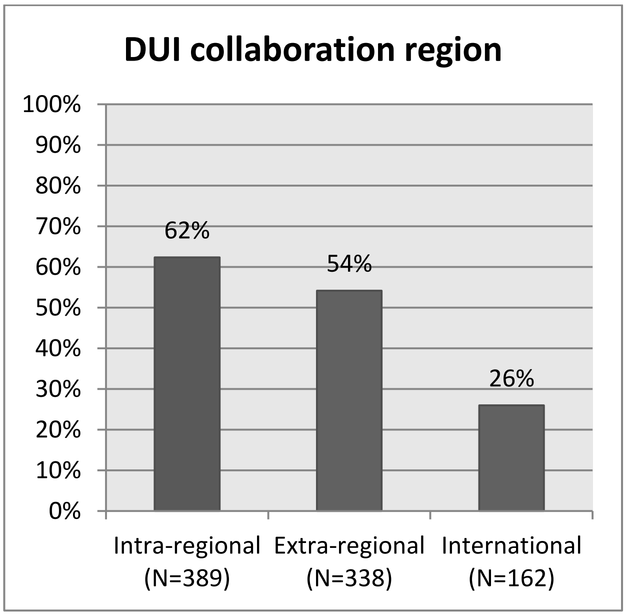

Figure 7. Number and share of firms in the analysis sample (N=624) that collaborate in different regions with DUI mode partners

4 Method

The analysis of the relationship between collaboration and innovation type in this paper is done with a binary logistic regression model, also called binary logit model. This form of regression is commonly used for the analysis of a binary categorical dependent variable. Four different dependent variables are analyzed in four different models: Product innovation, process innovation, both innovations and the last for no innovation[3] (Hair et al., 2006).

An alternative to using a logit model would be a discriminant analysis. A big advantage of logistic regression over discriminant analysis is the general lack of model assumptions. Neither normality of the independent variables, nor homoscedasticity, nor a linear relationship between dependent and independent variables are required. It is therefore the preferred analysis technique. The estimation technique for logit models is maximum likelihood, which requires a larger sample size than the least squares technique. Hosmer and Lemeshow (2000) recommend an overall size of more than 400, what the underlying sample size of 624 observations meets (Hair et al., 2006).

The binary variables in this analysis have an indicator coding, which addresses observations with 1, when the respective event is occurring, e.g. a firm develops product innovations, and with 0 as reference category in the case of non-occurrence, e.g. the firm does not develop product innovations. The variate of the logit model is similar to that of a multiple regression model with a metric dependent variable, in the way that it consists of regression coefficients for each independent variable describing their relative impact on the dependent variable. The difference is that in a logit model the probability of the relationship between regressant and regressors is measured. This functions in a similar way as in a multiple regression model, since the marginal effect of the regressors on the dependent variable is measured. Since a binary regressor only has two outcomes (0 and 1), a unit change in the regressor just means that the event described by the variable occurs (Hair et al., 2006).

The outcome variable is expressed as log-transformed odds, and the coefficients for the dependent variables as log-transformed odds ratios. As an example, the relationship between the binary regressor that describes whether a firm is small (coded 1) or not small (coded 0), and the regressant that describes whether a firm is innovative (coded 1) or not innovative (coded 0) is presented. In this case, the odds of being innovative given the occurrence that the firm is small, is the nominator in Equation 1. It is the probability of being innovative, given the firm is small and holding the other variables in the regression model constant, divided by the probability of not being innovative, given the firm is small and holding the other variables constant. Contrary, the denominator in Equation 1 describes the odds of being innovative given the occurrence that the firm is not small. That is the probability of being innovative given the firm is not small and holding the other variables constant, divided by the probability of not being innovative given the firm is not small and holding the other variables constant. This second odds is the original odds, before a unit change in the predictor variable. The odds ratio, which is the exponentiated regression coefficient, now measures the proportionate change in the original odds, when the firm is small. This is the way of interpretation of the coefficients from the exponentiated regression equation (Equation 2), while Equation 3 describes the original logit model (Hair et al., 2006).

[3] A multinomial logistic regression approach does not come into consideration in this case, because the four dependent variables do not form categories that exclude each other.

Equation 1

$$Odds\ ratio = exp\left(\hat{b}_{Small\ firm}\right) = \frac{P\ (Innovative = 1|Small\ firm = 1,\ other\ variables)/P(Innovative = 0|Small\ firm = 1,\ other\ variables)}{P\ (Innovative = 1|Small\ firm = 0,\ other\ variables)/P(Innovative = 0|Small\ firm = 0,\ other\ variables)}$$

Equation 2

$$Odds = \left(\frac{prob_{event}}{1 - prob_{event}}\right) = e^{b_0 + b_1X_1 + \cdots + b_nX_n}$$

Equation 3

$$Logit = ln\left(\frac{prob_{event}}{1 - prob_{event}}\right) = b_0 + b_1X_1 + \cdots + b_nX_n$$

The logit transformation is a means to keep the predicted probability values in the range of 0 and 1. Since the impact of the coefficients on the logged odds of the outcome variable does not offer a straightforward interpretation, the coefficients will be stated in the exponentiated form, to interpret the regressors' effect on the odds of the regressant. For the exponentiated coefficients, a value of 1 means no impact on the odds, a value lower than one means a negative influence, and a value larger than 1 describes a positive effect. The lower bound is 0, which can only be reached asymptotically, while there is no upper limit (Hair et al., 2006).

There are several model diagnostic measures available to assess the goodness-of-fit for a logit model. The -2 log likelihood value is used to compare the change of fit between two models. The lower the value, the better the model fit. This is done by the chi-square test, which measures if the fit of the final model is significantly improved compared to the null model (or baseline model), which includes only the dependent variable and the constant. Furthermore, the Hosmer and Lemeshow test is a chi-square-based measure that evaluates the correspondence of the actual and predicted values of the dependent variable. If the outcome of the test is significant, this means that there is a significant difference between the values. With regard to practical significance measures, the Nagelkerke R^2 value provides a measure for the overall model fit. It is calculated from the -2 log likelihood value and lies in the range of 0 and 1. Similarly as the R^2 value in multiple regression, a perfect fit has a value of 1. Finally, the hit ratio expresses the percentage of correctly classified cases (Hair et al., 2006).

5 Model building and results

The correlation matrix (Appendix, Table A 1) reveals mostly significant correlations between regressant and regressors. Insignificant correlations are only found for the process innovation variable with the competitor, high education and age variable, as well as between the variable describing the development of both innovations and the competitor and high education variable respectively. Regarding the relationships between the different regressors, a relatively high correlation is found between the supplier and the client collaboration (r = 0.541), which could lead to collinearity problems in the regression model. Further relatively high correlations are identified for the industry variable with all three variables related to a firm collaboration within and outside the supply chain, i.e. with a supplier (r = 0.442), client (r = 0.454) and competitor (r = 0.489). Additionally, being part of a multinational concern is strongly related to both the collaboration within the same concern (r = 0.445) and with a consultancy (r = 0.649). Several model specifications with differently composed variates are built, which address the problem of collinearity. Moreover, all models have been tested for multicollinearity and outliers, for which no significant violations have been found.

Table 2 presents the regression results which aim at explaining the likelihood of firms to develop product innovations. The model specifications 1.1 to 1.4 describe both the effects of interactions with the respective DUI and STI partner types. The impacts of collaborations within the same concern and the same industry are analyzed separately from the effects of supplier, client and competitor collaborations in order to avoid collinearity. In specification 1.2, the variable multinational is omitted to eliminate its influence on the corporate group and consultancy variables. Similarly, in specification 1.4, the supplier variable is removed with the ambition to see whether the effect of the collaboration with a client changes. In specifications 1.5 and 1.6, the regional dimensions of DUI collaboration are analyzed. Obviously, the DUI partner variables need to be excluded from that specification, since they describe the same type of cooperation, but only on another dimension. This is also supported by the correlation matrix (Appendix, Table A 1). The regression models for the other three outcome variables are specified in a similar way (Table 3 to 5).

Figure 6 in the descriptive statistics section indicates a strong overlap of DUI and STI collaborations. Though the bivariate correlations between DUI and STI partner variables are relatively low (Appendix, Table A 1), a connection of the two variable types is visible in the way that almost all firms (except for 3 percent) in the analysis sample that cooperate with DUI partners, also collaborate with STI partners. Therefore, Table A 2 (Appendix) shows the regression results for model specifications that include the DUI partner variables, while excluding the STI partner variables. However, the marginal effects of the DUI partner variables only change to a low degree, which supports the assumption that there is no problem of multicollinearity in the model specifications in Table 2 to 5.

The number of observations reduces from originally 624 in the analysis sample to 611 (in specification 1.5 to 610), due to 'don't know' answers and missing answers in the regressors. Regarding overall model fit, the -2 log likelihood values for all model specifications indicate statistically significant model improvements compared to the null model. Moreover, the Hosmer and Lemeshow tests find no significant differences between the actual and predicted values of the dependent variable. With respect to the practical significance measures, the Nagelkerke R^2 values are rather low (Nagelkerke R^2 = 0.295 in specification 1.1). However, the so-called pseudo R^2 values used in logistic regression are usually low and should not be compared with the R^2 values in linear regression (Tödtling et al., 2008). The hit ratio for all specifications reaches a score of around 70 percent, which is an improvement of classification accuracy of 8 to 10 percent compared to the baseline model.

The results are only partly in accordance with the assumptions. A look at the metric variables that relate to characteristics about the employees reveals lower magnitudes compared to the binary regressors, which does not mean that the effect is low. If the share of highly educated employees increases by 1 percent, the odds of product innovation increases by 1.4 percent in model specification 1.1. This means that if half of the employees have a university degree, this will increase the odds by 70 percent, which is a quite strong improvement. Almost the same magnitude, but with a negative direction, is found for the share of employees older than 60 years. These results meet the expectations. On the contrary, the share of employees born abroad has no effect. Interestingly, also the size of the firm turns out to be not relevant for the likelihood of product innovations. This supports the findings of Cohen and Klepper (1996), who claim that small firms, although they are equipped with less capital than large firms, are likely to develop product innovations, since product improvements usually are directly related to higher profits, which will compensate for the lack of capital resources. Moreover, access to international markets and knowledge in the form of exporting activities or being part of a multinational conglomerate are fruitful for product innovations.

Regarding the DUI collaboration partners, an organizational proximity, depicted by the variable same concern, has, as expected, a strong effect on the probability to develop product innovations, even the strongest among all collaboration variables. It increases the odds of product innovation by about 2.4 in specification 1.1, and increases it even by about 3.4 when omitting the multinational variable (specification 1.2). Fitjar and Rodrígez-Pose (2013) find in their study about Norwegian firms a moderate effect of this form of collaboration on the likelihood to develop product innovations, and no significant impact on process innovations. Bjerke and Johansson (2014), who use the same data as in this paper, identify partnerships within the same concern to be the most supportive factor for innovative activities, among all variables they include in their analysis. Also, a cognitive proximity, captured by the variable same industry, proves to have a positive impact, which is in accordance with the results of Bjerke and Johansson (2014).

Furthermore, linkages to suppliers have a positive effect on the likelihood to develop product innovations (exp(b)=1.775, specification 1.3). The interaction with clients shows no significant effect in specification 1.3, but dropping the supplier variable in specification 1.4 reveals a positive marginal effect of collaborations with clients (exp(b)=1.546), which has presumably been suppressed due to the strong correlation with the supplier variable. With regard to the standard errors, the impacts of the two collaboration partners that are part of the supply chain are on a relatively similar level, with a slightly higher importance of a backward vertical integration.[4] Fitjar and Rodrígez-Pose (2013), whose study does not comprise small firms, find a similar pattern in their regression results for product innovations, while the results of Bjerke and Johansson (2014) for the probability of being innovative reveal a slightly higher importance of a forward vertical integration. Bjerke and Johansson (2014) support this finding with the high degree of customer-dominated subcontractors among the firms in Jönköping County. The limits of the underlying analysis sample, with a bias towards larger firms, do not allow such a strong reference to the firm population in the county of Jönköping. Furthermore, a horizontal integration has no influence.

[4] Excluding the client variable from specification 1.3 results in an exponentiated marginal effect of the supplier variable of 1.910 *(S.E.=0.198).*

While Bjerke and Johansson (2014) also have an insignificant result for the competitor variable, Fitjar and Rodrígez-Pose (2013) even identify a negative impact on product innovations.

The STI collaboration variables show less significant results than the DUI partner variables, but still have some influence. Most influence is identified for a collaboration with private R&D institutes, which increases the odds of product innovation by around 2.8. Furthermore, interactions with universities increase the odds by around 60 percent. A significant impact of consultancies is only found when the multinational variable is excluded. While the results of Fitjar and Rodrígez-Pose (2013) only indicate a significant influence of collaboration with universities on the likelihood of product innovations, González-Pernía et al. (2015) find evidence that a mix of STI collaboration partners is more favorable than a focus on university linkages only. This will also depend on the novelty of the respective innovation. While radical innovations and science-based products will rather require collaboration with universities, incremental innovations, which are related to the adoption of new technologies, will require the interaction with more business-related STI partners, such as private R&D institutes or consultancies (Pavitt, 1984; Tödtling et al., 2008). The mostly insignificant results for a collaboration with consultancies may be due to the more advisory nature of such STI partners, which usually offer expertise based on experience in a particular business field, rather than offering research-based insights and new technologies. Furthermore, the insignificance of public research institutes is in accordance with the higher importance of universities among public research institutions (World Bank and OECD, 2013).

Regarding the regional DUI variables in specification 1.5, only intra-regional collaborations turn out to be significant. They double the odds of product innovations. This outcome is contradicting both the results of the Swedish (Bjerke and Johansson, 2014) and the Norwegian study (Fitjar and Rodrígez-Pose, 2013). Bjerke and Johansson (2014) only find a significant effect of extra-regional linkages on the probability to be innovative. They refer the insignificance of intra-regional cooperation to the lack of resources in a rural region with low density, as Jönköping County. But even Fitjar and Rodrígez-Pose (2013) do not find any significance of intra-regional DUI partnerships, though they analyze data from city agglomerations. This contradicts the theory that innovation networks are localized. In this context, it needs to be considered that Fitjar and Rodrígez-Pose (2013) include in their extra-regional variable both the DUI interaction outside the region, but still in Norway, and international cooperations, whereas in this paper and the one by Bjerke and Johansson (2014), they are covered in separate variables. Furthermore, the differences to the results of Bjerke and Johansson (2014) will be due to the different specifications of the variables and models in this paper, as well as to the fact that the models in Table 2 aim at explaining the likelihood to develop product innovations, and not the likelihood of generally being innovative.

A further consultation of the correlation matrix (Appendix, Table A 1) reveals that the extra-regional variable is relatively strongly correlated both with the intra-regional (r = 383) and the international variable (r = 406), which could lead to collinearity problems and suppress the effect of extra-regional partnerships. The exclusion of the intra-regional variable in specification 1.6 results in positive effects on the probability to develop product innovations of both extra-regional and international cooperation. Still, the overall results suggest that, contrary to the findings of Bjerke and Johansson (2014) and though Jönköping County is rather rural, the region offers some relevant innovative resources. Since 72 percent of the firms in the analysis sample say that they are innovative, as described in the descriptive statistics section, they will possibly also find innovative collaboration partners among each other and benefit from the spatial proximity. This may especially be true for product innovations of small firms, that are more likely to sell their products locally and consequently collaborate to some extent with local clients and suppliers (Freel, 2003). However, for this interpretation it needs to be kept in mind that the underlying analysis sample is not fully representative for the firms in Jönköping County.

Table 2. Results of the logistic regression estimation: Product innovation

Variables	**1.1**	**1.2**	**1.3**	**1.4**	**1.5**	**1.6**
Firm characteristics						
High education	1.014***	1.014***	1.015***	1.014***	1.015***	1.013***
	(0.005)	*(0.004)*	*(0.005)*	*(0.005)*	*(0.005)*	*(0.005)*
Born abroad	1.010	1.010	1.011*	1.011*	1.012*	1.010*
	(0.006)	*(0.006)*	*(0.006)*	*(0.006)*	*(0.006)*	*(0006)*
Older than 60	0.984***	0.984***	0.986**	0.984***	0.985***	0.985***
	(0.006)	*(0.006)*	*(0.006)*	*(0.005)*	*(0.005)*	*(0.005)*
Small firm	0.882	0.814	0.830	0.864	0.845	0.859
	(0.211)	*(0.209)*	*(0.213)*	*(0.211)*	*(0.214)*	*(0.211)*
Exporter	1.729**	1.855***	1.567**	1.642**	1.486*	1.460*
	(0.213)	*(0.211)*	*(0.215)*	*(0.214)*	*(0.222)*	*(0.220)*
Multinational	2.345**		3.409***	3.483***	3.218***	2.941***
	(0.378)		*(0.351)*	*(0.348)*	*(0.360)*	*(0.355)*
Industry	Controlled	Controlled	Controlled	Controlled	Controlled	Controlled
DUI collaboration partner						
Same corporate group	2.433**	3.366***				
	(0.360)	*(0.330)*				
Same industry	1.562**	1.504**				
	(0.196)	*(0.195)*				
Supplier			1.775**			
			(0.222)			
Client			1.182	1.546**		
			(0.231)	*(0.204)*		
Competitor			1.322	1.407		
			(0.212)	*(0.209)*		
DUI collaboration region						
Intra-regional					2.019***	
					(0.220)	
Extra-regional					1.300	1.666**
					(0.222)	*(0.206)*
International					1.566	1.642*
					(0.285)	*(0.283)*
STI collaboration partner						
Universities and colleges	1.590	1.611*	1.648*	1.654*	1.521	1.550
	(0.289)	*(0.286)*	*(0.288)*	*(0.286)*	*(0.295)*	*(0.292)*
Public R&D institutes	1.944	2.165	1.807	1.916	1.848	1.758
	(0.550)	*(0.543)*	*(0.552)*	*(0.558)*	*(0.556)*	*(0.549)*
Private R&D institutes	2.846*	2.807*	2.619*	2.826*	2.813*	2.589
	(0.596)	*(0.592)*	*(0.583)*	*(0.588)*	*(0.595)*	*(0.594)*
Consultancies	1.761	1.945*	1.583	1.657	1.622	1.703
	(0.381)	*(0.374)*	*(0.384)*	*(0.380)*	*(0.388)*	*(0.384)*
N	611	611	611	611	610	611
-2 log likelihood	666.100	671.470	663.539	670.208	656.509	667.074
Hosmer and Lemeshow test (5% level)	insignificant	insignificant	insignificant	insignificant	insignificant	insignificant
Nagelkerke R^2	0.295	0.286	0.300	0.288	0.311	0.294
Hit ratio	70.5	71.0	71.8	69.6	71.1	71.4
Baseline hit ratio	61.2	61.2	61.2	61.2	61.1	61.2

Exponentiated logistic coefficients with the standard error listed in parantheses
Significant at the level ***0.01, **0.05, *0.1

In Table 3, the regression results for the outcome variable process innovation are presented. The different model specifications follow the same logic as in Table 2. The goodness-of-model-fit measures overall indicate a lower fit of the process innovation model compared to the product innovation model. Nevertheless, the Hosmer and Lemeshow test at-tests to all specifications in Table 3 satisfactory prediction accuracy.[5] Furthermore, the chi-square test indicates a significant reduction of the -2 log likelihood values in comparison to the baseline model. Also, the classification accuracy increases by around 15 percent and results in a hit ratio of 67 to 68 percent, which is a quite acceptable score with regard to the low baseline hit ratio of 52.4 percent.

An overall comparison of the regression results in Table 3 with the above discussed results from Table 2 does not reveal strong differences in the regression coefficients, also with regard to the standard errors. Considering this together with the fact that half of the firms that innovate conduct both product and process innovations (Figure 3 in section 3), the idea of an interconnection of the two innovation types again is supported. However, some differences can be identified.

Regarding the magnitudes of the regressors, there are overall slightly weaker effects visible than for the product innovation model, except for the variable same industry. An explanation may again be delivered by Cohen and Klepper (1996), who stress that investments in process innovations depend more on the capital resources that the firm has at its disposal at the time of the development process. They argue that the return on investments in process innovations is less direct than it is the case for product innovations, since the sale of a new product on the market generates a profit more rapidly. With respect to this, the firms in Jönköping County, which to a high degree are small and have a rather low amount of human and physical resources at their disposal need to consider the trade-off between the investment in external knowledge, and the associated return.

Having a more detailed look at the regression results for the firm characteristics shows that the absorptive capacity is to a lower degree relevant for the likelihood to develop process innovations than for product innovations. The influences of the share of employees with a migratory background as well as the employees' age turn out to be negligible for process innovations. Being a small firm proves to be negatively associated with the outcome variable, and decreases the odds of process innovations by more than 30 percent. This confirms the findings of Cohen and Klepper (1996) described above. Furthermore, being an exporter has no effect, while being part of a multinational concern more than doubles the odds, when the variable same concern is omitted.

The outcomes for the DUI collaboration variables reveal a less clear distinction of the importance of organizational and cognitive proximity, as it was the case for product innovations. Excluding the multinational variable in model specification 2.2, addresses a magnitude of almost 2 to the collaboration within the same corporate group, and a magnitude of 1.5 to the cooperation within the same industry. The relative importance between an interaction with suppliers and clients respectively shows a similar pattern as for the probability of product innovations. With regard to the regional dimension of DUI collaboration, both an intra- and extra-regional interaction increases the odds of process innovation by more than 50 percent respectively. Concerning the STI collaboration partners, only linkages to universities and colleges turn out to positively influence the odds, which confirms the findings of Fitjar and Rodrígez-Pose (2013) and of González-Pernía et al. (2015) that STI collaboration is less important for process than for product innovations.

[5] Except for model specification 1.4, which omits the highly significant variable supplier on purpose to address the problem of collinearity between the supplier and the client variable.

Table 3. Results of the logistic regression estimation: Process innovation

Variables	2.1	2.2	2.3	2.4	2.5
Firm characteristics					
High education	1.007* *(0.004)*	1.008* *(0.004)*	1.007* *(0.004)*	1.007* *(0.004)*	1.008* *(0.004)*
Born abroad	1.008 *(0.006)*	1.008 *(0.006)*	1.009 *(0.006)*	1.009 *(0.006)*	1.010* *(0.006)*
Older than 60	0.992 *(0.005)*	0.992 *(0.005)*	0.994 *(0.005)*	0.993 *(0.005)*	0.994 *(0.005)*
Small firm	0.667** *(0.202)*	0.623** *(0.198)*	0.642** *(0.202)*	0.662** *(0.201)*	0.648** *(0.203)*
Exporter	1.115 *(0.206)*	1.190 *(0.202)*	1.018 *(0.208)*	1.066 *(0.207)*	0.978 *(0.215)*
Multinational	1.770* *(0.315)*		2.181*** *(0.279)*	2.232*** *(0.278)*	2.035** *(0.290)*
Industry	Controlled	Controlled	Controlled	Controlled	Controlled
DUI collaboration partner					
Same corporate group	1.536 *(0.292)*	1.973*** *(0.257)*			
Same industry	1.552** *(0.191)*	1.505** *(0.189)*			
Supplier			1.573** *(0.216)*		
Client			1.120 *(0.220)*	1.387* *(0.195)*	
Competitor			1.188 *(0.198)*	1.241 *(0.196)*	
DUI collaboration region					
Intra-regional					1.554** *(0.212)*
Extra-regional					1.530** *(0.214)*
International					1.339 *(0.249)*
STI collaboration partner					
Universities and colleges	1.566* *(0.249)*	1.559* *(0.247)*	1.584* *(0.248)*	1.584* *(0.247)*	1.470 *(0.254)*
Public R&D institutes	1.720 *(0.416)*	1.866 *(0.410)*	1.611 *(0.415)*	1.647 *(0.416)*	1.866 *(0.427)*
Private R&D institutes	1.074 *(0.380)*	1.085 *(0.376)*	1.056 *(0.378)*	1.100 *(0.378)*	0.974 *(0.387)*
Consultancies	0.957 *(0.311)*	1.046 *(0.303)*	0.920 *(0.311)*	0.959 *(0.309)*	0.897 *(0.315)*
N	611	611	611	611	610
-2 log likelihood	738.128	741.448	737.390	741.809	725.969
Hosmer and Lemeshow test (5% level)	insignificant	insignificant	insignificant	significant	insignificant
Nagelkerke R^2	0.215	0.209	0.217	0.209	0.235
Hit ratio	67.6	67.1	67.3	67.4	68.0
Baseline hit ratio	52.4	52.4	52.4	52.4	52.3

Exponentiated logistic coefficients with the standard error listed in parantheses
Significant at the level ***0.01, **0.05, *0.1

Overall, the results lead to the conclusion that process innovations rely more on cognitive proximity than this is the case for product innovations. Firms that focus on conducting product innovations need to respond to market needs and new trends, and try to distinguish their products from those of the competitors. Following Boschma (2005), too much cognitive proximity has a detrimental effect on innovations, because less new ideas come into play. With respect to process innovations instead, firms focus on cost reduction, which is not necessarily achieved by radical changes, but rather by continuous incremental improvements (Pavitt, 1984; Tödtling, 2008). This will require tacit knowledge of collaboration partners who share the same problems and experiences, rather than groundbreaking research results from STI collaborators. Therefore, firms that conduct process innovations will to a large extent search for collaboration partners within the same industry. Given a cognitive proximity between partners, a high education of employees is less relevant to absorb unfamiliar knowledge. Furthermore, due to the less radical nature of process innovations, also risk-aversion is no limiting factor. The insignificance of both the exporter and the international cooperation variable also support the idea of a cognitive proximity between partners rather than knowledge linkages to foreign partners.

Also organizational proximity will play an important role for the likelihood to develop process innovations, indicated by the significance of both the multinational and the same concern variable. Large conglomerates are likely to be confronted with complex processes. The firms that are part of the concern and that are connected to these processes will presumably work together on improving the processes. Additionally, since Jönköping County is a favorable place for logistics, extra-regional collaboration partners will be crucial to the development of process innovations, which is confirmed by the regression results.

Table 4 shows the regression results for the likelihood to develop both product and process innovations. The model fit measures are all deemed satisfactory. The Nagelkerke R^2 values are larger than for the process innovation model, but lower compared to the product innovation model, and the -2 log likelihood values all prove to be significantly lower than for the null model. In addition, the predictive accuracy of the models is deemed acceptable, as the Hosmer and Lemeshow tests indicate. The hit ratio of more than 70 percent has a satisfiably high level.

A look at the overall results in Table 4 reveals an interesting fact: The effects of most of the coefficients show a higher similarity with the regression outcomes for process innovations than for product innovations. However, the differences to the product innovation results are again not strong. The influence of the absorptive capacity of a firm has almost the same low magnitude and significance as for process innovations. The impact of the firm size has a similarly strong negative influence on the probability to develop both innovation types, being part of a multinational concern or collaborating with a partner within the same concern show again a similar impact as for the likelihood of process innovations. Also, the relatively equally importance of both intra- and extra-regional collaborations is similar to the patterns of the process innovation outcomes, as well as the focus on collaborations with universities and colleges concerning the STI interaction types.

The gap between the importance of supplier and client collaboration is more distinct than in the previous models. The interaction with suppliers doubles the odds of both innovation types, and although the supplier variable is omitted in model specification 3.3, the client variable is insignificant, even the directionality of this variable is not clear with regard to model specifications 3.2 and 3.3.

Similarities to the product innovation results can be seen in the significant negative effect of risk aversion. This is not surprising, since the higher degree of innovative efforts associated with the development of both innovation types is likely to involve less risk adverse employees. Furthermore, being an exporter increases the odds of both innovation types by around 60 percent in model specification 3.1., and indicates that also international knowledge linkages are supportive for the development of both product and process innovations.

The similarities to the process innovation outcomes are also supported by the correlation matrix (Appendix, Table A 1), which show a stronger correlation of the variable both innovations with process innovation (r = 0.802), as opposed to the correlation with product innovation (r = 0.604). This may suggest that process innovations often go hand in hand with product innovations, whereas this is less often the case the other way around. The descriptive statistics (Figure 3) support this idea, since 25 percent of the firms in the analysis sample exclusively develop product innovations, while 11 percent focus solely on process innovations. This phenomenon will be to some extent due to the higher costliness of process innovations, but it will also be related to the complexity of the products a firm produces. Link (1982) finds evidence that a greater product complexity increases the effort dedicated to process improvements. These findings also show the interconnection of the two innovation types. Additionally, Barge-Gil et al. (2011) suggest that larger firms that are confronted with more complex and technologically advanced production processes and that rely to a higher degree on their internal capabilities than small firms, are more likely to collaborate with universities than with other research institutions. This is supported by the regression results.

Table 4. Results of the logistic regression estimation: Both innovation types

Variables	**3.1**	**3.2**	**3.3**	**3.4**	**3.5**
Firm characteristics					
High education	1.008* *(0.004)*	1.009* *(0.004)*	1.008* *(0.004)*	1.008* *(0.004)*	1.009* *(0.004)*
Born abroad	1.008 *(0.006)*	1.008 *(0.006)*	1.008 *(0.006)*	1.008 *(0.006)*	1.010 *(0.006)*
Older than 60	0.985** *(0.006)*	0.985** *(0.006)*	0.988* *(0.007)*	0.985** *(0.006)*	0.987** *(0.006)*
Small firm	0.641** *(0.218)*	0.594** *(0.214)*	0.587** *(0.218)*	0.620** *(0.216)*	0.612** *(0.219)*
Exporter	1.612** *(0.220)*	1.733** *(0.215)*	1.465* *(0.222)*	1.569** *(0.219)*	1.413 *(0.228)*
Multinational	1.781* *(0.308)*		2.293*** *(0.273)*	2.374*** *(0.271)*	2.146*** *(0.282)*
Industry	Controlled	Controlled	Controlled	Controlled	Controlled
DUI collaboration partner					
Same corporate group	1.694* *(0.287)*	2.185*** *(0.251)*			
Same industry	1.523** *(0.205)*	1.468* *(0.203)*			
Supplier			2.004** *(0.234)*		
Client			0.786 *(0.238)*	1.101 *(0.207)*	
Competitor			1.143 *(0.210)*	1.231 *(0.207)*	
DUI collaboration region					
Intra-regional					1.550* *(0.229)*
Extra-regional					1.482* *(0.228)*
International					1.343 *(0.248)*
STI collaboration partner					
Universities and colleges	1.671** *(0.248)*	1.668** *(0.246)*	1.757** *(0.248)*	1.760** *(0.246)*	1.578* *(0.251)*
Public R&D institutes	1.720 *(0.401)*	1.866 *(0.396)*	1.612 *(0.402)*	1.638 *(0.403)*	1.820 *(0.411)*
Private R&D institutes	1.775 *(0.379)*	1.763 *(0.375)*	1.799 *(0.377)*	1.876* *(0.375)*	1.661 *(0.384)*
Consultancies	1.079 *(0.312)*	1.192 *(0.303)*	0.027 *(0.311)*	1.096 *(0.308)*	1.018 *(0.314)*
N	611	611	611	611	610
-2 log likelihood	673.787	677.286	672.700	681.695	665.757
Hosmer and Lemeshow test (5% level)	insignificant	insignificant	insignificant	insignificant	insignificant
Nagelkerke R^2	0.262	0.256	0.264	0.248	0.276
Hit ratio	73.2	71.5	74.8	73.0	72.8
Baseline hit ratio	63.2	63.2	63.2	63.2	63.1

Exponentiated logistic coefficients with the standard error listed in parantheses
Significant at the level ***0.01, **0.05, *0.1

Finally, the regression results for the probability to develop neither product nor process innovations are presented in Table 5. The goodness-of-model-fit measures indicate, overall, quite satisfying values. The Nagelkerke R^2 values are similarly high as for the product innovation model, and the -2 log likelihood values are all deemed to be significantly lower than for the null model. The hit ratios have an accurate level, though there is no strong improvement in predictive accuracy compared to the baseline hit ratios, which are already quite high. A closer look at the group hit ratios, reveals a drawback in the model fit. While the group hit ratio for not being innovative reaches a high percentage of 91.6 in model specification 4.1, the prediction accuracy for the group of not being innovative is on an unsatisfactory level of only 35.7 percent. The other model specifications in Table 5 show similar patterns. This big gap between the two group hit ratios can partly be explained by the differences in the group sample sizes. Figure 3 in section 3 reveals that 451 firms in the analysis sample say that they innovate, whereas only 173 do not innovate. Also, the Hosmer and Lemeshow test indicates weaknesses in the model fit. In model specification 4.3, the test reveals that the actual and predicted values of the dependent variable significantly deviate from each other.

As already mentioned in section 2, the impacts of the exponentiated coefficients for the regression on not being innovative should resemble the findings of Bjerke and Johansson (2014), only in opposite direction, since their outcome variable is being innovative. Here, the motivation for having chosen no innovation as the dependent variable is to highlight the relation of collaboration and innovation from the non-innovative perspective as opposed to the previous analyses in this paper. An overall look at the results in Table 5 reveals an interesting insight: None of the STI variables has a significant influence on the likelihood not to innovate, whereas all DUI variables turn out to be significant. This may implicate that the level of advancement of an innovation with regard to the use of science-based research is not decisive for a firm to innovate. Instead, the use of more tacit knowledge sources, which, according to Tödtling et al. (2008), has a stronger relation to less advanced and incremental innovations, is important. This may at least be true for the rural area Jönköping County, which comprises many small firms. This pattern will probably look different in city regions with larger firms, that form innovative networks of both STI and DUI firms.

Regarding the firm characteristics, the share of highly educated employees, as well as of employees with a migratory background, reduce the probability of not being innovative by around 15 percent. The share of employees who are older than 60 years has an opposite effect and increases the odds of no innovations by 13 percent. External knowledge linkages through exporting activities and also the firm size do not affect the likelihood of not being innovative. Strong impacts are found for the variables multinational and same concern. Collaborating with partners from the conglomerate decreases the odds of no innovations by 80 percent in model specification 4.2., around the same effect is found for being part of a multinational firm in model specifications 4.3 and 4.4. Also, a collaboration within the same industry is negatively associated with the outcome variable, and decreases the odds by more than 40 percent. Nevertheless, this is only half of the impact of the same concern variable. These results are in accordance with the findings of Bjerke and Johansson (2014), who stress that in Jönköping County, an organizational proximity between collaborators outperforms a cognitive closeness. The lack of internal resources of small firms, which decreases their innovative capability, seems to be much less relevant when the firm has access to a large network of collaboration partners within the conglomerate.

Linkages to suppliers and clients also prove to have a relevance for the probability not to innovate, and decrease the odds by 38 (supplier) and 44 (client) percent. Although in the previous models the importance of collaborations with suppliers consistently dominated the influence of linkages to clients, the results in Table 5 reveal another pattern for the likelihood not to innovate. This pattern is also found in the results of Bjerke and Johansson (2014). Contrary to their findings, the underlying model addresses also a significant influence to the collaboration with competitors, which decreases the odds of no innovations by 32 percent in model specification 4.3. However, the Hosmer and Lemeshow test addresses a week predictive accuracy to this model specification. Furthermore, the confidence interval for this variable does not even show a clear directionality of the effect. Fitjar and Rodrígez-Pose (2013), as an example, find a negative association for competitor linkages and the probability of developing product innovations.

Table 5. Results of the logistic regression estimation: No innovation

Variables	**4.1**	**4.2**	**4.3**	**4.4**
Firm characteristics				
High education	0.984*** *(0.005)*	0.984*** *(0.005)*	0.983*** *(0.005)*	0.982*** *(0.005)*
Born abroad	0.986** *(0.007)*	0.986** *(0.007)*	0.984** *(0.007)*	0.984** *(0.007)*
Older than 60	1.013** *(0.005)*	1.013** *(0.005)*	1.011** *(0.006)*	1.012** *(0.006)*
Small firm	1.190 *(0.227)*	1.311 *(0.223)*	1.217 *(0.231)*	1.233 *(0.233)*
Exporter	0.790 *(0.228)*	0.739 *(0.226)*	0.886 *(0.233)*	0.949 *(0.241)*
Multinational	0.297** *(0.502)*		0.191*** *(0.475)*	0.203*** *(0.487)*
Industry	Controlled	Controlled	Controlled	Controlled
DUI collaboration partner				
Same corporate group	0.310** *(0.485)*	0.201*** *(0.457)*		
Same industry	0.553*** *(0.209)*	0.578*** *(0.207)*		
Supplier			0.619** *(0.242)*	
Client			0.559** *(0.248)*	
Competitor			0.677* *(0.235)*	
DUI collaboration region				
Intra-regional				0.422*** *(0.236)*
Extra-regional				0.659* *(0.245)*
International				0.553* *(0.344)*
STI collaboration partner				
Universities and colleges	0.581 *(0.347)*	0.572 *(0.343)*	0.586 *(0.346)*	0.622 *(0.357)*
Public R&D institutes	0.307 *(0.806)*	0.274 *(0.794)*	0.341 *(0.800)*	0.366 *(0.807)*
Private R&D institutes	0.948 *(0.625)*	0.947 *(0.615)*	1.037 *(0.613)*	1.000 *(0.625)*
Consultancies	0.535 *(0.457)*	0.493 *(0.451)*	0.613 *(0.464)*	0.578 *(0.470)*
N	611	611	611	610
-2 log likelihood	584.292	591.083	575.414	568.525
Hosmer and Lemeshow test (5% level)	insignificant	insignificant	significant	insignificant
Nagelkerke R^2	0.295	0.282	0.312	0.323
Hit ratio	75.9	74.5	76.9	76.2
Baseline hit ratio	72.0	72.0	72.0	72.0

Exponentiated logistic coefficients with the standard error listed in parantheses
Significant at the level ***0.01, **0.05, *0.1

Concerning the regional DUI collaboration variables, each geographical dimension turns out to decrease the odds of not being innovative significantly. This is also contradicting the results found by Bjerke and Johansson, and will, as has already been stated, be due to different specifications of the models and variables. The underlying results assign the strongest influence among the spatial DUI variables to cooperation within the region, which decreases the odds of no innovations by 58 percent. Extra-regional collaborations decrease the odds by 34 percent, whereas international interactions decrease it by 45 percent. Interestingly, while the effect of international interactions has been dominated by the impact of extra-regional collaborations in the previous models, here the effect of the international variable is larger.

Overall, the model reveals effects that are not visible when looking at the specific types of innovations. This shows that influencing factors on the probability to innovate are to some extent specific to the respective form of innovation developed. Results from a more general view on the likelihood to innovate or not are therefore not sufficient to induce implications for different innovation types.

6 Conclusion

The aim of this paper is to find a pattern in the relation of the external knowledge source a firm uses and the type of innovation the firm develops. The considered innovation forms are product innovations, process innovations, a combination of both, and no innovation. The external knowledge sources are divided into two groups of collaboration partners. The first group, which Jensen et al. (2007) define as Science, Technology and Innovation (STI) interaction partners, who are a source of science-based and codified knowledge, comprise universities and colleges, R&D institutes, and consultancies. The other group delivers tacit knowledge, which is based on on-the-job learning. Collaboration partners of this category are firms within the same conglomerate, within the same industry, within the supply chain (supplier, client) and outside the supply chain (competitor). Jensen et al. (2007) call the collaboration with these kinds of partners Doing, Using and Interacting (DUI).

The analysis is based on survey data about innovation and collaboration activities of firms in the county of Jönköping, Sweden. This region is a rural area with many small firms and low density. However, the results reveal strong innovative activities in this region. It is found that, generally, DUI collaboration partners are more important for the firms' propensity to innovate than STI collaboration partners are. The differentiated look at firms that develop product innovations and at firms that conduct process innovations reveals moderate differences in the use of external sources. The former kind shows a more diversified set of external sources of both DUI and STI type. The focus lies on partners from the same concern and private R&D institutes. Also, internal firm resources in the form of a high share of employees with a university degree and a low share of risk-averse employees, as well as external knowledge linkages provided by exporting activities and by being part of a multinational concern prove to be supportive factors for firms to develop product innovations. The most important factor is an organizational proximity between partners, which facilitates and accelerates the communication and innovation process. Furthermore, the firm size does not matter. Even small firms that possess a low degree of human and physical capital show strong innovative capabilities with regard to product innovations, thanks to quickly realizable profits through the direct sale of products. Process innovations, instead, require a higher degree of internal sources, since returns to this kind of innovation are not achieved that immediately. In this regard, firm size matters for the ability to develop process innovations. The portfolio of collaboration partners used for improvements of processes is less diversified than for product innovations. An organizational and a cognitive proximity between partners are to a similar degree important. The focus lies on tacit knowledge provided by collaboration with suppliers, who serve as an important source of materials for the production process. With regard to spatial dimensions of DUI collaboration, intra- and extra-regional interactions prove to have a stronger influence on the probability that a firm develops product and process innovations, than international linkages.

Considering the findings of the product and the process innovation models, and the strong similarities of the regression outcomes for the process innovation and the both innovations model, two main implications can be derived. Firstly, small firms that have less internal resources at their disposal, rely to a larger extent on external knowledge sources. Therefore, they focus on the development of product innovations, which generate quick profits and compensate directly for the production costs. Secondly, with increasing firm size and a higher amount of internal resources available, firms rely less on external sources. Also, larger firms are often confronted with an increased product complexity, which requires improvements of the production process. Consequently, there is a tendency that large firms develop both product and process innovations.

Overall, the strong marginal effects of collaboration imply that firms should collaborate in order to improve their innovative capabilities. There is furthermore evidence that the development of product and process innovations is interconnected. This can be seen in two ways: Firstly, the magnitudes of the regression coefficients do not differ strongly between the regression models of product and process innovation. Secondly, the results suggest that with increasing firm size and increasing product complexity, firms tend to develop both innovation types.

Since the underlying survey data has a bias towards a larger firm size, the results in this paper are limited with regard to conclusions about the firms in Jönköping County. The findings can only provide a tendency, and give grounds for further research, for example with a weighted analysis. Further discussions of the topic could lie in analyzing the effects of the spatial dimensions of STI collaborations. Fitjar and Rodrígez-Pose (2013) find in their study about innovative activities of Norwegian firms that a spatial proximity of STI collaboration partners does not matter for firms to innovate. The firms rather search for the most appropriate partner on higher spatial dimensions. Moreover, the differentiated look at innovation types, as it is presented in this paper, could be further analyzed with data of firms in city regions, since such regions provide a higher diversification of firms and infrastructure, and will presumably offer more diversified possibilities to collaborate.

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Appendix

Table A 1. Correlation matrix

	Product	Process	Both	None	Same concern	Same industry	Supplier	Client	Competitor	Uni & college	Private R&D	Public R&D	Consultancies	Intra-regional	Extra-regional	International	Exporter	Multinational	Small firm	Born abroad	High education	Older than 60
Product	1																					
Process	0.312	1																				
Both	0.604	0.802	1																			
None	-0.783	-0.590	-0.473	1																		
Same concern	0.280	0.245	0.298	-0.256	1																	
Same industry	0.137	0.128	0.137	-0.144	0.200	1																
Supplier	0.256	0.194	0.231	-0.246	0.289	0.442	1															
Client	0.202	0.182	0.153	-0.258	0.294	0.454	0.541	1														
Competitor	0.079	0.039[a]	0.035[a]	-0.092	0.058[a]	0.489	0.224	0.266	1													
Uni & college	0.287	0.232	0.293	-0.255	0.319	0.086	0.185	0.246	0.063[a]	1												
Private R&D	0.191	0.142	0.214	-0.135	0.211	0.128	0.182	0.181	0.063[a]	0.314	1											
Public R&D	0.166	0.146	0.178	-0.152	0.171	0.089	0.119	0.129	0.084	0.367	0.283	1										
Consultancies	0.104	0.129	0.148	-0.098	0.175	0.101	0.154	0.134	0.073[a]	0.221	0.193	0.158	1									
Intra-regional	0.146	0.129	0.124	-0.170	0.175	0.526	0.472	0.484	0.383	0.072[a]	0.032[a]	-0.009[a]	0.081	1								
Extra-regional	0.260	0.234	0.263	-0.260	0.315	0.491	0.496	0.515	0.289	0.319	0.207	0.169	0.124	0.383	1							
International	0.261	0.206	0.261	-0.232	0.379	0.284	0.352	0.327	0.136	0.226	0.284	0.199	0.171	0.134	0.406	1						
Exporter	0.258	0.199	0.265	-0.217	0.223	0.034[a]	0.228	0.228	-0.051[a]	0.269	0.206	0.118	0.179	0.004[a]	0.229	0.376	1					
Multinational	0.188	0.208	0.243	-0.174	0.445	0.068[a]	0.155	0.135	-0.032[a]	0.236	0.162	0.177	0.649	0.003[a]	0.169	0.299	0.294	1				
Small firm	-0.175	-0.236	-0.243	0.192	-0.321	-0.050[a]	-0.106	-0.196	-0.008[a]	-0.266	-0.116	-0.121	-0.128	-0.013[a]	-0.179	-0.185	-0.279	-0.302	1			
Born abroad	0.103	0.131	0.116	-0.134	0.045[a]	-0.037[a]	0.013[a]	0.005[a]	0.090	0.067[a]	0.038[a]	0.055[a]	0.090	-0.057[a]	-0.005[a]	0.033[a]	0.120	0.059[a]	-0.172	1		
High education	0.171	0.037[a]	0.077[a]	-0.145	0.001[a]	0.030[a]	0.006[a]	0.013[a]	0.032[a]	0.273	0.051[a]	0.092	-0.008[a]	-0.025[a]	0.062[a]	0.069[a]	0.042[a]	0.015[a]	0.121	-0.099	1	
Older than 60	-0.133	-0.077[a]	-0.112	-0.110	-0.050[a]	0.004[a]	-0.159	-0.063[a]	0.035[a]	-0.019[a]	-0.017[a]	0.079	-0.061[a]	-0.025[a]	-0.098	-0.044[a]	-0.078[a]	-0.085	0.165	-0.082	0.101	1

[a] insignificant at the 0.05 level

Table A 2. Logistic regression results when excluding the STI variables

Variables	Product innovation (1)	Product innovation (2)	Process innovation (1)	Process innovation (2)	Both innovations (1)	Both innovations (2)	No innovation (1)	No innovation (2)
Firm characteristics								
High education	1.016*** *(0.004)*	1.017*** *(0.004)*	1.009** *(0.004)*	1.009** *(0.004)*	1.010** *(0.004)*	1.011** *(0.004)*	0.982*** *(0.005)*	0.981*** *(0.005)*
Born abroad	1.010* *(0.006)*	1.011* *(0.006)*	1.008 *(0.005)*	1.009* *(0.006)*	1.008 *(0.006)*	1.008 *(0.006)*	0.986** *(0.007)*	0.983** *(0.007)*
Older than 60	0.985*** *(0.005)*	0.987** *(0.005)*	0.993 *(0.005)*	0.995 *(0.005)*	0.986** *(0.006)*	0.989* *(0.006)*	1.012** *(0.005)*	1.010* *(0.005)*
Small firm	0.834 *(0.206)*	0.783 *(0.208)*	0.621** *(0.198)*	0.595*** *(0.198)*	0.594** *(0.212)*	0.537*** *(0.212)*	1.238 *(0.223)*	1.261 *(0.227)*
Exporter	1.920*** *(0.210)*	1.704** *(0.213)*	1.176 *(0.202)*	1.055 *(0.206)*	1.779*** *(0.214)*	1.584** *(0.218)*	0.729 *(0.225)*	0.842 *(0.232)*
Multinational	2.863*** *(0.370)*	4.399*** *(0.341)*	1.963** *(0.303)*	2.488*** *(0.268)*	2.083** *(0.295)*	2.813*** *(0.258)*	0.252*** *(0.493)*	0.155*** *(0.468)*
Industry	Controlled	Controlled	Controlled	Controlled	Controlled	Controlled	Controlled	Controlled
DUI collaboration partner								
Same corporate group	2.696*** *(0.351)*		1.678* *(0.285)*		1.893** *(0.279)*		0.275*** *(0.476)*	
Same industry	1.682*** *(0.193)*		1.605** *(0.189)*		1.632** *(0.202)*		0.522*** *(0.20)*	
Supplier		1.906*** *(0.218)*		1.615** *(0.214)*		2.126** *(0.231)*		0.583** *(0.237)*
Client		1.276 *(0.226)*		1.184 *(0.218)*		0.861 *(0.234)*		0.533** *(0.243)*
Competitor		1.401 *(0.209)*		1.216 *(0.196)*		1.190 *(0.206)*		0.632* *(0.233)*
N	612	612	612	612	612	612	612	612
-2 log likelihood	684.611	679.398	746.350	745.094	689.240	688.344	595.987	584.285
Hosmer and Lemeshow test (5% level)	insignificant	insignificant	insignificant	insignificant	insignificant	insignificant	insignificant	insignificant
Nagelkerke R^2	0.264	0.273	0.203	0.205	0.237	0.239	0.274	0.296
Hit ratio	70.3	70.3	66.3	67.8	71.1	72.1	75.2	77.0
Baseline hit ratio	61.3	61.3	52.3	52.3	63.1	63.1	72.1	72.1

Exponentiated logistic coefficients with the standard error listed in parantheses
Significant at the level ***0.01, **0.05, *0.1